Regional

STORMWATER/WETLAND

Management Master Plan

AUGUST 2016

Prepared by:

PACIFIC ENGINEERING

Grette Associates LLC
ENVIRONMENTAL CONSULTANTS

THIS PAGE INTENTIONALLY LEFT BLANK

Acknowledgements

AUTHOR:
Thom Kutrich, PE | Pacific Engineering & Design, PLLC

CO-AUTHORS:
Ryan Walker | Grette Associates, LLC
Anne Hessburg | Grette Associates, LLC

DESIGN & GRAPHICS:
Kara Zupke | Pacific Engineering & Design, PLLC
Viktor Kramar | Pacific Engineering & Design, PLLC

STAKEHOLDER / ADVISORY GROUP:
Cheri Kelley Farivar | Mayor
Joel Walinksi | City Administrator
Nathan Pate, AICP | Planning Director
Gretchen Wearne | City Council Position No. 1
Mia Bretz | City Council Position No. 2
Margaret Neighbors | City Council Position No. 3
Carolyn Wilson | City Council Position No. 4
Robert Francis | City Council Position No. 5
Richard Brinkman | City Council Position No. 6
Elmer Larsen | City Council Position No. 7
Joel Martinez | Planning Commission Position No. 1
Charles Reppas | Planning Commission Position No. 2
Andy Lane | Planning Commission Position No. 3
Pete Olson | Planning Commission Position No. 4
Scott Bradshaw | Planning Commission Position No. 5
Larry Hayes | Planning Commission Position No. 6
Anne Hessburg | Planning Commission Position No. 7
Citizens | City of Leavenworth

FUNDING:
Washington State Department of Ecology

THIS PAGE INTENTIONALLY LEFT BLANK

TABLE OF CONTENTS

chapter 1

INTRODUCTION

In this Chapter:

1.1 Executive Summary

This plan is first and foremost a City of Leavenworth centric document. The basis for development of this plan is the Washington State Department of Ecology's 2004 Stormwater Management Manual for Eastern Washington (SMMEW). Leavenworth adopted the SMMEW via ordinance 1355. Ecology is currently in the process of producing the SMMEW 2nd edition.

The SMMEW forward and introduction contain comprehensive documentation of its purpose and scope, effects of urbanization, relationship to federal, state, and local statutes, and best management practices. This plan does not repeat that information. Interested readers are recommended to review the SMMEW on-line, request a copy from Ecology, or view a copy at the City.

The following two (2) technical documents have been prepared for the plan.

- Pacific Engineering & Design, PLLC (September 25, 2015, revised March 18, 2016), "City of Leavenworth Stormwater Infrastructure Preliminary Hydrologic/Hydraulic Analysis."
- Grette Associates, LLC (September 4, 2015) "Leavenworth Regional Stormwater Plan Wetland Delineation Report."

The plan is also indebted to the Ballinger, Susan Reynolds, (February 1999), "Leavenworth Water Problems Study". The documentation of the Ski Hill Drive area issues regarding stormwater, flooding, surface hydrology, hydrogeology and soils were an important influence on the plan.

Leavenworth is located in Region 1, an SMMEW designation for locales with annual precipitation exceeding 16 inches. Region 1 requires a stormwater management approach which differs from that of nearly all other North Central Washington locations, which typically share a designation of Region 2.

Leavenworth's stormwater infrastructure is neatly divided into four (4) drainage basins, i.e. Ski Hill, Downtown West, Downtown East, and Alpensee. A fifth drainage basin, north and east of Alpensee, will eventually be included as annexations occur within the urban growth area (UGA).

Two (2) large tributary areas to the west and north, i.e. Tumwater Mountain and Ski Hill ridge, have a significant impact to the capacity of the existing stormwater infrastructure, i.e. specifically the Ski Hill and Alpensee networks. These tributary areas account for 66% (1,588 acres) of the total 2,614 acre Leavenworth drainage basin. They are directly linked to the lack of capacity in both networks for larger storm events, i.e. 10 year storms or greater.

Twelve (12) existing wetlands totaling 52.91 acres were identified within the Leavenworth drainage basin. They range in size from 0.02 acres to 42.20 acres. They provide a number of benefits and functions such as wildlife habitat, natural water quality improvement, flood storage, recreation opportunities, and aesthetic appeal. Storm drainage discharge to naturally occurring wetlands for the purpose of water quality treatment is allowed only under special conditions.

Leavenworth hydrogeology is generally characterized as: snowmelt from the Tumwater Mountain and Ski Hill tributary areas infiltrate into the ground, reappear as surface waters, and infiltrate again as groundwater flow; wetland waters are a transitional phase of surface to subsurface flows; there may be three aquifers at 15' to 150' depths, all hydraulically connected; groundwater discharges to the surface via upward hydrostatic pressure; and base flow to the Wenatchee River has been observed up to 4 cfs. Groundwater issues have been a constant problem for many constituents.

The plan emphasis is on the management of stormwater utilizing water quality treatment, flow control, and naturally occurring wetlands. The methods which attempt to mitigate adverse stormwater impacts are known as Best Management Practices (BMPs). BMPs are under Ecology jurisdiction and include well established practices and emerging technologies. BMPs are generally categorized as Source Control, Water Quality Treatment, and Flow Control.

Source control BMPs are utilized to prevent pollution from ever occurring. They are very cost effective, however, management can be problematic as these BMPs require use specific individual plans, i.e. each control approach is uniquely based on the target pollutant, and responsible self-policing.

Water quality treatment currently focuses on the application of BMPs to treat the following pollutants; total suspend solids (TSS), hydrocarbons (oils), metals (dissolved), and phosphorus (when mandated by others). Water quality treatment commonly takes the form of bio-filtration such as vegetated filters, swales, and ponds.

Flow control BMPs are used to control the flow rate and duration of stormwater runoff, preserving the physical capacity of existing infrastructure such as ditches, gutters, culverts, and pipe networks. Flow control commonly takes the form of detention ponds, tanks, and vaults.

BMPs can be applied to surface runoff generated by areas as small as a single family residential driveway. Developments are commonly required to apply BMP(s) to treat project generated surface runoff. Regional (publicly owned) facilities, i.e. an individual or series of BMPs treating a large area, are an effective way to economically treat surface water runoff. The existing City stormwater utility is an appropriate regulatory vehicle for financing regional capital improvements.

In-depth research was completed on water quality treatment BMP applications and efficiencies. The emphasis concentrated on compiling readily available BMP research of locales with similar climates. The data collected was used to score and weight a variety of common characteristics in order to develop a ranking of the most effective BMPs for Leavenworth.

Goals, policies, and strategies are included in the plan, to help guide the City through a changing regulatory environment. Topics addressed include comprehensive stormwater planning, compliance criteria, streamlining applicant processes, streamlining engineering requirements, encouraging and promoting local partnerships, financing, use of existing wetlands, and maintaining a citywide stormwater model.

A preliminary 6 and 20 year capital improvement program is included. These improvements are recommended based on model simulation results. The simulations illustrate where physical capacity deficiencies and flooding are expected to occur within the network(s)

The plan includes procedures intended to replace the "City of Leavenworth Standard Operating Procedures for Stormwater Applicability Thresholds" resolution. Procedures are included for a developer option to pay a "Fee-in-lieu-of" applying required BMPs. Residential driveway water quality treatment procedures are included.

1.2 History

On July 1, 2014, the City was awarded a $150,000 Centennial Clean Water Program Grant via our funding partner the Washington State Department of Ecology (Ecology). Securing funding was the top priority and first step in addressing the wetland and stormwater issues in the City and Urban Growth Area.

This funding allowed the City to move forward with collecting information to identify the issues and also to develop solutions for addressing wetland and stormwater issues while allowing for future development. On March 24, 2015, the Council approved the Professional Service Agreements (contracts) with three qualified consultants to develop a Regional Stormwater Quality / Wetland Management Master (Plan) for stormwater control, protection, restoration, and enhancement through green infrastructure planning within the Urban Growth Area (UGA) of the City of Leavenworth (City).

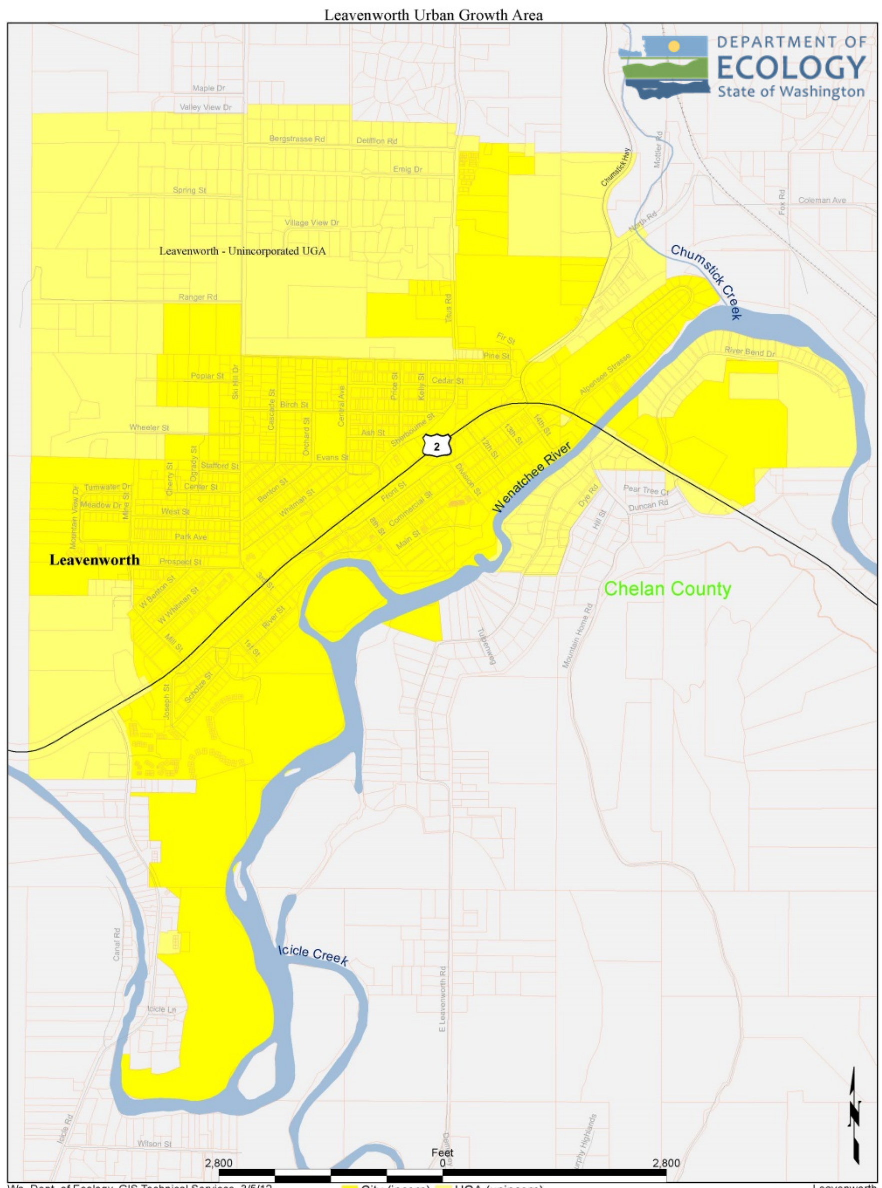


FIGURE 1A: LEAVENWORTH URBAN GROWTH AREA (UGA)
Source: Washington State Department of Ecology, GIS Technical Services, 2012

chapter 2

GOALS, POLICIES, AND STRATEGIES

In this Chapter:

2.1 Goal 1: *Update Municipal Code Text*

2.1.1 POLICY 1A

Clarify existing code language related to storm water.

Strategy: Apply uniform verbiage to all terms related to storm water. Clarify and distinguish storm sewer from sanitary sewer. Titles needed to be addressed include but may not be limited to:

- Title 3.78,
- Title 8.56,
- Titles 13.02, 13.68, 13.72, 13.76, 3.82, 13.83, 13.88, 13.90,
- Titles 14.04, 14.14,
- Title 17.14,
- Titles 18.50, 18.51.

2.1.2 POLICY 1B

Update Titles 13.90, 14.04, and 14.14.

Strategy:

- Bring titles into conformance with this Plan,
- Adopt additional existing appropriate guidelines, i.e. WSDOT Highway Runoff Manual, and Low Impact Development Guide for Eastern Washington.

2.2 Goal 2: *Prepare Compliance Criteria*

2.2.1 POLICY 2A

Develop clear and concise project thresholds.

Strategy: Define the following category thresholds:

- New Development
- Redevelopment (retrofit),
- Single Family Residential.

2.2.2 POLICY 2B

Develop clear and concise performance standards.

Strategy: Define the standards for the following core elements:

- Water Quality Treatment,
- Runoff Control.

2.2.3 POLICY 2C

Develop clear and concise local core requirements.

Strategy: Address the following Core Elements (CE):

- CE No. 1: Stormwater Site Plan (SSP),
- CE No. 2: Construction Stormwater Prevention Pollution Plan (SWPPP),

- CE No. 3: Source Control of Pollution,
- CE No. 4: Preservation of Natural Drainage Systems,
- CE No. 5: Water Quality Treatment,
- CE No. 6: Runoff Control,
- CE No. 7: Operations and Maintenance.

2.2.4 POLICY 2D
Review Pollutants of Concern.

Strategy: Address and monitor the following pollutants and categories:
- Total Suspended Solids (TSS),
- Oils,
- Metals,
- Water Quality Assessment Categories 4a, 4b, 4c, and 5:
    - 4a) Has a total maximum daily load (TMDL),
    - 4b) Has a pollution control program,
    - 4c) Is impaired by a non-pollutant,
    - 5) Requires a TMDL.
- Use definition and procedures.

2.3 Goal 3: *Streamline Applicant Process and Expectations*

2.3.1 POLICY 3A
Develop new permit compliance template(s) and checklist(s).

Strategy: Define and document the following requirements in chronological order:
- Application,
- Permitting (local, state, and federal),
- Construction Plans,
- Stormwater Report,
- Plans examiner review standards,
- Post construction,
- All documentation GIS input ready and prepared by professional engineer.

Strategy: Prepare separate simplified procedures for single family residential building permits.

2.3.2 POLICY 3B
Develop procedures for fee in-lieu-of project required stormwater improvements for 1) runoff control and 2) water quality treatment.

Strategy: Develop the following:
- Identify locations for regional runoff control and water quality treatment capital improvements,
- Develop planning level designs and cost estimates,
- Annually adopt updates to the stormwater capital improvement program,
- Adopt procedures for calculating fees.

2.4 Goal 4: *Streamline Engineering Requirements*

2.4.1 POLICY 4A
Develop hydrologic and hydraulic analysis minimum standards.

Strategy: Address the following:
- Acceptable analysis methods and applicability,
- Standardize use of ground cover runoff curve numbers,
- Minimum conveyance roughness coefficient standards,
- Required precipitation depths,
- Eliminate rain on snow requirements.

2.4.2 POLICY 4B
Develop a water quality treatment BMP selection matrix.

Strategy: Rank approved BMPs based on local requirements and conditions.

2.4.3 POLICY 4C
Develop a runoff control BMP selection matrix.

Strategy: Rank approved BMPs based on local requirements and conditions.

2.5 Goal 5: *Encourage and Promote Local Partnerships*

2.5.1 POLICY 5A
Partner with the Icicle Irrigation District to eliminate the discharge of unused irrigation distribution water.

Strategy: Separate irrigation discharge flows from stormwater runoff facilities.

2.5.2 POLICY 5B
Encourage the establishment of a local Drainage District (Special Purpose District) via RCW 85 to reduce or eliminate impacts from nuisance surface / ground waters (non-stormwater).

Strategy: Manage, finance, design, and construct facilities to mitigate existing impacts of naturally occurring hydrogeological flows (non-precipitation).

2.5.3 POLICY 5C
Partner with Chelan County Natural Resources to 1) increase in-stream flows in the Wenatchee River, and 2) improve stormwater quality prior to discharge to the Wenatchee River.

Strategy: Mutually finance, design, and construct facilities to mitigate low in-stream flows and treat stormwater runoff prior to discharge to the river.

2.6 Goal 6: *Pursue and Leverage Grant and Loan Financing for Capital Improvement Program*

2.6.1 POLICY 6A

Prepare a 6 year and 20 year Capital Improvement Program.

Strategy: Plan, finance, design, and construct regional facilities to mitigate capacity impacts to the existing stormwater network and improve water quality via treatment.

2.6.2 POLICY 6B

Pursue stormwater system improvement funding from state programs and agencies, including but not limited to, Department of Commerce, Public Works Trust Fund, Ecology, and Transportation Improvement Board.

Strategy: Plan, leverage financing, design, and construct regional facilities to mitigate capacity impacts to the existing stormwater network and improve water quality via treatment.

2.6.3 POLICY 6C

Separate sanitary sewer and storm drainage combined flows.

Strategy: Eliminate the combined flows and reduce the inflow/infiltration (I/I) of stormwater into the sanitary sewer collection system to increase the stormwater network capacity and reduce peak flows to the wastewater treatment plant.

2.7 Goal 7: *Enhance Existing Wetlands*

2.7.1 POLICY 7A

Detention Improvements.

Strategy: Provide passive detention, e.g. low berm, with a controlled released discharge, e.g. weir, prior to discharge to the stormwater network.

2.7.2 POLICY 7B

Habitat Improvements.

Strategy: Provide suitable enhancements for local wildlife.

2.7.3 POLICY 7C

Water Quality Improvements.

Strategy: Provide water quality treatment prior to discharges of upstream tributary areas to identified wetlands. Utilize eligible wetlands for water quality treatment.

2.8 Goal 8: *Maintain a Storm Drainage System Model*

2.8.1 POLICY 8A

Complete the field survey of the existing four networks.

Strategy: Fund surveys by consultants to complete gaps in the networks.

2.8.2 POLICY 8B

Calibrate model based on actual storm events.

Strategy: Install wireless flow meters in strategic network storm drain manhole locations and apply resulting data to model for improved simulation results. Install a wireless rain gauge at the city center.

2.8.3 POLICY 8C

Perform routine and timely updates of the network models.

Strategy: Update model annually from received survey data, flow meter, and rain gauge results.

2.8.4 POLICY 8D

Require permit applicants to field survey and submit network infrastructure as-built data for model input.

Strategy: Require land use applicants to provide onsite digital files and survey data of un-surveyed downstream network, up to ¼ mile, for input into the model.

2.8.5 POLICY 8E

Commit network models, reports, and maintenance records to GIS.

Strategy: Evaluate, purchase, and train personnel for implementation of a GIS system via request for proposals. Input stormwater model network, existing digital data, and hard copy (to be scanned) documentation as funds allow.

chapter 3

STANDARD PROCEDURES FOR DETERMINING STORMWATER MANAGEMENT THRESHOLDS

In this Chapter:

3.1 General

The following standard procedures are presented to provide streamlined guidance for stormwater management related to development.

Via Ordinance No. 1355 the City Council adopted the 2004 Washington State Department of Ecology (Ecology) Stormwater Management Manual for Eastern Washington (SMMEW). The SMMEW contains eight (8) core elements required to be reviewed at the permit phase prior to design approval and construction. All of those core elements are extensively discussed in the SMMEW and seven (7) are summarized below. Core element eight (8) addresses local requirements which are the subject of this section.

Ecology has developed technical manuals, guidelines, regulations, and model ordinances relating to stormwater management. The SMMEW core elements address those topics as follows: (CE 1) guide design of stormwater facilities, (CE 2) prevent construction stormwater pollution, (CE 3) provide control pollution at its source, (CE 4) preserve natural drainage systems, (CE 5) provide water quality treatment best management practices, (CE 6) provide runoff control best management practices, and (CE 7) ensure documentation of operations and maintenance procedures.

3.2 Policy

Applicable thresholds for stormwater management impacts due to development shall be evaluated at the time of permitting. All development, *with the exception of a single family residential building permit under special circumstances as described in section 3.2.6 below*, shall comply with the following:

3.2.1 ALL DEVELOPMENT SHALL BE CATEGORIZED AS EITHER:

a) New Development
  i) Includes projects which expand the impervious area on existing road(s).
b) Redevelopment
  i) ***Definition:*** Replacement of 5,000 sf or more of pollutant generating impervious surfaces (PGIS).

3.2.2 APPLICATION OF SMMEW CORE ELEMENTS (CE) 1 THROUGH 7:

a) All Development Shall Comply With:
  i) CE 1 – 4 and 7,
  ii) CE 5 ***if*** water quality treatment thresholds are met,
  iii) CE 6 ***if*** runoff control thresholds are met.
b) Exemptions to the core elements
  i) Road and parking preservation/maintenance, i.e. patching, crack sealing, resurfacing, overlays, shoulder grading, vegetation maintenance, and drainage reshaping/regrading.
  ii) CE 6 geographic exemption:
    (1) Projects with a zoning designation of Central Commercial or General Commercial within the following areas.
      (a) Ski Hill drainage basin: Parcels south of Whitman Street, east of Ski Hill Drive / 3rd Street, or with frontage on SR2.

(b) Downtown West drainage basin: Parcels south of Whitman Street or with frontage on SR2.
(c) Downtown East drainage basin.
iii) CE 6 minor peak flow impact exemption:
(1) Projects located within the Ski Hill and Alpensee drainage basins provided both conditions are met:
(a) Project storm model simulations document a negligible network peak flow rate increase for all performance standards, and,
(b) Network model flooding and/or surcharging is not increased.
c) Partial exemptions:
i) Underground linear utility projects shall only comply with CE 2,
ii) Road and parking preservation/maintenance, i.e. remove, replace or repair paving, surfacing, and subgrade without expanding the impervious area, shall only comply with CE 2.

3.2.3 REDEVELOPMENT

i) All redevelopment shall comply with:
(1) CE 1 – 4 and 7,
(2) CE 5 ***at***:
(a) Industrial sites with outdoor handling, processing, storage, or transfer of solid raw materials or finished products (40 CFR 122.26(b)(14)),
(b) Commercial sites with outdoor storage or transfer of solid raw materials or treated wood products,
(c) Site that discharge to surface water with an Ecology water quality assessment designation of Category 4a (has a TMDL), 4b (has a pollution control program) or 5 (requires a TMDL),
(d) High use sites.
(3) CE 6 ***at***:
(a) Any site exceeding the maximum allowable coverage per Title 18.

3.2.4 PAYMENT-IN-LIEU OF COMPLYING WITH CE 5 AND/OR CE 6

a) Applicants may opt to provide a payment to the city in-lieu-of construction of required on site compliant BMP facilities for CE 5 and/or CE 6. Eligibility for payment of such fee will based on all of the following:
i) There is an adopted regional capital improvement within the drainage basin of the applicant, and
ii) A pro-rata cost share has been adopted to design and construct the regional capital improvement.

3.2.5 PERFORMANCE STANDARDS

a) CE 5 Water Quality Treatment
i) See section 4, table 4a, City of Leavenworth Stormwater Infrastructure Preliminary Hydrology / Hydraulic Analysis.
b) CE 6 Flow Control
i) See section 4, table 4b, City of Leavenworth Stormwater Infrastructure Preliminary Hydrology / Hydraulic Analysis.
ii) All required flow control BMPs shall be designed to maintain the predeveloped peak flow rate of the 2, 10, and 25 year design storms
c) Road Projects
i) See section 4, table 4c, City of Leavenworth Stormwater Infrastructure Preliminary

Hydrology / Hydraulic Analysis.

d) Design Storm Precipitation Depths
   i) See section 6, table 6, City of Leavenworth Stormwater Infrastructure Preliminary Hydrology / Hydraulic Analysis.

3.2.6 SINGLE FAMILY RESIDENTIAL BUILDING PERMIT (SFR)

a) Provided that the subject permit parcel's stormwater discharge is not treated by approved or pending BMPs (within a subdivision or by regional facility), then:
   i) Apply section 5 Residential Driveway Water Quality Treatment of this Master Plan, and
   ii) CE 6 (above) unless exempt as follows:
      (1) The subject property,
         (a) is zoned RR 2.5, RR 5, RR 10, or RR 20, or
         (b) discharges directly to a wetland and the wetland meets the criteria for "Hydrologic Modification of a Wetland", or
         (c) discharges to an irrigation return and has written permission from the irrigation purveyor, or
         (d) Is able to infiltrate or fully disperse a post developed 10 year design storm.

chapter 4

PROCEDURES FOR FEE IN-LIEU-OF STORMWATER IMPROVEMENTS

In this Chapter:

4.1 Fee in-lieu-of Water Quality Treatment BMPs

The fee is based on several factors, i.e. 1) the planned regional BMP capital improvement estimated cost, and 2) the tributary pollutant generating impervious surface (PGIS) area being treated by the regional BMP, and 3) the project PGIS area discharging to the regional BMP.

TABLE 4A: FEE IN-LIEU-OF PROJECT REQUIRED WATER QUALITY TREATMENT BMPS

DRAINAGE BASIN	AREA (AC)	WETLANDS (AC)	WOODS (AC)	TOTAL DEVELOPABLE (AC)
Ski Hill	1,578.0	42.8	1,012.4	522.88
Downtown West	128.6	2.2		126.45
Downtown East	22.7	-	-	22.66
Alpensee	457.6	2.3	150.5	304.81

EXAMPLE: DOWNTOWN EAST BASIN				
Regional Capital Project Title:	*Water Quality Treatment at Outfall*			
Estimated Cost:	$200,000			
Tributary Area to BMP:	22.67	ac	*Assumed Zone Coverages:* 75% max. impervious coverage and 25% minimum landscaping	
Public PGIS (Parking / Road)	6.00	ac (est.)		
Private PGIS (Parking / Road)	5.00	ac (est.)		
Roofs (NPGIS)	6.00	ac (est.)		
Landscaping	5.67	ac		
				22.67
Project Title:	*Subdivision*			
PGIS:	0.50	ac		
Fee-in-lieu-of Equation:	**(Estimated Cost ÷ BMP PGIS) x Project PGIS**			
	Cost	BMP PGIS (ac)	Project PGIS	Project Fee
	$200,000	11.00	0.50	**$9,091**

4.2 Fee in-lieu-of Detention BMPs

The fee is based on several factors, i.e. 1) the planned regional BMP capital improvement estimated cost, and 2) the tributary impervious surface area being detained by the regional BMP, and 3) the project impervious surface area discharging to the regional BMP.

TABLE 4B: FEE IN-LIEU-OF PROJECT REQUIRED DETENTION BMP

DRAINAGE BASIN	AREA (AC)	WETLANDS (AC)	WOODS (AC)	TOTAL DEVELOPABLE (AC)
Ski Hill	1,578.0	42.8	1,012.4	522.88
Downtown West	128.6	2.2		126.45
Downtown East	22.7	-	-	22.66
Alpensee	457.6	2.3	150.5	304.81

EXAMPLE: DOWNTOWN EAST BASIN				
Regional Capital Project Title:	*Water Quality Treatment at Outfall*			
Estimated Cost:	$200,000			
Tributary Area to BMP:	22.67	ac	*Assumed Zone Coverages:* 75% max. impervious coverage and 25% minimum landscaping	
Public Impervious Surface (Parking / Road)	9.00	ac (est.)		
Private Impervious Surface (Parking / Road / Roofs)	8.00	ac (est.)		
Landscaping	5.67	ac		
				22.67
Project Title:	*Subdivision*			
PGIS:	0.50	ac		
Fee-in-lieu-of Equation:	**(Estimated Cost ÷ BMP Impervious Surface Area) x Project Impervious Surface Area**			
	Cost	BMP PGIS (ac)	Project PGIS	Project Fee
	$200,000	17.00	0.50	**$5,882**

THIS PAGE INTENTIONALLY LEFT BLANK

chapter 5
RESIDENTIAL DRIVEWAY WATER QUALITY TREATMENT

In this Chapter:

5.1 Residential Driveway Stormwater Runoff

All residential driveways, subject to 3.2.6, are required to discharge their stormwater surface runoff as sheet flow to a vegetated filter strip prior to discharge downstream. This may be achieved by a combination of proper grading of the driveway finished surface, collection of runoff by slotted drains, discharge of runoff to a vegetated filter strip via a level spreader, and proper grading of the vegetated filter strip finished surface. Several combinations of the previously described elements are possible to achieve this requirement.

5.1.1 SIZING PROCEDURES

- See City Standard Plan (*Figure 5A and 5B*).
- Sizing: See Table 5A below in conjunction with the following 3 design steps.
- Step 1: Determine the greater of the proposed driveway width or flow path length "D".
- Step 2: Determine the proposed average cross slope "C" of the vegetated filter strip.
- Step 3: Using Table 5A, select the cell that best represents "C" and "D". Choose the upper most cell row for "D" when one or more cells share the same value, e.g. for "C"= 17.5% choose the cell row which correlates to a "W" of 10'.
- Option: When using a level spreader, its total length "LL" must be equal to the "LD" as shown on the standard plan. More than one level spreader may be used to achieve this requirement.

FIGURE 5A: RESIDENTIAL DRIVEWAY VEGETATED FILTER STRIP (PLAN)

Source: Pacific Engineering & Design

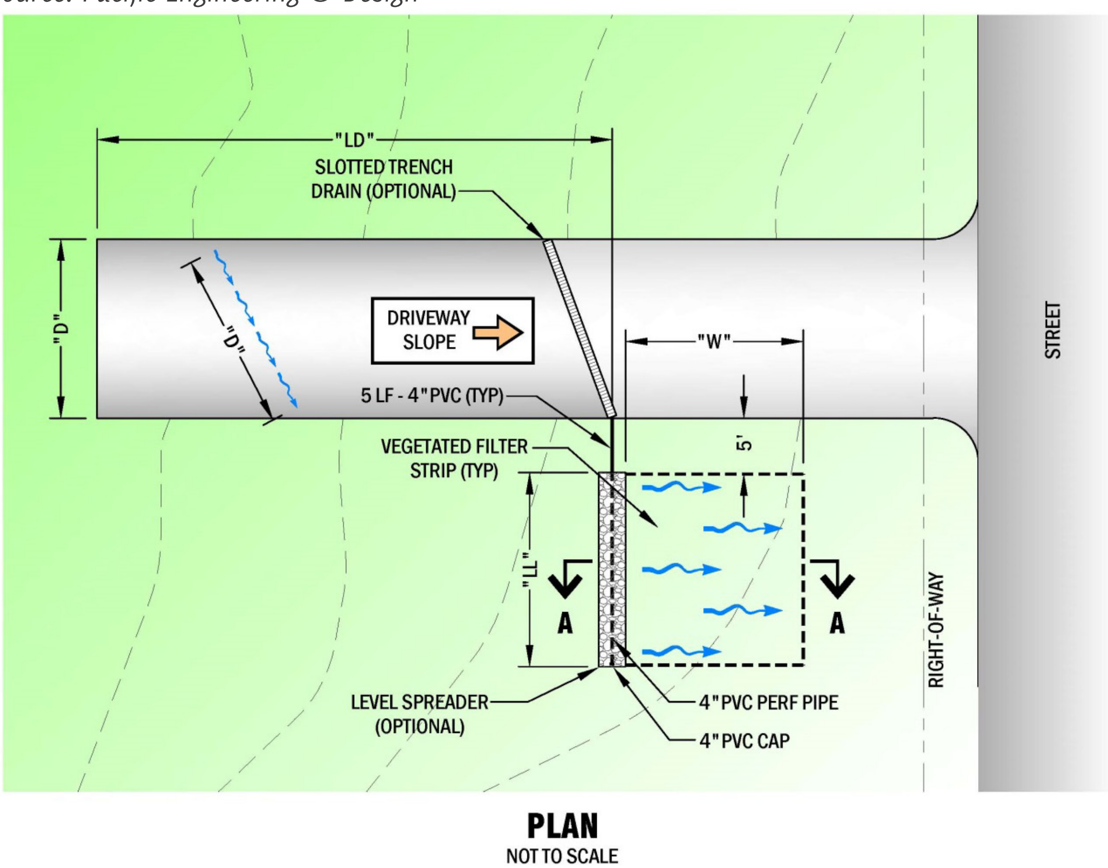


FIGURE 5B: RESIDENTIAL DRIVEWAY VEGETATED FILTER STRIP (SECTION)

Source: Pacific Engineering & Design

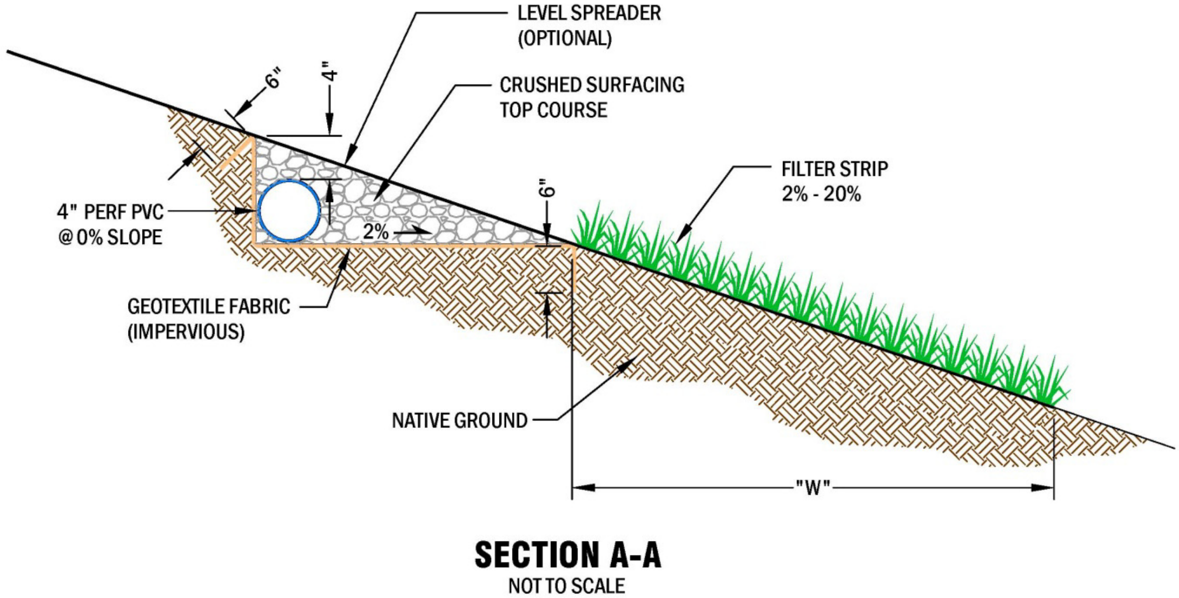


TABLE 5A: VEGETATIVE FILTER STRIP WIDTH SIZING (W)

<table>
<tr><th colspan="10">DRIVEWAY WIDTH OR FLOW PATH LENGTH (D) IN FEET</th></tr>
<tr><td rowspan="8">Filter Strip Width (W) in Feet</td><td>20’</td><td colspan="8">30’</td></tr>
<tr><td>17.5’</td><td colspan="7">30’</td><td>25’</td></tr>
<tr><td>15’</td><td colspan="6">30’</td><td>25’</td><td>20’</td></tr>
<tr><td>12.5’</td><td colspan="4">30’</td><td>25’</td><td>20’</td><td>15’</td><td>10’</td></tr>
<tr><td>10’</td><td colspan="2">30’</td><td>25’</td><td>20’</td><td colspan="2">15’</td><td colspan="2">10’</td></tr>
<tr><td>7.5’</td><td>30’</td><td>25’</td><td colspan="2">15’</td><td colspan="4">10’</td></tr>
<tr><td>5’</td><td>15’</td><td colspan="7">10’</td></tr>
<tr><td>-</td><td>2.5</td><td>5</td><td>7.5</td><td>10</td><td>12.5</td><td>15</td><td>17.5</td><td>20</td></tr>
<tr><td colspan="10">Filter Strip Cross Slope (C) in %</td></tr>
</table>

5.2 BMP T5.50: *Vegetated Filter Strip*

A vegetated filter strip (filter strip) is a biological surface area designed to provide stormwater quality treatment of conventional pollutants. Discharge from a level spreader passes through the filter strip prior to discharge downstream.

5.3 BMP C206: *Level Spreader*

A linear open (top) facility which converts concentrated runoff to sheet flow and releases it to an engineered vegetated filter strip.

5.4 Construction and Maintenance Criteria

- Construct filter strips immediately after paving.
- Groomed filter strips planted in grasses should be mowed during the summer to promote growth.
- Inspect filter strips periodically, especially after periods of heavy runoff.
- Remove sediments and reseed as necessary.
- The spreader shall be inspected after every runoff event.

chapter 6

PRELIMINARY CAPITAL IMPROVEMENT PROGRAM

In this Chapter:

6.1 PRELIMINARY CAPITAL IMPROVEMENT PROGRAM

This preliminary capital improvement program was developed by performing repeated model simulations of design storm events, e.g. after each simulation, obvious problem areas were identified, potential solutions to the problem(s) were introduced to the model, and a new simulation was performed to evaluate the solution.

TABLE 6A: CAPITAL IMPROVEMENT PROGRAM

6 YEAR CAPITAL IMPROVEMENTS					
Priority	Basin/Location	Problem	Event	Capital Improvement	Result
1	**Alpensee** - Cascade High School	Chumstick Road: Pipe crossing downstream 18” dia. pipe (84 LF) is at capacity. Upstream flooding results.	Regional 10, 25, and 100 yr. storm. Short Duration 100 yr. storm.	Replace 84 LF of 18” dia. pipe with 30” dia. smooth wall pipe. Cost - $17,000	Eliminates all flooding except for Regional 100 yr. storm.
2	**Ski Hill** - Basin BS-4D	Whitman Street: 32 acre basin enters storm network at Whitman/Clinton. Flooding along Whitman.	Regional and Short Duration 100 yr. storm.	Slip line ±829 LF of 18” pipe. Cost - $83,000	Eliminates all flooding.
3	**Downtown East** - Commercial Avenue	Commercial Ave: Division to 14th, 18” dia. pipe (1,355 LF) is at capacity. Upstream flooding occurs.	Short Duration 100 yr. storm.	Slip line ±1,159 LF of 18” pipe. Cost - $116,000	Eliminates all flooding.
20 YEAR CAPITAL IMPROVEMENTS					
Priority	Basin/Location	Problem	Event	Capital Improvement	Result
4	**Ski Hill** - Basin BS-13	Ski Hill Drive: 1,038 acre basin enters storm network at Pine/Ski Hill. Widespread flooding from Pine to Whitman including side streets.	Regional 100 yr. storm.	Detention basin(s) to reduce peak flow rate and attenuate the peak flow. Cost - $3,800,000 (excludes land costs)	Eliminates all flooding.
5	**Alpensee** - Basin BA-7	Titus Road: 376 acre basin enters storm network at roadway storm crossing.	Short Duration 100 yr. storm.	Detention basin(s) to reduce peak flow rate and attenuate the peak flow. Cost - $1,600,00 (excludes land costs)	Eliminates all flooding except Regional and Short Duration 100 yr. storm.
6	**Downtown West** - Basin BW-23	Burke Avenue: Birch to Pine flooding.	Short Duration 100 yr. storm.	Detention basin(s) to reduce peak flow rate and attenuate the peak flow. Cost - $121,000 (excludes land costs)	Eliminates all flooding

FIGURE 6A: DRAINAGE BASIN KEY MAP

Source: Pacific Engineering & Design

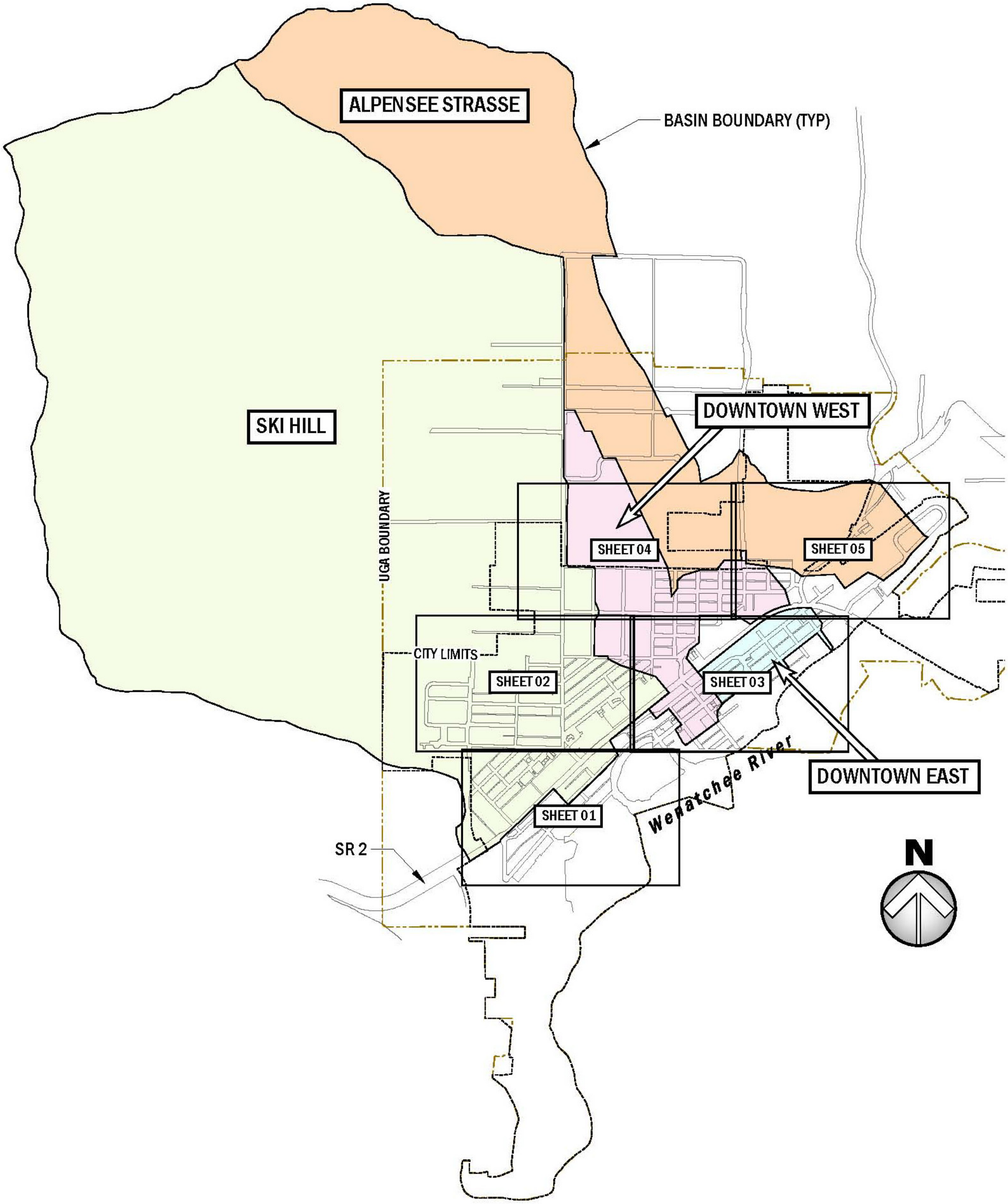


FIGURE 6B: SHEET 01

Source: Pacific Engineering & Design

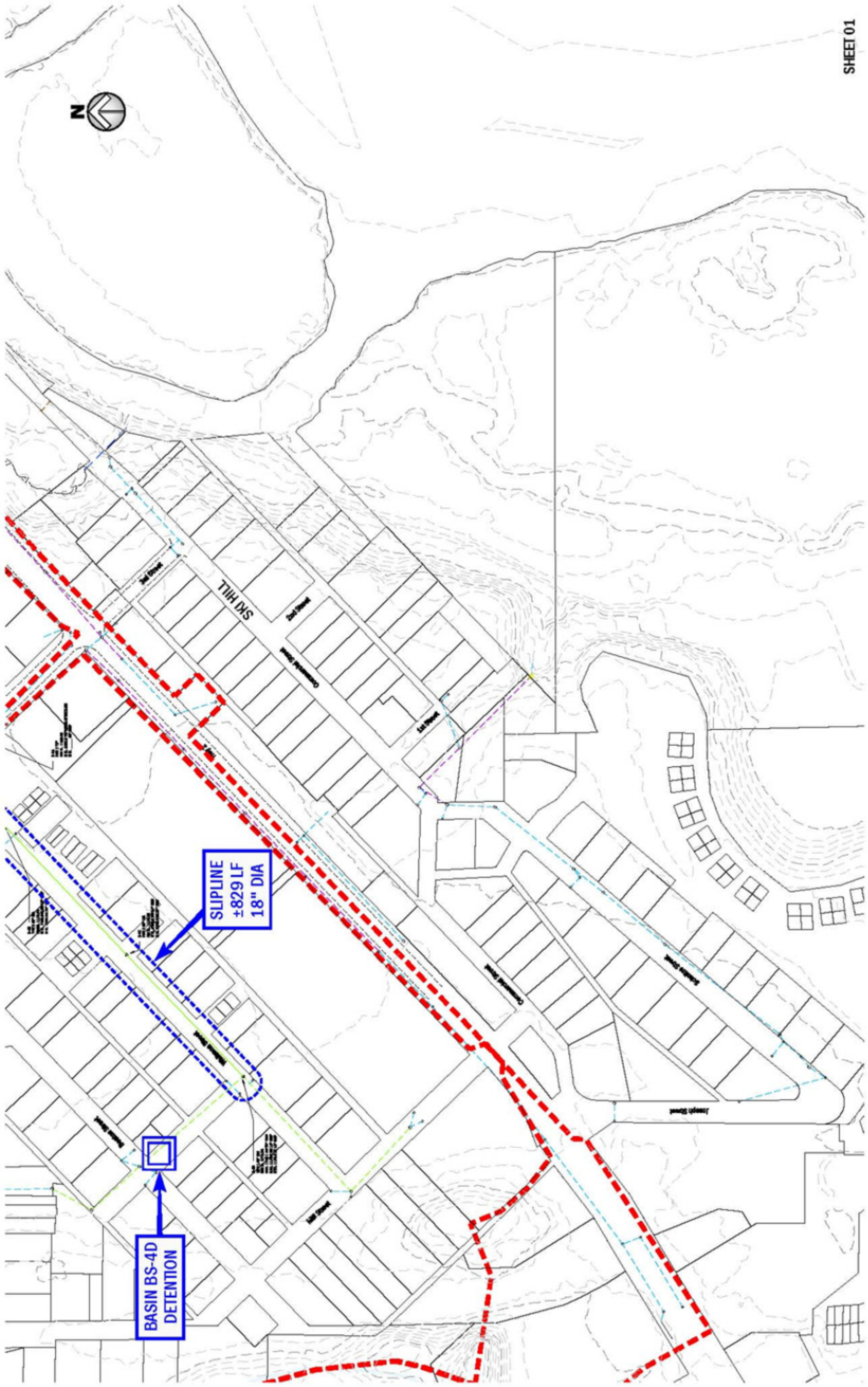


FIGURE 6C: SHEET 02

Source: Pacific Engineering & Design

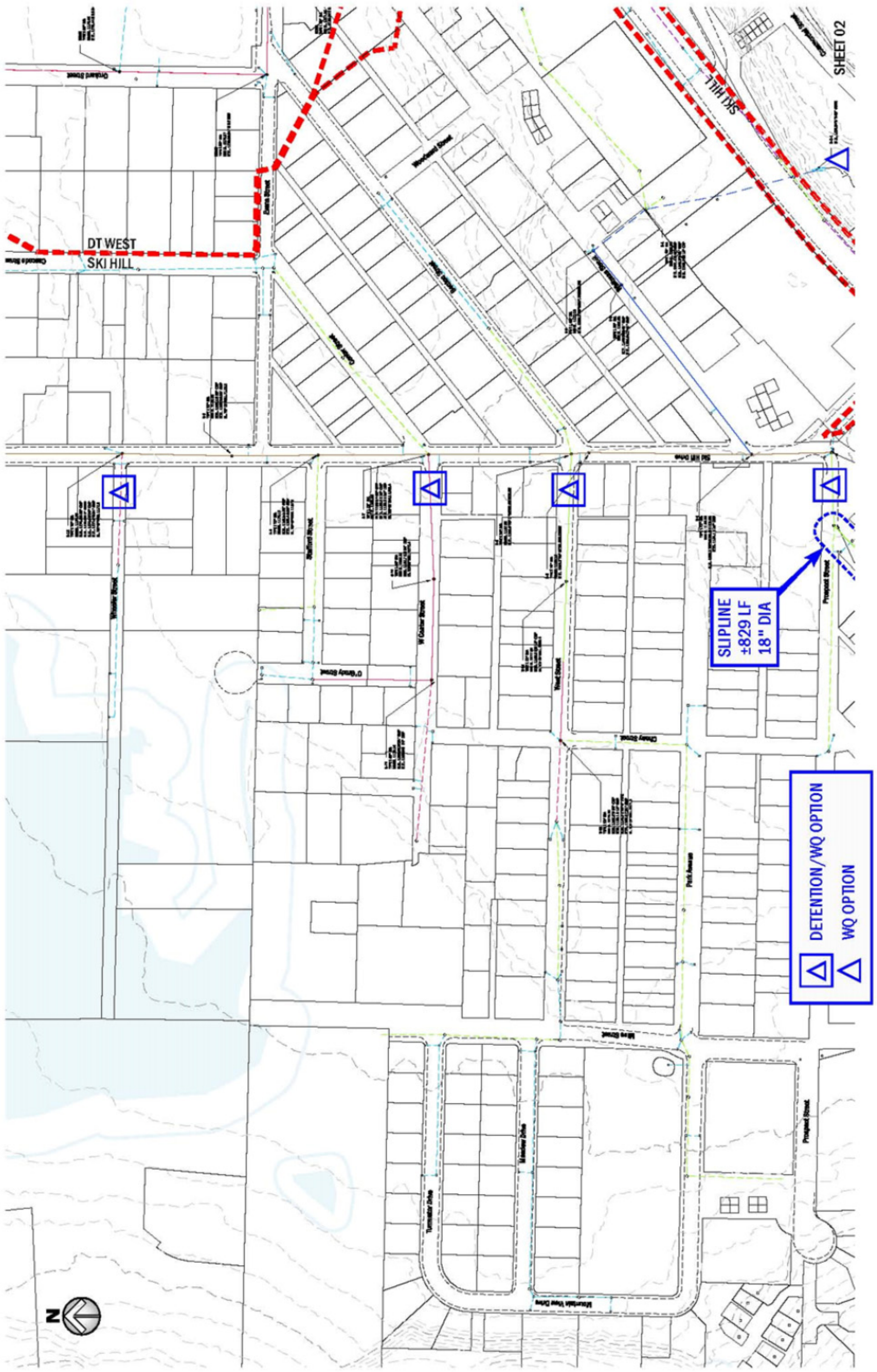


FIGURE 6D: SHEET 03 – DOWNTOWN EAST

Source: Pacific Engineering & Design

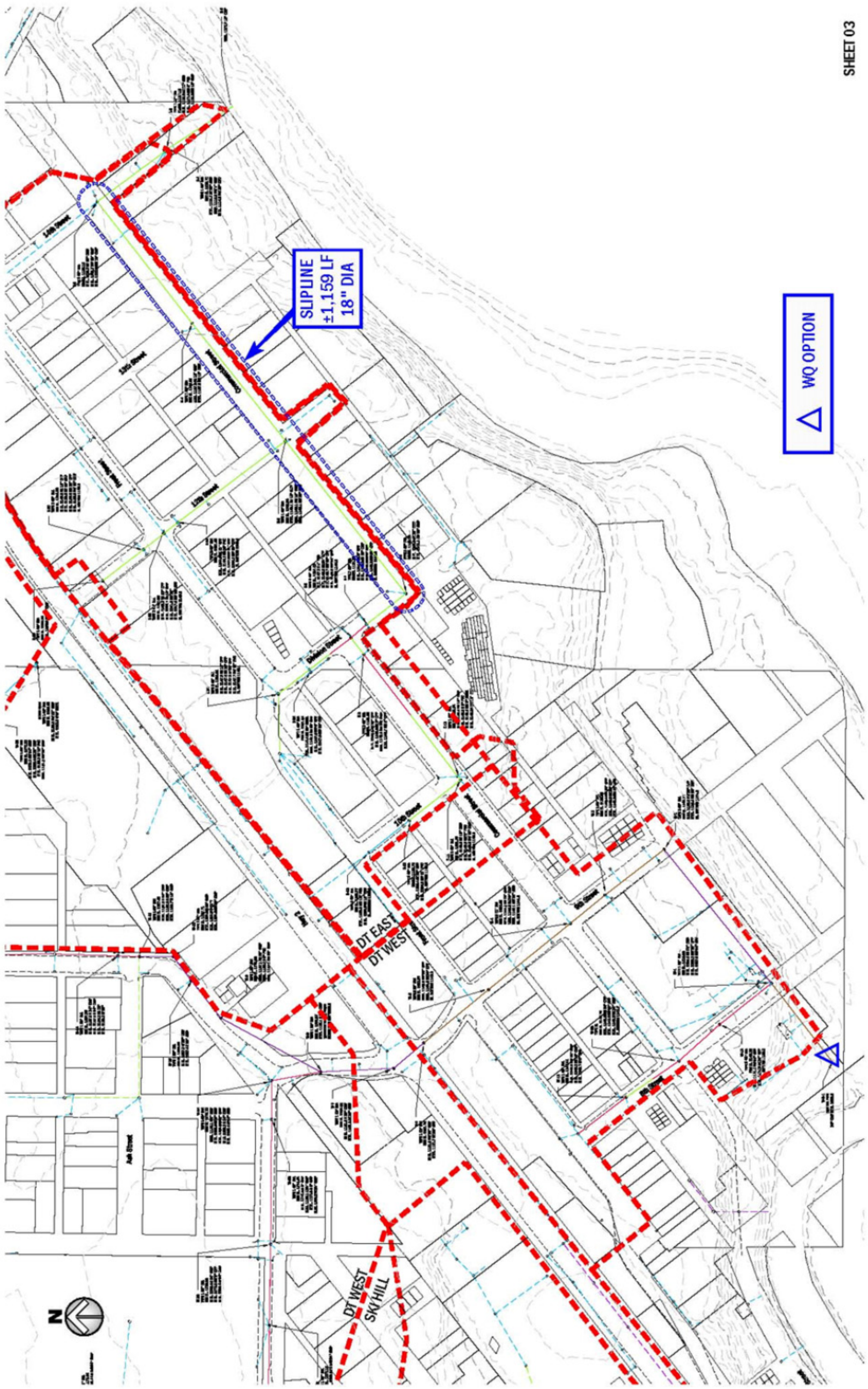


FIGURE 6E: SHEET 04 – DOWNTOWN WEST

Source: Pacific Engineering & Design

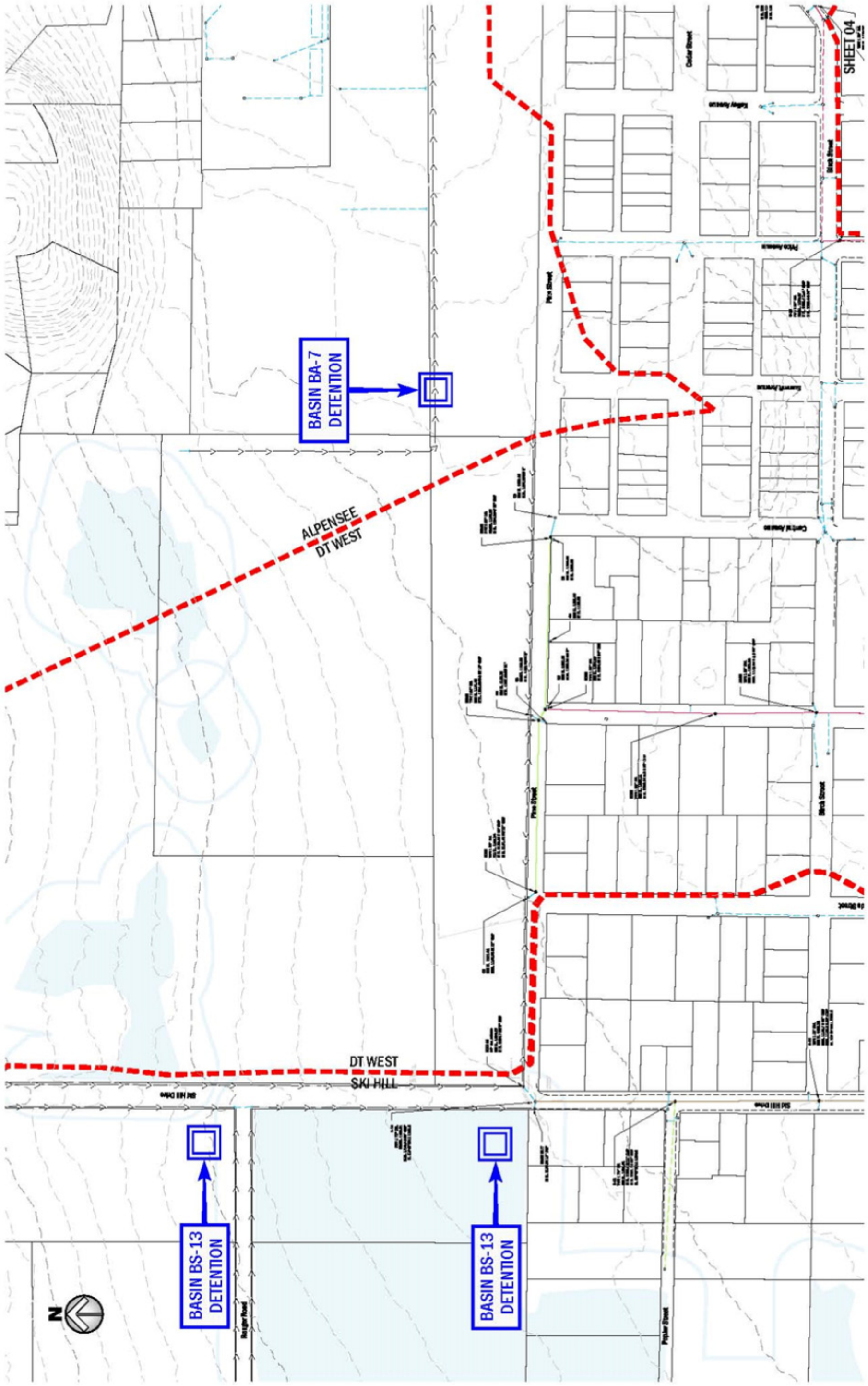
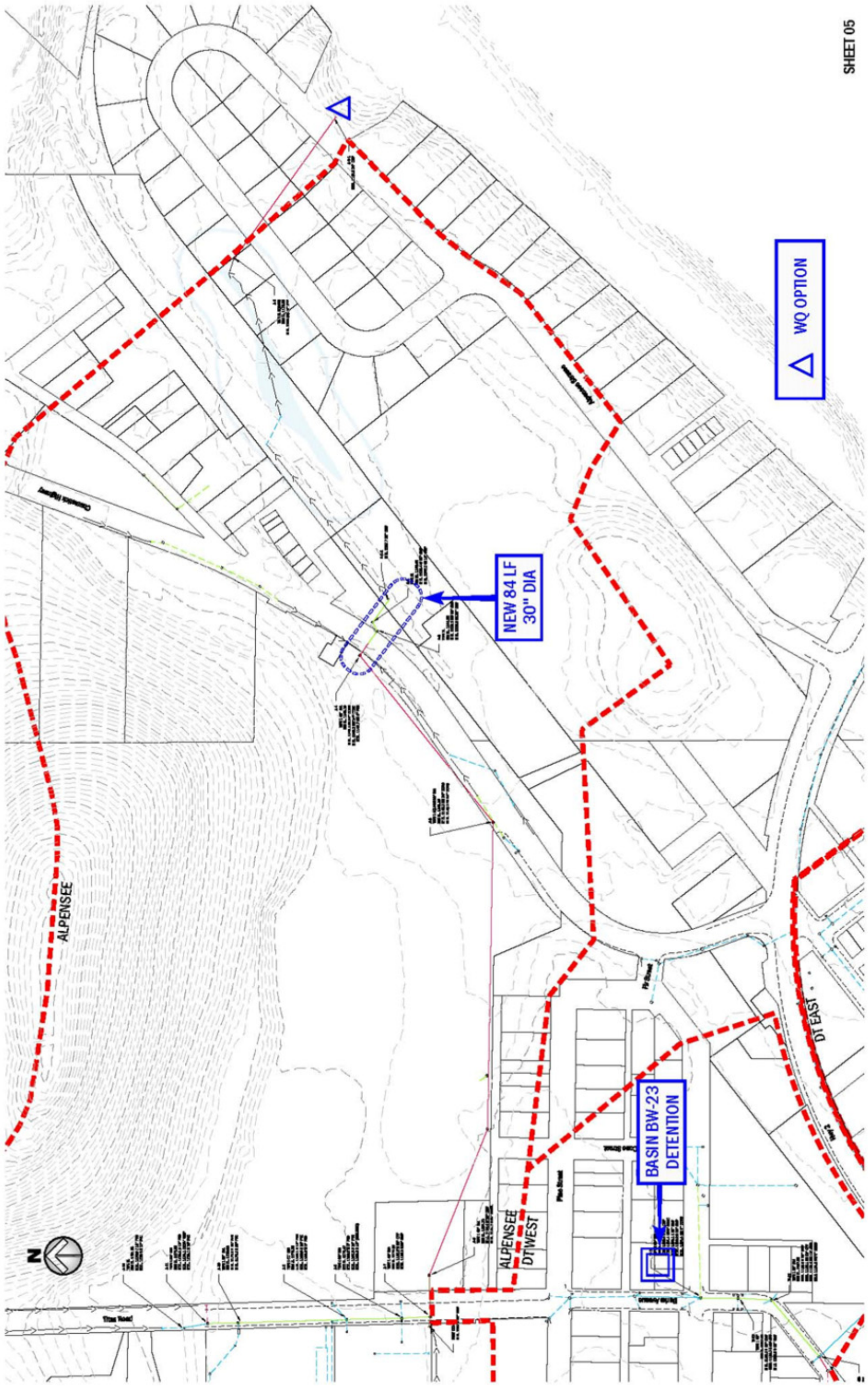


FIGURE 6F: SHEET 05

Source: Pacific Engineering & Design



chapter 7

BEST MANAGEMENT PRACTICES (BMP$_S$)

In this Chapter:

7.1 Introduction

Brief summaries of each of the most commonly used Best Management Practices (BMP_S) are presented here. Emerging technologies are not addressed.

This Chapter includes design guidance on the following stormwater / wetland BMPs:

7.2 Bio-Filtration
7.3 Bio-Infiltration
7.4 Filtration
7.5 Infiltration
7.6 Miscellaneous

TABLE 7A: SUMMARY APPLICATION OF BMP_S

**Listed in order of effectiveness.*

<table>
<tr><th colspan="3">BEST MANAGEMENT PRACTICES (BMPs)</th></tr>
<tr><th>Water Quality Treatment</th><th>Dual Purpose</th><th>Runoff Control</th></tr>
<tr><td colspan="3">Bio-filtration</td></tr>
<tr><td colspan="3">Wetland - Constructed</td></tr>
<tr><td colspan="3">Retention</td></tr>
<tr><td>Vegetated Strip</td><td></td><td></td></tr>
<tr><td></td><td></td><td>Wetland - Natural</td></tr>
<tr><td>Media Filter Drain / Swale</td><td></td><td></td></tr>
<tr><td>Continuous Inflow Swale</td><td></td><td></td></tr>
<tr><td>Swale Wet</td><td></td><td></td></tr>
<tr><td colspan="3">Vegetated Roof</td></tr>
<tr><td colspan="3">Amended Soils</td></tr>
<tr><td colspan="3">Bio-infiltration</td></tr>
<tr><td colspan="3">Dispersion</td></tr>
<tr><td colspan="3">Pond / Swale</td></tr>
<tr><td></td><td></td><td>Trees</td></tr>
<tr><td colspan="3">Filters</td></tr>
<tr><td>Sand Amended</td><td></td><td></td></tr>
<tr><td>Sand Basic / Sand Large</td><td></td><td></td></tr>
<tr><td>Sand Vault / Sand Linear</td><td></td><td></td></tr>
<tr><td colspan="3">Infiltration</td></tr>
<tr><td colspan="3">Trench</td></tr>
<tr><td colspan="3">Drywell</td></tr>
<tr><td colspan="3">Swale</td></tr>
<tr><td colspan="3">Pond</td></tr>
<tr><td colspan="3">Permeable Pavement</td></tr>
<tr><td colspan="3">Vault</td></tr>
<tr><td colspan="3">Miscellaneous</td></tr>
<tr><td colspan="3">Wet Pool / Pond</td></tr>
<tr><td colspan="3">Extended Dry Pond</td></tr>
<tr><td colspan="3">Wet Vault</td></tr>
<tr><td></td><td></td><td>Tank / Vault</td></tr>
<tr><td></td><td></td><td>Pond</td></tr>
<tr><td>Oil / Water Separator</td><td></td><td></td></tr>
<tr><td></td><td></td><td>Rain Water Harvesting</td></tr>
</table>

7.2 BIO - FILTRATION

Vegetated treatment systems (typically grasses) which remove pollutants by means of sedimentation, filtration, soil sorption, and/or plant uptake. These facilities are designed to remove low concentrations and quantities of total suspended solids (TSS), heavy metals, petroleum hydrocarbons, and/or nutrients.

7.2.1 WETLAND: *CONSTRUCTED*

A shallow man-made pond of varying geometry which treats stormwater through biological processes associated with emergent aquatic plants. Ideal for capturing pollutants in a managed environment so that they will not reach natural wetlands and other ecologically important habitats.

7.2.2 BIO - RETENTION

A sloped, vegetated open channel, with amended soils, of varying geometry that can also convey high flows. Locally, the term is used to describe an engineered facility designed and sized for specific water quality treatment and flow control objectives.

7.2.3 VEGETATED STRIP

A sloped vegetated linear strip located adjacent and parallel to paved areas such as parking lots, driveways, and roads. Thin sheet flow from the paved area passes through the filter strip prior to conveyance downstream.

7.2.4 WETLAND: *NATURAL*

Stormwater treatment facilities are not allowed within a wetland or its natural vegetated buffer except for necessary conveyance systems approved by local government; or as allowed in a wetland mitigation plan; or if the wetland meets the criteria for “Hydrologic Modification of a Wetland”.

7.2.5 MEDIA FILTER DRAIN

A linear strip flow-through filter sited parallel to roadway / parking side slopes.

7.2.6 SWALES: *STANDARD / CONTINUOUS INFLOW / WET*

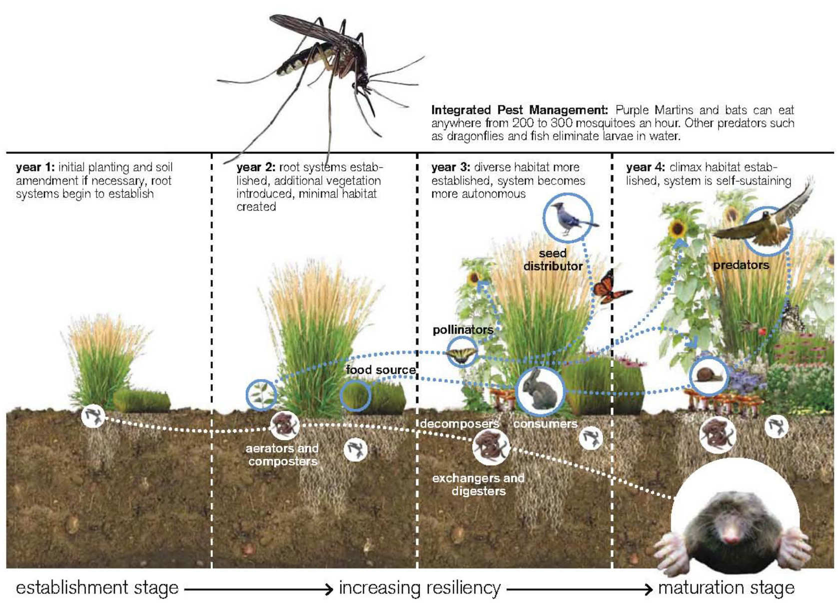
A sloped, vegetated open channel, of varying geometry, which can also convey high flows.

7.2.7 VEGETATED ROOF

Thin layers of engineered soil and vegetation constructed on top of conventional flat or sloped roofs.

7.2.8 AMENDED SOILS

Installation of amended soils over broad areas to regain functions lost when development strips away native soil and vegetation and replaces it with minimal soil, sod or other plantings. Requires adequate depth, permeability, and organic matter to sustain itself.



7.3 BIO - INFILTRATION

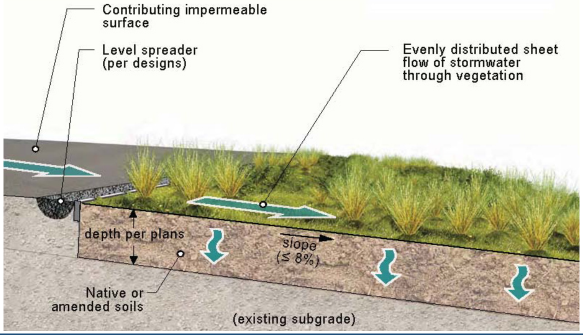
Attempts to minimize the hydrologic changes created by new impervious surfaces by restoring the natural drainage patterns of sheet flow to existing preserved natural areas.

7.3.1 FULL DISPERSION

Runoff from roofs, driveways, roads and other impervious surfaces are traditionally collected then uniformly dispersed via level spreaders to areas of existing preserved vegetation.

7.3.2 SHEET FLOW DISPERSION

An engineered graded surface which maintains sheet flow (eliminates the concentration of surface runoff). Flows need only traverse a narrow strip of adjacent vegetation for effective attenuation and treatment.



7.3.3 CONCENTRATED FLOW DISPERSION

An engineered vegetated pervious area which disperses concentrated flows from impervious surfaces. Effectively attenuates runoff prior to entry into the conveyance system.

7.3.4 SWALE / POND

An impoundment of varying geometry excavated out of native soil with added biological treatment via vegetation.

7.4 FILTRATION

Begins with a pretreatment component, followed by a flow spreader which delivers runoff to a sand filter bed, and collection by an underdrain pipe which conveys treated flow downstream. Ideal for locations with space constraints. Typically utilized in small drainage basins. Does not provide runoff control.

7.4.1 BASIC SAND FILTER / LARGE SAND FILTER

A surface filter located at the low point of a pond or swale. Will not provide treatment when the ground is frozen.

7.4.2 LINEAR SAND FILTER

A linear, shallow, two-celled, underground rectangular vault(s). Cell no. one settles out coarse particles. Cell no. 2 contains a sand bed.

7.4.3 SAND FILTER VAULT

An underground or subgrade vault with a sand filter layer.

7.5 INFILTRATION

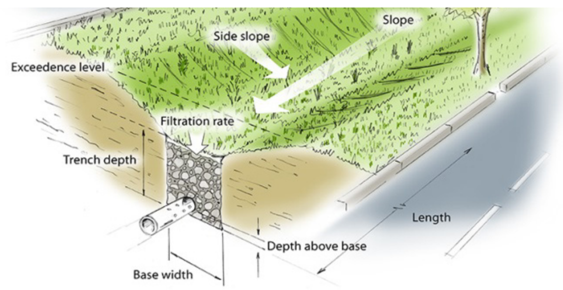
Water Quality Treatment: An impoundment, typically a pond, trench, or swale whose underlying native soil filters pollutants from stormwater.

Runoff Control: Typically an open basin (pond), trench, or buried perforated pipe used for distributing stormwater runoff into the underlying native soil.

Pretreatment for removal of TSS, oil, and/or soluble pollutants may be necessary. Companion practices, such as street sweeping and catch basin inserts can provide additional benefits, and reduce cleaning and maintenance needs.

7.5.1 TRENCH

A subsurface trench with a perforated pipe(s) and backfilled with a coarse stone aggregate. Common when dry wells are insufficient.



7.5.2 DRYWELL

A precast concrete perforated manhole installed underground and backfilled with a coarse stone aggregate. Suitable for small areas.

7.5.3 SWALE / POND

An impoundment of varying geometry excavated out of native soil.

7.5.4 PERMEABLE PAVEMENT

Hot mix asphalt, concrete, and pavers which capture surface runoff and allow it to percolate into native soils. Most common in parking lots.

7.5.5 VAULT

A subsurface constructed or precast vault trench backfilled with a coarse stone aggregate.

7.6 MISCELLANEOUS

The following are categorized as miscellaneous stormwater / wetland BMPs:

7.6.1 WET POND / POOL

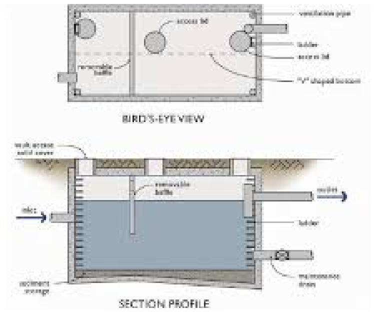
A constructed surface pond which retains a permanent pool of water. The wetpool volume is directly correlated to its effectiveness in settling particulate pollutants. A shallow marsh component can also provide nutrient treatment.

7.6.2 EXTENDED DRY POND

A structure that completely drains between runoff events. A perforated riser or outlet control device enables water to slowly drain from the pond.

7.6.3 WET VAULT

An underground structure which retains a permanent pool of water. Lacks biological pollutant removal mechanisms, such as algae uptake.



7.6.4 DETENTION TANK

Underground storage facility commonly constructed with large diameter corrugated metal pipe associated with a runoff control device. Provides for the temporary storage and metered release of surface water runoff pursuant to the runoff control performance standards.

7.6.5 DETENTION VAULT

Underground box-shaped storage facility typically constructed with reinforced concrete associated with a runoff control device. Provides for the temporary storage and metered release of surface water runoff pursuant to the runoff control performance standards.

7.6.6 DETENTION POND

A surface pond of varying geometry and depth associated with a runoff control device. Provides for the temporary storage and metered release of surface water runoff pursuant to the runoff control performance standards.

7.6.7 OIL / WATER SEPARATOR

Oil and water separators are prebuilt structures which use a gravity mechanism for separation and typically consist of three bays; forebay, separator section, and the after bay. Without intense maintenance, oil/water separators may not be sufficiently effective in achieving oil and TPH removal.

7.6.8 RAIN WATER HARVESTING

Traditional use is in environments where rainfall or other conditions limit water supply. Some well-documented benefits include: Reduces domestic water demand; Emergency water for fire suppression; Source for minor irrigation, non-potable uses, and runoff control.

7.7 BMPs DETAILED SUMMARIES

BMP	Rank	Runoff Control	WQ Treatment	Hydrocarbons	Phosphorus	Total Suspended Solids (TSS)	Metals	Pesticides / Fungacides	Capital Costs	O & M Costs	Effective Life (yr)	Region Suitability	Cold Region Suitability	Pretreatment Required	Slope Limitations	High groundwater limitations	Footprint	Comments
Amended Soils LID4.2	12	√	√												≤ 3:1	√	Varies	4 year soil maturation.
Bio-filtration: Media Filter Drain (cfs)	35		√		√		√		Low	Low to Moderate	5-20	Limited	Fair		≤ 4:1	√	Linear	Ideal for roads / parking - mulitple alternatives. Snow storage.
Bio-filtration: Swale (cfs) *RT.04, T5.40	35		√	~	~	√ ~**	~ √*	~	Low to Moderate	Low to Moderate	5-20	Limited - 1 No - 2	Fair		1.5-5%	√	Linear	*CA only - not allowed in areas with phosphorus TMDL **EPA Region 1 Vegetation maturation period
Bio-filtration: Swale Continuous Inflow (cfs) RT.06	34		√			√	~		Low to Moderate	Low to Moderate	5-20	Limited - 1 No - 2	Poor to Fair		1.5-5%		Linear	*CA only - not allowed in areas with a phosphorus TMDL Vegetation maturation period
Bio-filtration: Swale Wet (cfs) RT.05	33		√			√			Low to Moderate	Low to Moderate	5-20	Limited - 1 No - 2	Poor to Fair		≤ 1.5%		Linear	Good in high groundwater and saturated soils Vegetation maturation period
Bio-filtration: Vegetated Filter Strip (cfs) *RT.02, T5.50	40		√	~ √*	~	√	~ √*	~	Low	Low	20-50	Limited - 1	Fair		≤ 3:1	√	Linear	Ideal for roads / parking. Snow storage. *CA only - not allowed in areas with phophorus TMDL. Vegetation maturation period
Bio-infiltration Pond / Swale (cf) IN.01, T5.30	44	√	√	√	~ √*	√	√	√	Low to Moderate	Low	5-20	Preferred-1 Limitations-2	Fair	√	≤ 1%	√	Small to Large	Snow storage. Vegetation maturation period. *EPA Region 1
Bio-retention (cfs) RT.08, LID4.4	44	√	√	√	~	√	√	√	Moderate	Moderate	5-20	Preferred-1 Limitations-2	Fair		√	√	Varies	
Buildings: Rain Water Harvesting LID4.9	14	√															Small	Supplements other water sources. Roof material limitations.
Buildings: Vegetated Roof LID4.7	28	√	√	~	~	√	~	~					Fair				Varies	Highest benefit from large buildings. Small benefit from individual residences. High roof loads (lb/sf). Energy savings
Detention: Extended Dry (cf)	39	√	√	√*** *	~* √**	~* √**	~* √**		Low	Low	5-20	Acceptable-1 Preferred-2	Fair to Good	√	√	√	Large	Snow Storage. *IDEQ. **ISBD ***Spokane
Detention: Pond (cfs) FC.03, F6.10	23	√							Moderate	Low	20-50	Limited	Fair to Good	√	√	√	Small to Large	Snow storage. Fencing.
Detention: Tank / Vault (cfs) F6.11, F6.12	25	√							Moderate to High	High	50-100	Limitations	Good		√	√	Small	
Dispersion: Natural / Engineered FC.01, FC.02, F6.40, F6.41, F6.42, LID4.3	47	√	√	√	√	√	√		Low	Low	50-100	Limited	Fair		≤ 3:1	√	Linear	Ideal for roads / parking. Utilizes only native existing vegetation. Groundwater vertical separation (≥3').
Filter: Compost Vault (cfs) Emerging Technology	34		√	√		√	~ √*	√	Moderate to High	High	*20	Limited	*Fair			√	Small	*IDEQ
Filter: Sand / Amended (cf/cfs)	34		√	~	~ √*	√	√		Low to Moderate	Moderate	*25	Preferred	Poor	√		√	Medium to Large	Not effective in winter *IDEQ
Filter: Sand Basic/Large (cf/cfs) T5.80, T5.81	33		√	~	~ √*	√	~ √*		Low to Moderate	Moderate	**25	Preferred	Poor	√		√	Medium to Large	Not effective in winter *ISBD **IDEQ
Filter: Sand Vault/Linear (cf/cfs) T5.82, T5.83	29		√	~	~	√	~		Moderate to High	High	*25	Preferred	Poor to Fair	√		√	Small to Medium	Effective in winter. *IDEQ
Infiltration: Drywell (cfs) IN.05, F6.20	37	√	√	~	√	√	~	~	Low to Moderate	Low to Moderate	5-20	Limitations	Fair to Good	√		√	Small	Ecology registration required

TABLE 7B: BMPs DETAILED SUMMARY

BMP	Rank	Runoff Control	WQ Treatment	Hydrocarbons	Phosphorus	Total Suspended Solids (TSS)	Metals	Pesticides / Fungacides	Capital Costs	O & M Costs	Effective Life (yr)	Region Suitability	Cold Region Suitability	Pretreatment Required	Slope Limitations	High groundwater limitations	Footprint	Comments
Infiltration: Permeable Pavement (cfs) IN.06, LID4.6	32	√	√	*	*	√	*	*	High	High	5-20	Limitations	Fair		√	√	Varies	Restricted to light-medium vehicular loads. Succeptible to clogging (winter sanding, sedimentation). *Dependent on supporting native soils
Infiltration: Pond (cfs) IN.02, T5.10, F6.21	33	√	√	~	√	√	~	~	Moderate	Moderate	5-10	Limitations	Fair	√	≤ 3%	√	Medium to Large	Snow storage.
Infiltration: Swale (cfs) T5.21	33	√	√	~	√	√	~	~	Moderate	Moderate	5-10	Limitations	Fair	√	√	√	Medium	
Infiltration: Trench (cfs) IN.03, T5.20, F6.22	40	√	√	~ √*	√	√	~ √*	~	Low	Low	20-50	Limitations	Fair	√	√	√	Linear	*IDEQ
Infiltration: Vault (cfs) IN.04	30	√	√	~	√	√	~	~	Moderate to High	Moderate to High	5-10	Limitations	Fair	√	≤ 4%	√	Varies	
Oil Water Separator: Baffle / Coalescing (cfs) T5.100, T5.110	20		√	√			*~		High		*20	Limited	*Fair	√		√	Small	Intense maintenance. *IDEQ Last choice for oil control.
Trees LID4.5	39	√							Low	Low	20-50	Preferred	Good				Small	Large trees provide highest benefit. Utility conflicts. Encourages infiltration.
Wet Pool / Pond (cf) *RT.12, T5.70, T5.71	42	√	√	~	~ √*	√ ~***	~ √**		Moderate to High	Low to Moderate	20-50	Limited - 1 No - 2	Fair to Good		√		Large	Snow storage. Needs water source. *Large only **IDEQ ***EPA Region 1
Wet Vault (cf) T5.72	33	√**	√	~*		√	~*		Moderate to High	High	50-100	Limitations	Good *Fair			√	Small	*IDEQ **limited
Wetland: Constructed Treatment (cf) RT.13, T5.73	45		√	√	~	√	√	√	Moderate to High	Moderate	20-50	Limited - 1 No - 2	Good		√		Large	Year round adequate water supply. Aquatic plant establishment required. Not intended as an aquatic habitat.
Wetland: Constructed WQ / Runoff (cf/cfs) CO.02	50	√	√	√	~	√	√	√	Low to Moderate	Moderate	20-50	Limited - 1 No - 2	Good		√		Large	Year round adequate water supply. Evaporation can be a concern. Aquatic plant establishment required.
Wetlands: Natural	36	√							NA	NA	NA	NA	NA	√			Varies	Hydroperiod analysis required.

TABLE 7B: BMP_S DETAILED SUMMARY *(CONTINUED)*

chapter 8

SCORING AND RANKING OF BMPs

In this Chapter:

8.1 SCORING MATRIX

TABLE 8A: SCORING MATRIX

SCORING PARAMETER	Points (max)			5	4	3	2	1
Type								
Runoff Control	3	6	11%			High vol.	Mid vol.	Small vol.
WQ Treatment	3					Yes		
Treatment Effectiveness								
Hydrocarbons	3	15	27%			√		~
Phosphorus	5			√		~		
TSS	3					√		~
Metals	3					√		~
Pesticide/Fungicide	1					√		~
Cost								
Capital Costs	5	15	27%	Low	Low to Moderate	Moderate	Moderate to High	High
O&M Costs	5			Low	Low to Moderate	Moderate	Moderate to High	High
Effective Life	5			50-100	20-50	5-20	5-10	
Climate								
Regional Suitability	5	10	18%	Preferred	Acceptable	Limitations	Limited Use	
Cold Suitability	5			Good	Good to Fair	Fair	Fair to Poor	Poor
Site Constraints								
Slope Limitations	1	9	16%					No
High Groundwater Limitations	5			No				
Footprint	3					Large	Medium	Small
No Pretreatment	5		9%	No				
TOTAL		**55**						

8.2 RANKINGS

TABLE 8B: COMPARISON WITH POLLUTANT REMOVAL EFFICIENCY

BMP$_S$	Rank	Runoff Control	WQ Treatment	Hydrocarbons	Phosphorus	Total Suspended Solids (TSS)	Metals	Pesticides / Fungicides
Wetland: Constructed WQ / Runoff (cf/cfs) CO.02	**50**	3	3	3	3	3	3	3
Dispersion: Natural / Engineered FC.01, FC.02, F6.40, F6.41, F6.42, LID4.3	**47**	3	3	3	5	3	3	
Wetland: Constructed Treatment (cf) RT.13, T5.73	**45**		3	3	3	3	3	3
Bio-infiltration Pond / Swale (cf) IN.01, T5.30	**44**	3	3	3	4	3	3	3
Bio-retention (cfs) RT.08, LID4.4	**44**	2	3	3	3	3	3	3
Wet Pool / Pond (cf) *RT.12, T5.70, T5.71	**42**	3	3	1	4	2	2	
Infiltration: Trench (cfs) IN.03, T5.20, F6.22	**40**	2	3	2	5	3	2	1
Bio-filtration: Vegetated Filter Strip (cfs) *RT.02, T5.50	**40**		3	2	3	3	2	1
Detention: Extended Dry (cf)	**39**	3	3	2	4	2	2	
Trees LID4.5	**39**	1						
Infiltration: Drywell (cfs) IN.05, F6.20	**37**	1	3	1	5	3	1	1
Wetlands: Natural	**36**	3						
Bio-filtration: Media Filter Drain (cfs)	**35**		3		5		3	
Bio-filtration: Swale (cfs) *RT.04, T5.40	**35**		3	1	3	2	2	1
Filter: Compost Vault (cfs) Emerging Technology	**34**		3	3		3	2	3
Bio-filtration: Swale Continuous Inflow (cfs) RT.06	**34**		3			3	1	
Filter: Sand / Amended (cf/cfs)	**34**		3	1	4	3	3	
Wet Vault (cf) T5.72	**33**	1	3	1		3	1	
Bio-filtration: Swale Wet (cfs) RT.05	**33**		3			3		
Infiltration: Swale (cfs) T5.21	**33**	3	3	1	5	3	1	1
Infiltration: Pond (cfs) IN.02, T5.10, F6.21	**33**	3	3	1	5	3	1	1
Filter: Sand Basic/Large (cf/cfs) T5.80, T5.81	**33**		3	1	4	3	2	
Infiltration: Permeable Pavement (cfs) IN.06, LID4.6	**32**	2	3	1	3	3	1	1
Infiltration: Vault (cfs) IN.04	**30**	1	3	1	5	3	1	1
Filter: Sand Vault/Linear (cf/cfs) T5.82, T5.83	**29**		3	1	3	3	1	
Buildings: Vegetated Roof LID4.7	**28**	1	3	1	3	3	1	1
Detention: Tank / Vault (cfs) F6.11, F6.12	**25**	1						
Detention: Pond (cfs) FC.03, F6.10	**23**	3						
Oil Water Separator: Baffle / Coalescing (cfs) T5.100, T5.110	**20**		3	3			1	
Buildings: Rain Water Harvesting LID4.9	**14**	1						
Amended Soils LID4.2	**12**	2	3					

TABLE 8C: COMPARISON WITH COSTS

BMPs	Rank	Runoff Control	WQ Treatment	Capital Costs	O & M Costs	Effective Life (yr.)
Wetland: Constructed WQ / Runoff (cf/cfs) CO.02	**50**	3	3	4	3	4
Dispersion: Natural / Engineered FC.01, FC.02, F6.40, F6.41, F6.42, LID4.3	**47**	3	3	5	5	5
Wetland: Constructed Treatment (cf) RT.13, T5.73	**45**		3	2	3	4
Bio-infiltration Pond / Swale (cf) IN.01, T5.30	**44**	3	3	4	5	3
Bio-retention (cfs) RT.08, LID4.4	**44**	2	3	3	3	3
Wet Pool / Pond (cf) *RT.12, T5.70, T5.71	**42**	3	3	2	4	4
Infiltration: Trench (cfs) IN.03, T5.20, F6.22	**40**	2	3	5	5	4
Bio-filtration: Vegetated Filter Strip (cfs) *RT.02, T5.50	**40**		3	5	5	4
Detention: Extended Dry (cf)	**39**	3	3	5	5	3
Trees LID4.5	**39**	1		5	5	4
Infiltration: Drywell (cfs) IN.05, F6.20	**37**	1	3	4	4	3
Wetlands: Natural	**36**	3		5	5	5
Bio-filtration: Media Filter Drain (cfs)	**35**		3	5	4	3
Bio-filtration: Swale (cfs) *RT.04, T5.40	**35**		3	4	4	3
Filter: Compost Vault (cfs) Emerging Technology	**34**		3	2	1	3
Bio-filtration: Swale Continuous Inflow (cfs) RT.06	**34**		3	4	4	3
Filter: Sand / Amended (cf/cfs)	**34**		3	4	3	4
Wet Vault (cf) T5.72	**33**	1	3	2	1	5
Bio-filtration: Swale Wet (cfs) RT.05	**33**		3	4	4	3
Infiltration: Swale (cfs) T5.21	**33**	3	3	3	3	2
Infiltration: Pond (cfs) IN.02, T5.10, F6.21	**33**	3	3	3	3	2
Filter: Sand Basic/Large (cf/cfs) T5.80, T5.81	**33**		3	4	3	4
Infiltration: Permeable Pavement (cfs) IN.06, LID4.6	**32**	2	3	1	1	3
Infiltration: Vault (cfs) IN.04	**30**	1	3	3	2	2
Filter: Sand Vault/Linear (cf/cfs) T5.82, T5.83	**29**		3	2	1	4
Buildings: Vegetated Roof LID4.7	**28**	1	3			
Detention: Tank / Vault (cfs) F6.11, F6.12	**25**	1		2	1	5
Detention: Pond (cfs) FC.03, F6.10	**23**	3		3	5	4
Oil Water Separator: Baffle / Coalescing (cfs) T5.100, T5.110	**20**		3	1		3
Buildings: Rain Water Harvesting LID4.9	**14**	1				
Amended Soils LID4.2	**12**	2	3			

TABLE 8D: COMPARISON WITH REGION SUITABILITY

BMPs	Rank	Runoff Control	WQ Treatment	Region 1 Suitability	Cold Region Suitability
Wetland: Constructed WQ / Runoff (cf/cfs) CO.02	**50**	3	3	2	5
Dispersion: Natural / Engineered FC.01, FC.02, F6.40, F6.41, F6.42, LID4.3	**47**	3	3	2	3
Wetland: Constructed Treatment (cf) RT.13, T5.73	**45**		3	2	5
Bio-infiltration Pond / Swale (cf) IN.01, T5.30	**44**	3	3	5	3
Bio-retention (cfs) RT.08, LID4.4	**44**	2	3	5	3
Wet Pool / Pond (cf) *RT.12, T5.70, T5.71	**42**	3	3	2	4
Infiltration: Trench (cfs) IN.03, T5.20, F6.22	**40**	2	3	3	3
Bio-filtration: Vegetated Filter Strip (cfs) *RT.02, T5.50	**40**		3	2	3
Detention: Extended Dry (cf)	**39**	3	3	5	4
Trees LID4.5	**39**	1		5	5
Infiltration: Drywell (cfs) IN.05, F6.20	**37**	1	3	3	4
Wetlands: Natural	**36**	3		5	5
Bio-filtration: Media Filter Drain (cfs)	**35**		3	2	3
Bio-filtration: Swale (cfs) *RT.04, T5.40	**35**		3	2	3
Filter: Compost Vault (cfs) Emerging Technology	**34**		3	2	3
Bio-filtration: Swale Continuous Inflow (cfs) RT.06	**34**		3	2	2
Filter: Sand / Amended (cf/cfs)	**34**		3	5	1
Wet Vault (cf) T5.72	**33**	1	3	3	4
Bio-filtration: Swale Wet (cfs) RT.05	**33**		3	2	2
Infiltration: Swale (cfs) T5.21	**33**	3	3	3	3
Infiltration: Pond (cfs) IN.02, T5.10, F6.21	**33**	3	3	3	3
Filter: Sand Basic/Large (cf/cfs) T5.80, T5.81	**33**		3	5	1
Infiltration: Permeable Pavement (cfs) IN.06, LID4.6	**32**	2	3	3	3
Infiltration: Vault (cfs) IN.04	**30**	1	3	3	3
Filter: Sand Vault/Linear (cf/cfs) T5.82, T5.83	**29**		3	5	2
Buildings: Vegetated Roof LID4.7	**28**	1	3		3
Detention: Tank / Vault (cfs) F6.11, F6.12	**25**	1		3	5
Detention: Pond (cfs) FC.03, F6.10	**23**	3		2	4
Oil Water Separator: Baffle / Coalescing (cfs) T5.100, T5.110	**20**		3	2	3
Buildings: Rain Water Harvesting LID4.9	**14**	1			
Amended Soils LID4.2	**12**	2	3		

TABLE 8E: COMPARISON WITH PHYSICAL LIMITATIONS

BMPs	Rank	Runoff Control	WQ Treatment	Region 1 Suitability	Slope Limitations	High Groundwater Limitations	Footprint
Wetland: Constructed WQ / Runoff (cf/cfs) CO.02	**50**	3	3	2		5	1
Dispersion: Natural / Engineered FC.01, FC.02, F6.40, F6.41, F6.42, LID4.3	**47**	3	3	2			2
Wetland: Constructed Treatment (cf) RT.13, T5.73	**45**		3	2		5	1
Bio-infiltration Pond / Swale (cf) IN.01, T5.30	**44**	3	3	5			2
Bio-retention (cfs) RT.08, LID4.4	**44**	2	3	5			2
Wet Pool / Pond (cf) *RT.12, T5.70, T5.71	**42**	3	3	2		5	1
Infiltration: Trench (cfs) IN.03, T5.20, F6.22	**40**	2	3	3			2
Bio-filtration: Vegetated Filter Strip (cfs) *RT.02, T5.50	**40**		3	2			2
Detention: Extended Dry (cf)	**39**	3	3	5			1
Trees LID4.5	**39**	1		5	1	5	3
Infiltration: Drywell (cfs) IN.05, F6.20	**37**	1	3	3	1		3
Wetlands: Natural	**36**	3		5	1	5	2
Bio-filtration: Media Filter Drain (cfs)	**35**		3	2			2
Bio-filtration: Swale (cfs) *RT.04, T5.40	**35**		3	2			2
Filter: Compost Vault (cfs) Emerging Technology	**34**		3	2	1		3
Bio-filtration: Swale Continuous Inflow (cfs) RT.06	**34**		3	2		5	2
Filter: Sand / Amended (cf/cfs)	**34**		3	5	1		1.5
Wet Vault (cf) T5.72	**33**	1	3	3	1		3
Bio-filtration: Swale Wet (cfs) RT.05	**33**		3	2		5	2
Infiltration: Swale (cfs) T5.21	**33**	3	3	3			2
Infiltration: Pond (cfs) IN.02, T5.10, F6.21	**33**	3	3	3			1.5
Filter: Sand Basic/Large (cf/cfs) T5.80, T5.81	**33**		3	5	1		1.5
Infiltration: Permeable Pavement (cfs) IN.06, LID4.6	**32**	2	3	3			2
Infiltration: Vault (cfs) IN.04	**30**	1	3	3			2
Filter: Sand Vault/Linear (cf/cfs) T5.82, T5.83	**29**		3	5	1		2.5
Buildings: Vegetated Roof LID4.7	**28**	1	3			5	2
Detention: Tank / Vault (cfs) F6.11, F6.12	**25**	1		3			3
Detention: Pond (cfs) FC.03, F6.10	**23**	3		2			2
Oil Water Separator: Baffle / Coalescing (cfs) T5.100, T5.110	**20**		3	2	1		3
Buildings: Rain Water Harvesting LID4.9	**14**	1				5	3
Amended Soils LID4.2	**12**	2	3				2

TABLE 8F: EMERGING TECHNOLOGY RANKINGS

EMERGING TECHNOLOGY								
Manufacturer	Product	Ranking	Pretreatment	Oil	Metals	Basic	Phosphorus
Contech	Filterra Boxless 100 in/hr	18		General	General	General	General
Contech	Filterra System 100 in/hr	18		General	General	General	General
Bio Clean	Modular Wetland 0.46 cfs or 20,145 cf	13			General	General	General
WSDOT	Media Filter Drain	13			General	General	General
WSDOT	CA Biofiltration Swale	11		Conditional	General	General	
BaySaver Technologies	BayFilter	9			Conditional	General	Conditional
Kristar / Oldcastle	FloGard Perk Filter 2.1 cfs	8				General	General
StormwateRx	Aquip	8			Conditional	Conditional	Conditional
AquaShield	Aqua-Swirl System	6	General			General	
Contech	CDS Stormwater Treatment	6	General	Pilot		Conditional	
Contech	Media Filtration Perlite	5				Conditional	Conditional
Contech	StormFilter MetalRx Media	5			Conditional	Conditional	
Contech	StormFilter PhosphoSorb	5				Conditional	Conditional
Lean Environment	Enpurion Metals Treatment	5			Conditional	Conditional	
AquaShield	Aqua-Filter System	4		Pilot	Pilot	Pilot	Pilot
Contech	Jellyfish Filter	4		Pilot		Conditional	Pilot
Contech	UrbanGreen BioFilter	4		Pilot	Pilot	Conditional	
Contech	StormFilter Perlite	3				Conditional	Pilot
Contech	StormFilter ZPG Media	3				General	
Contech	Vortechs System	3	General				
Hydro International	Downstream Defender	3	General				
Imbrium Systems	Stormceptor	3	General				
Royal Environmental	ecoStorm plus	3				General	
BaySaver Technologies	BaySeparator	2	Conditional				
Hydro International	Up-Flo Filter	2				Conditional	
Torrent Resources	Maxwell Plus	2		Pilot		Pilot	
Environment 21	StormPro	1	Pilot				

General	Ok for use	3	**Points**
Conditional	Under Testing	2	
Pilot	Ecology Notification Required	1	

THIS PAGE INTENTIONALLY LEFT BLANK

chapter 9

BMPs REFERENCES

In this Chapter:

9.1 REFERENCES

Brief summaries of the references used for scoring and ranking BMP best suited to Leavenworth are presented here. They are listed in order of decreasing localized focus, e.g. Washington State, Idaho, California, and Region 1: Northeast.

The development of the 2012 International Stormwater BMP Database (ISBD) was sponsored by the Water Environmental Research Foundation (WERF), American Society of Civil Engineers (ASCE), Environmental and Water Resources Institute (EWRI), American Public Works association (APWA), Federal Highway Administration (FHWA), and the Environmental Protection Agency (EPA). Its purpose was intended to provide a consistent and scientifically defensible set of data on Best Management Practice ("BMP") designs and related performance.

9.1.1 STORMWATER MANAGEMENT MANUAL FOR EASTERN WASHINGTON, ECOLOGY, 2004

- Table 5.2.2 Ability of Treatment Facilities To Remove Key Pollutants
- Table 5.2.3 Screening Treatment Facilities Based on Soil Type
- Table 5.2.4 Suggested Stormwater Treatment Options Based on Annual Average Rainfall
- Table 5.2.6 Summary of BMP Applicability in Cold Regions
- 5.11 Phosphorus Treatment and Metals Treatment, p. 5-112 to 5-116
- Table 5.11.1 Treatment Trains for Phosphorus Removal
- Table 5.11.2 Treatment Trains for Dissolved Metals Removal

9.1.2 HIGHWAY RUNOFF MANUAL, WSDOT, 2014

- Figure 5-3 Runoff treatment BMP selection flow chart
- Figure 5-4 Site development LID BMP selection flow chart
- Table 5-1 Relative rankings of cost elements and effective life of BMP options

9.1.3 REGIONAL STORMWATER MANUAL, SPOKANE, 2008

- 6.5 Treatment Goals, p. 6-9 to 6-10

9.1.4 STORM WATER BEST MANAGEMENT PRACTICES CATALOGUE, IDAHO DEPARTMENT OF ENVIRONMENTAL QUALITY (IDEQ), 2005

- Table 4-1b Selection Matrix for Post Construction BMPs

9.1.5 CALTRANS, 2010

- Table data below is highly weighted towards infiltration
- Table 4.1 Concentration-based BMP Ranking for Target Design Constituents
- Table 4.2 Load-based BMP Ranking for Target Design Constituents

9.1.6 BMP PERFORMANCE ANALYSIS, EPA, REGION 1 (NORTHEAST), 2008

- 4.1.4 BMPDDS Test Results, p. 42-44

9.1.7 INTERNATIONAL STORMWATER BMP DATABASE (ISBD), 2013

- Advanced Analysis: Influence of Design Parameters on Performance, ISBD, p. 69-71
- Pollutant Category Statistical Summary Report, ISBD, 2014

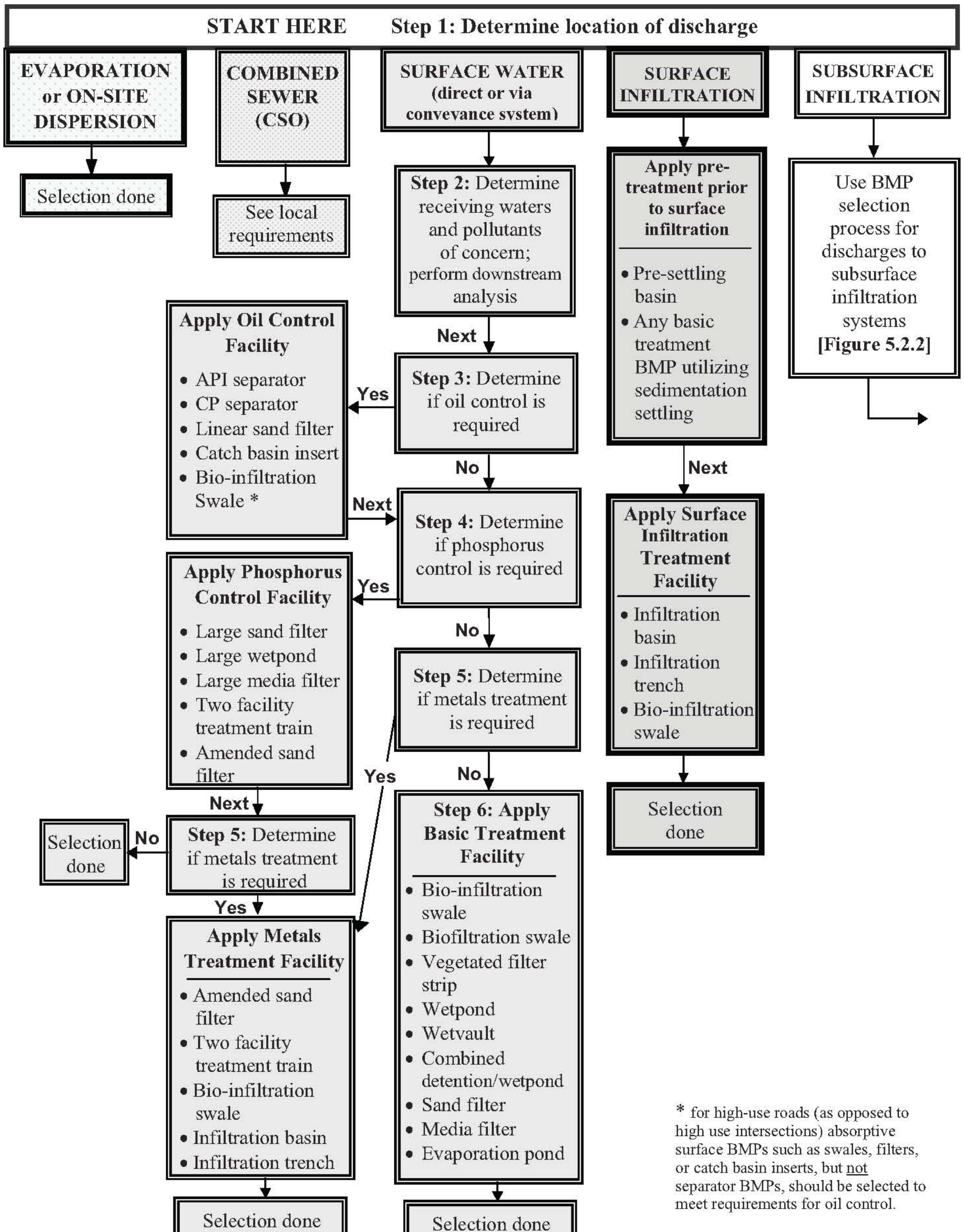
appendix A

REFERENCE EXCERPTS

In this Appendix:

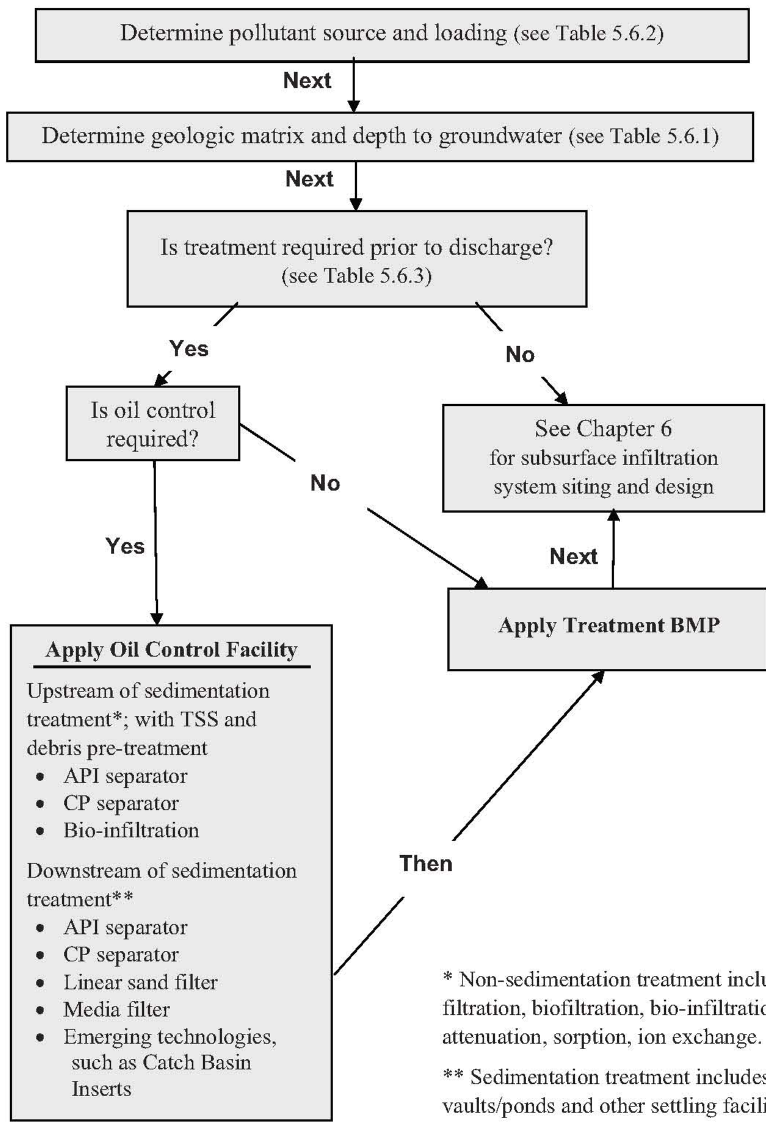
A.1 Stormwater Management Manual for Eastern Washington, Ecology, 2004

Figure 5.2.1 BMP Selection Process



* for high-use roads (as opposed to high use intersections) absorptive surface BMPs such as swales, filters, or catch basin inserts, but not separator BMPs, should be selected to meet requirements for oil control.

Figure 5.2.2 BMP Selection Process for Discharges to Subsurface Infiltration Systems



* Non-sedimentation treatment includes: filtration, biofiltration, bio-infiltration, soil attenuation, sorption, ion exchange.

** Sedimentation treatment includes: wet vaults/ponds and other settling facilities.

Table 5.2.2[4] Ability of Treatment Facilities to Remove Key Pollutants[1] [3]

Treatment Facility	TSS	Dissolved Metals incl. Cu, Zn	Total Phosphorus	Pesticides/ Fungicides	Hydro-carbons incl. O&G, PAH
Wet Pond	■	+	+		+
Wet Vault	■				
Biofiltration	■	+	+	+	+
Sand Filter	■	+	+		+
Constructed Wetland	■	■	+	■	■
Leaf Compost Filters	■	+		■	■
Infiltration[2]	■	+		+	+
Oil/Water Separator					■
Bio-infiltration	■	■	+	■	■

Footnotes:

■ *Significant Process*

+ *Lesser Process*

(1) *Adapted from Kulzer, King Co. Additional BMPs not included in the table, but that have metals treatment benefit, are amended sand filter, and two facility treatment trains; for phosphorus treatment are large sand filter, two facility treatment trains, and amended sand filter.*

(2) *Assumes loamy sand, sandy loam, or loam soils*

(3) *If a cell is blank, then the treatment facility is not particularly effective at treating the identified pollutant*

Table 5.2.3 Screening Treatment Facilities Based on Soil Type

Soil Type	Infiltration	Wet Pond*	Bio-Infiltration	Biofiltration* (Swale or Filter Strip)
Coarse Sand or Cobbles	-	-	-	-
Sand	■	-	-	-
Loamy Sand	■	-	■	■
Sandy Loam	■	-	■	■
Loam	-	-	■	■
Silt Loam	-	-	■	■
Sandy Clay Loam	-	■	-	■
Silty Clay Loam	-	■	-	-
Sandy Clay	-	■	-	-
Silty Clay	-	■	-	-
Clay	-	■	-	-

Notes:

■ *Indicates that use of the technology is generally appropriate for this soil type.*

\- *Indicates that use of the technology is generally not appropriate for this soil type*

* *Coarser soils may be used for these facilities if a liner is installed to prevent infiltration, or if the soils are amended to reduce the infiltration rate.*

Note: *Sand filtration is not listed because its feasibility is not dependent on soil type.*

Table 5.2.4 Suggested Stormwater Treatment Options Based on Average Annual Rainfall

Stormwater Practice	Arid Watersheds < 16 in. rainfall	Semi-Arid Watersheds 16 in. to 35 in. rainfall
Sand filters	Preferred: ▪ Requires greater pretreatment ▪ Sensitive to sediment loadings	Preferred
Bio-infiltration Swales	Acceptable with Limitations: ▪ Use dryland grass	Preferred: ▪ Use dryland or irrigated grass
Extended detention dry ponds	Preferred: ▪ Multiple storm extended detention ▪ Stable pilot channels ▪ "Dry" forebay	Acceptable: ▪ Dry or wet forebay needed
Infiltration	Acceptable with Limitations: ▪ See Table 5.6.3 ▪ Minimize erodable soils that reduce infiltration ▪ Pretreatment ▪ Soil limitations	Acceptable with Limitations: ▪ See Table 5.6.3 ▪ Minimize erodable soils that reduce infiltration ▪ Pretreatment
Wet ponds	Not Recommended: ▪ Evaporation rates are too high to maintain a normal pond without extensive use of scarce water	Limited Use: ▪ Liners to prevent water loss require water balance analysis design for a variable rather than permanent normal pool ▪ Use water sources such as AC condensate for pool ▪ Aeration unit to prevent stagnation
Stormwater wetlands	Not Recommended: ▪ Evaporation rates too great to maintain wetlands plants	Limited Use: ▪ Require supplemental water ▪ Submerged gravel wetlands can help reduce water loss
Biofiltration Swales	Not Recommended: ▪ Not recommended for pollutant removal, but rock berms and grade control needed for open channels to prevent channel erosion	Limited Use: ▪ Limited use unless irrigated or use dryland grasses ▪ Rock berms and grade control essential to prevent erosion in open channels

Adapted from: *Stormwater Strategies for Arid and Semi-Arid Watersheds*, Watershed Protection Techniques, Vol. 3, No. 3, March 2000

Other Physical Factors

- Slope: Steep site slopes restrict the use of several BMPs. A geotechnical/hydrologic evaluation should be done for sites on steeper slopes. See specific guidance for each BMP.
- High Water Table: Unless there is sufficient horizontal hydraulic receptor capacity, the water table acts as an effective barrier to exfiltration and can sharply reduce the efficiency of an infiltration system. If the high water table extends to within five (5) feet of the bottom of an infiltration BMP, the site is seldom suitable.
- Depth to Limiting Layer: The downward exfiltration of stormwater is also impeded if a bedrock or till layer lies too close to the surface. If

Table 5.2.6 Summary of BMP Applicability in Cold Regions

Section ---- BMP #	BMP Category or Type	Applica-bility	Notes
5.4	***Infiltration and Bio-infiltration***		
T5.10	Infiltration Pond	fair	Can be effective but may be restricted by groundwater quality concerns related to infiltration of chlorides. Frozen ground may inhibit the infiltration capacity of ground.
T5.20	Infiltration Trench	fair	Same concerns as for Infiltration Pond
T5.21	Infiltration Swale	fair	Same concerns as for Infiltration Pond
T5.30	Bio-infiltration Swale	fair	Same concerns as for Infiltration Pond
5.5	***Biofiltration***		
T5.40	Biofiltration Swale	fair	Reduced effectiveness in the winter because of dormant vegetation. Very valuable for snow storage and meltwater infiltration.
T5.50	Vegetated Filter Strip	fair	Reduced effectiveness in the winter because of dormant vegetation. Very valuable for snow storage and meltwater infiltration.
5.6	***Subsurface Infiltration***	fair to good	Infiltration surface below frost line.
	Drywell	fair to good	Infiltration surface below frost line.
5.7	***Wetpools and Dry Ponds***		
T5.70	Basic Wetpond	fair	Can be effective but needs modifications to prevent freezing of outlet pipes. Limited by reduced treatment volume and biological activity during ice cover.
T5.71	Large Extended Detention (ED) Wetpond	good	Some modifications needed to conveyance structures. Extended detention storage provides treatment during winter season.

Table 5.2.6 Summary of BMP Applicability in Cold Regions

Section ---- BMP #	BMP Category or Type	Applica-bility	Notes
See section 5.7.3	Large Extended Detention (ED) Dry Ponds	fair	Few modifications needed to adapt to cold climates. Not highly recommended because of relatively poor warm season performance.
T5.72	Wet Vault	good	Design pool elevation below frost line or per manufacturer specs. Some modifications needed to conveyance structures.
T5.73	Extended Detention (ED) Wetland	good	Extended detention storage provides treatment during winter season. Modifications needed to wetland plant species. Some modifications needed to conveyance structures.
5.8	***Sand Filtration***		
T5.80	Basic Sand Filter	poor	Frozen ground considerations, combined with frost heave, make this ineffective in cold climates.
T5.81	Large Sand Filter	poor	Same concerns as for Basic Sand Filter.
T5.82	Sand Filter Vault	good	Design filter elevation below frost line or per manufacturer specs
T5.83	Linear Sand Filter	poor to fair	Design filter elevation below frost line or per manufacturer specs. Cold conditions may plug surface inlet and impact performance.
5.9	***Evaporation Ponds***	fair to good	Evaporation not expected to result in significant water losses during cold weather; hence must size to provide adequate storage.
5.10	***Oil and Water Separator***		
T5.100	API Separator Bay	poor to fair	Check with the manufacturer for cold weather applicability.
T5.110	Coalescing Plate Bay	poor to fair	Check with the manufacturer for cold weather applicability.

- ~~Inspect oil/water separators monthly during the wet season of October 1-June 30 (WEF & ASCE, 1998; Woodward-Clyde Consultants) to ensure proper operation, and, during and immediately after a large storm event of greater than or equal to 1 inch per 24 hours. In region 2, it is most important to check these facilities in the spring before the summer thunderstorm season begins; one annual check done at this time of year should be sufficient for oil/water separators in region 2.~~
- ~~Clean oil/water separators regularly to keep accumulated oil from escaping during storms. They must be cleaned by October 15 to remove material that has accumulated during the dry season (Woodward-Clyde Consultants), after all spills and after a significant storm. Coalescing plates may be cleaned in-situ or after removal from the separator. An eductor truck may be used for oil, sludge, and wash water removal. (King County Surface Water Management, 1998) Replace wash water in the separator with clean water before returning it to service.~~
- ~~Remove the accumulated oil when the thickness reaches 1 inch. Also remove sludge deposits when the thickness reaches 6 inches (King County Surface Water Management, 1998).~~
- ~~Replace oil absorbent pads before their sorbed oil content reaches capacity.~~
- ~~Train designated employees on appropriate separator operation, inspection, record keeping, and maintenance procedures.~~

~~See Appendix 5A for more detailed information.~~

5.11 Phosphorus Treatment and Metals Treatment

5.11.1 Phosphorus Treatment

Where Applied

Phosphorus treatment applies to projects within watersheds that have been determined by local governments, the Department of Ecology, or the USEPA to be sensitive to phosphorus and that are being managed to control phosphorus inputs from stormwater.

Performance Goal

The Phosphorus Treatment facility choices are intended to achieve a goal of 50% total phosphorus removal for a range of influent concentrations of 0.1 – 0.5 mg/l total phosphorus. In addition, the choices are intended to achieve the Basic Treatment performance goal. The performance goal applies to the water quality design storm volume or flow rate, whichever is applicable, and on an annual average basis. The incremental portion of runoff in excess of the water quality design flow rate or volume can be routed around the facility (off-line treatment facilities), or can be passed through the facility (on-line treatment facilities) provided a net pollutant reduction is maintained. Ecology encourages the design and operation of treatment facilities that engage a bypass at flow rates higher than the water quality design flow rate. However, this is acceptable provided that the overall reduction in phosphorus loading (treated plus bypassed) is at least equal to that achieved with initiating bypass at the water quality design flow rate.

Phosphorus Treatment Options

Any one of the following options may be chosen to satisfy the phosphorus treatment requirement.

Infiltration with Appropriate Pretreatment – See Section 5.4.

Infiltration treatment – If infiltration is through soils meeting the minimum site suitability criteria for infiltration treatment (see Section 5.4), a presettling basin or a basic treatment facility can serve for pretreatment.

Infiltration preceded by Basic Treatment – If infiltration is through soils that do not meet the site suitability criteria for infiltration treatment, treatment must be provided by a basic treatment facility unless the soil and site fit the description in the next option below.

Infiltration preceded by Phosphorus Treatment – Requirements to be determined by TMDL.

Amended Sand Filter – See Section 5.12.

Note: *Processed steel fiber and crushed calcitic limestone are the only sand filter amendments for which Ecology has data that document increased dissolved metals removal. Though Ecology is interested in obtaining additional data on the effectiveness of these amendments, local governments may exercise their judgment on the extent to which to allow their use.*

Large Wetpond – See Section 5.7.

Media Filter Targeted for Phosphorus Removal – See Section 5.12.

Note: *The use of a Stormfilter™ with iron-infused media is approved for use in limited circumstances, provided a monitoring program consistent with adopted protocols is implemented.*

Two-Facility Treatment Trains – See Table 5.11.1. Note that if a filter is preceded by a wetpond, a horizontal rock filter may reduce transfer of algae from the pond to the filter.

Table 5.11.1 - Treatment trains for phosphorus removal

First Basic Treatment Facility	Second Treatment Facility
Biofiltration Swale	Basic Sand Filter or Sand Filter Vault
Vegetated Filter Strip	Linear Sand Filter (no presettling needed)
Linear Sand Filter	Filter Strip
Basic Wetpond	Basic Sand Filter or Sand Filter Vault
Wetvault	Basic Sand Filter or Sand Filter Vault
Basic Combined Detention and Wetpool	Basic Sand Filter or Sand Filter Vault
NOTE: See Section 5.2.3 (or Table 5.2.6) for Cold Weather Considerations and Table 5.2.4 for Arid and Semi-Arid Climate Considerations.	

5.11.2 Metals Treatment

Where Applied

Metals treatment is required for sites and uses determined in Core Element 5 to be subject to metals treatment requirements. Metals treatment is required for moderate- and high-use sites as defined in section 2.2.5 and sites that meet any of the following definitions and discharge to a non-exempt surface water:

- Industrial sites as defined by EPA (40 CFR 122.26(b)(14)) with benchmark monitoring requirements for metals; or industrial sites subject to handling, storage, production, or disposal of metallic products or other materials, particularly those containing arsenic, cadmium, chromium, copper, lead, mercury, nickel or zinc; or
- An urban road with expected ADT greater than 7,500; or a rural road or freeway with expected ADT greater than 15,000; or
- A commercial or industrial site with an expected trip end count equal to or greater than 40 vehicles per 1,000 square feet of gross building area; or a customer or visitor parking lot with equal to or greater than 100 trip ends; or on-street parking areas of municipal streets in commercial and industrial areas; or highway rest areas; or
- Runoff from metal roofs not coated with an inert, non-leachable material.

Discharges to nonfish-bearing streams are exempt from additional metals treatment requirements. Direct discharges to the main channels of the following rivers and direct discharges to the following lakes are exempt from metals treatment requirements: Banks Lake, Lake Chelan, Columbia River, Grande Ronde River, Kettle River, Klickitat River, Methow River, Moses Lake, Potholes Reservoir, Naches River, Okanogan River, Pend Oreille River, Similkameen River, Snake River, Spokane River, Wenatchee River, and Yakima River. Subsurface discharges via ruleauthorized Underground Injection Control (UIC) facilities (see section 5.6) are also exempt from metals treatment requirements. Restricted residential and employee-only parking areas are exempt from metals treatment requirements unless subject to through traffic.

Areas of arterials and highways, multifamily, industrial and commercial project sites that do not discharge to fish-bearing streams or lakes or are identified in a storm drainage comprehensive plan or basin plan as subject to Basic Treatment requirements are not subject to Metals Treatment requirements. For developments with a mix of land use types, the Metals Treatment requirement shall apply when the runoff from the areas subject to the Metals Treatment requirement comprise 50% or more of the total runoff to a discharge location.

Performance Goal

The Metals Treatment facility choices are intended to provide a higher rate of removal of dissolved metals than Basic Treatment facilities. Due to the sparse data available concerning dissolved metals removal in stormwater treatment facilities, a specific numeric removal efficiency goal could not be established at the time of publication. Instead, Ecology relied on available nationwide and local data and knowledge of the pollutant removal mechanisms of treatment facilities to develop the list of options below. In addition, the choices are intended to achieve the Basic Treatment performance goal. The performance goal assumes that the facility is treating stormwater with dissolved copper typically ranging from 0.003 to 0.02 mg/l, and dissolved zinc ranging from 0.02 to 0.3 mg/l.

The performance goal applies to the water quality design storm volume or flow rate, whichever is applicable, and on an annual average basis. The incremental portion of runoff in excess of the water quality design flow rate or volume can be routed around the facility (off-line treatment facilities) or can be passed through the facility (on-line treatment facilities) provided a net pollutant reduction is maintained. Ecology encourages the design and operation of treatment facilities that engage a bypass at flow rates higher than the water quality design flow rate as long as the reduction in dissolved metals loading exceeds that achieved with initiating bypass at the water quality design flow rate.

Metals Treatment Options

Any one of the following options may be chosen to satisfy the Metals Treatment requirement:

<u>Infiltration with Appropriate Pretreatment</u> – See Section 5.4.

<u>Infiltration Treatment</u> – If infiltration is through soils meeting the minimum site suitability criteria for infiltration treatment (see Section 5.4), a presettling basin or a basic treatment facility can serve for pretreatment.

Infiltration preceded by Basic Treatment – If infiltration is through soils that do not meet the soil suitability criteria for infiltration treatment, treatment must be provided by a basic treatment facility unless the soil and site fit the description in the next option below.

Infiltration preceded by Metals Treatment – If the soils do not meet the soil suitability criteria and the infiltration site is within ¼ mile of a fish-bearing stream, a tributary to a fish-bearing stream, or a lake, treatment must be provided by one of the other treatment facility options listed below.

Large Sand Filter – See Section 5.8.

Amended Sand Filter – See Section 5.12.

Note: *Processed steel fiber and crushed calcitic limestone are the only sand filter amendments for which Ecology has data that document increased dissolved metals removal. Though Ecology is interested in obtaining additional data on the effectiveness of these amendments, local governments may exercise their judgment on the extent to which to allow their use.*

Two Facility Treatment Trains – See Table 5.11.2.

Table 5.11.2 -Treatment Trains for Dissolved Metals Removal

First Basic Treatment Facility	Second Treatment Facility
Biofiltration Swale	Basic Sand Filter or Sand Filter Vault or Media Filter(1)
Filter Strip	Linear Sand Filter with no pre-settling cell needed
Linear Sand Filter	Filter Strip
Basic Wetpond	Basic Sand Filter or Sand Filter Vault or Media Filter(1)
Wetvault	Basic Sand Filter or Sand Filter Vault or Media Filter(1)
Basic Combined Detention/Wetpool	Basic Sand Filter or Sand Filter Vault or Media Filter(1)
Basic Sand Filter or Sand Filter Vault with a presettling cell if the filter isn't preceded by a detention facility	Media Filter(1)
(1) The media must be of a nature that has the capability to remove dissolved metals effectively based on at least limited data. Ecology includes Stormfilter's ™ leaf compost and zeolite media in this category.	

A.2 Highway Runoff Manual, WSDOT, 2014

- **Groundwater management plans** (wellhead protection plans and sole-source aquifers): To protect groundwater quality and quantity, these plans may identify actions required of stormwater discharges.
- **Lake management plans:** These plans are developed to protect lakes from eutrophication due to phosphorus-laden runoff from the drainage basin. Control of phosphorus from new development is a likely requirement in any such plans.

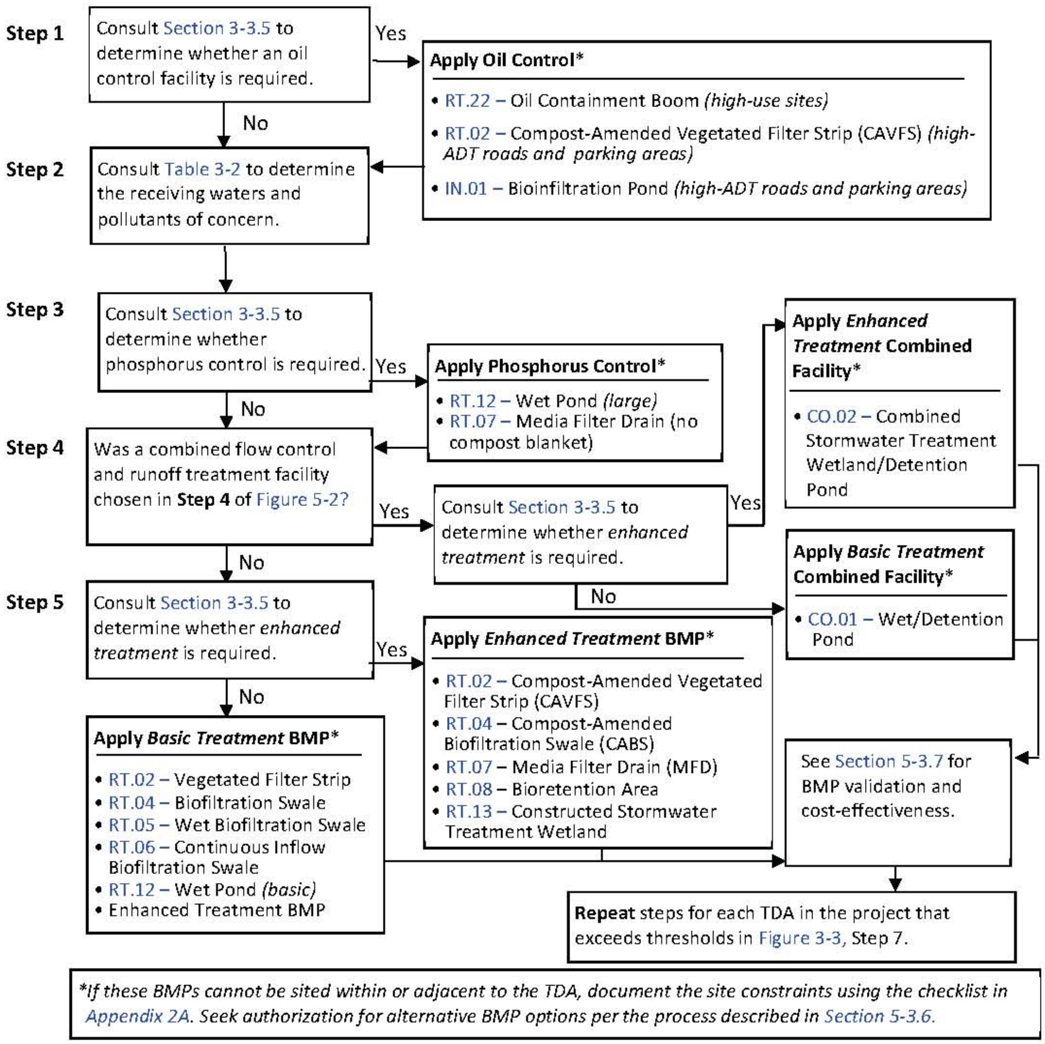
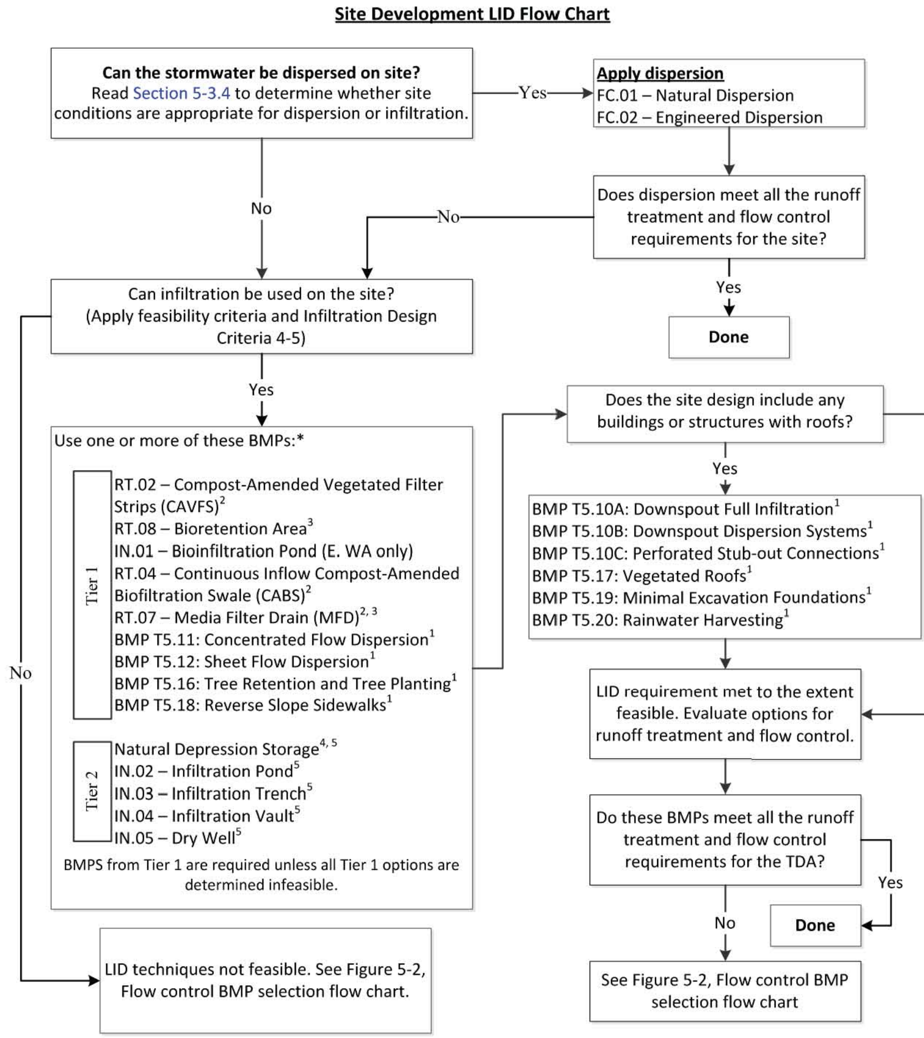


Figure 5-3 Runoff treatment BMP selection flow chart.



*** See Section 5-3.6 for BMP validation and cost-effectiveness. Repeat steps for each TDA in the project that exceeds thresholds in Figure 3-3, Step 7.**

1. Ecology SWMMWW Volume V.
2. Model for flow control benefit through infiltration using site-specific infiltration data.
3. The use of underdrains is not allowed if used to meet the LID requirement.
4. Use Section 4-7, Closed Depression Analysis, for modeling methods, and use performance requirements for infiltration pond.
5. Apply Pretreatment RT.24 – Presettling Basin or any basic treatment BMP listed on the next page if the underlying soils meet or exceed Soil Suitability Criteria 7. Otherwise, apply pretreatment in the form of any basic or enhanced treatment BMP.

Figure 5-4 Site development LID BMP selection flow chart.

Depending on the nature of the alternative approach proposal, you may need a dilution analysis to demonstrate that the project will not adversely affect water quality. If applicable to the proposal, base the dilution analysis on (1) critical flow rates of the discharge and the receiving water, and (2) estimated concentrations of pollutants of concern in the discharge and the upgradient receiving water. A standard procedure for determining the value of those four variables has yet to be developed by Ecology. Until it is developed, Ecology will have to make case-by-case decisions concerning valid approaches to the analysis.

5-3.7 BMP Validation and Cost-Effectiveness

Once you select a stormwater BMP, be aware that there are costs and obligations involved in the long-term operation and maintenance of the BMP. For this reason, you should contact the local maintenance office and discuss the proposed stormwater BMPs and overall stormwater design to determine any area-specific BMP restrictions or requirements. Table 5-1 helps you evaluate the cost-effectiveness of different stormwater BMPs by assessing typical construction costs, annual operation and maintenance (O&M) expenses, and effective life (how soon the BMP may need to be replaced).

Table 5-1 Relative rankings of cost elements and effective life of BMP options.

BMP	Capital Costs	O&M Costs	Effective Life[1]
Vegetated Filter Strip	Low	Low	20–50 years
Wet Biofiltration Swale	Low to Moderate	Low to Moderate	5–20 years
Continuous Inflow Biofiltration Swale	Low to Moderate	Low	5–20 years
Media Filter Drain	Low	Low to Moderate	5–20 years[2]
Compost-Amended Vegetated Filter Strip	Low	Low	5–20 years[2]
Wet Pond	Moderate to High	Low to Moderate	20–50 years
Combined Wet/Detention Pond	Moderate	Low to Moderate	20–50 years
Constructed Stormwater Treatment Wetland	Moderate to High	Moderate	20–50 years
Combined Stormwater Wetland/Detention Pond	Low to Moderate	Moderate	20–50 years
Wet Vault (Category 1 BMP)	Moderate to High	High	50–100 years
Combined Wet/Detention Vault (Category 1 BMP)	Moderate to High	High	50–100 years
Bioinfiltration Pond	Low to Moderate	Low	5–20 years
Infiltration Pond	Moderate	Moderate	5–10 years before deep tilling required
Infiltration Trench	Moderate to High	Moderate	10–15 years
Infiltration Vault	Moderate	Moderate to High	5–10 years
Drywell	Low to Moderate	Low to Moderate	5–20 years
Engineered and Natural Dispersion	Low	Low	50–100 years
Detention Pond	Moderate	Low	20–50 years
Detention Vault (Category 1 BMP)	Moderate to High	High	50–100 years
Detention Tank (Category 1 BMP)	Moderate to High	High	50–100 years
Presettling Basin	Low to Moderate	Moderate	
Proprietary Presettling Devices	Moderate	Moderate	50–100 years
Bioretention	Moderate	Moderate	5–20 years

Sources: Adapted from Young et al. (1996); Claytor and Schueler (1996); U.S. EPA (1993); and others.

[1] Assumes regular maintenance, occasional removal of accumulated materials, and removal of any clogged media.

[2] Estimated based on best professional judgment.

A.3 Regional Stormwater Manual, Spokane, 2008

6.5 TREATMENT GOALS

The goal for water quality treatment facilities is to treat approximately 90% of the annual runoff volume generated at a project site. Facilities that are designed according to the criteria set forth in this chapter should also capture and treat nearly all of the runoff from first flush events (heavy rainfall after a dry period). In urban areas, bio-infiltration swales are the expected BMP for providing basic treatment. The following subsections describe the key pollutants of concern.

6.5.1 TOTAL SUSPENDED SOLIDS (TSS)

Basic treatment facilities presented in this chapter are intended to achieve 80% removal of suspended solids, including solid components of metals, for flows with TSS concentrations ranging from 100 mg/L to 200 mg/L. The following BMPs have been found to provide a significant removal process for TSS:

- Bio-infiltration swales;
- Biofiltration channels;
- Vegetated buffer strips;
- Evaporation ponds.

6.5.2 TOTAL PETROLEUM HYDROCARBONS (TPH)

The oil control facilities presented in this chapter are intended to achieve the goal of removing any visible sheen and reducing the TPH concentration to a maximum of 10 mg/L for a 24-hour average and a maximum of 15 mg/L for a discrete sample. The following BMPs provide removal of TPH:

- Significant removal for high-use and high-ADT sites:
  - Bio-infiltration swales;
  - Oil/water separators (coalescing plate and baffle type);
  - Vegetated buffer strips (for High-ADT sites only); and,
  - Evaporation ponds designed using the Alternative Method (refer to Section 5.7.2)
- Significant removal for all sites except high-ADT sites:
  - Oil/water separators (spill control type).
- Lesser removal (this BMP shall not be used for high-use or high-ADT sites unless preceded by an oil/water separator):
  - Biofiltration channels.

6.5.3 METALS TREATMENT

Metals treatment facilities presented in this chapter are intended to achieve approximately 50% removal of dissolved metals. The following BMPs have been found to provide removal for metals:

- Significant removal:
  - Bio-infiltration swales; and,
  - Evaporation ponds designed using the Alternative Method (refer to Section 5.7.2)
- Lesser removal (this BMP shall not be used for high-use or high-ADT sites without being preceded by another treatment BMP)
  - Biofiltration channels.

6.5.4 PHOSPHOROUS TREATMENT

The phosphorus treatment facilities are intended to achieve a goal of 50% total phosphorus removal for a range of influent concentrations from 0.1 to 0.5 mg/L of total phosphorus. Bio-infiltration swales are the only BMP presented here that have been found to meet this removal goal for phosphorus. The following BMPs have been found to provide a lesser removal of phosphorus and shall only be used for phosphorus removal in combination with some other basic treatment BMP:

  - Biofiltration channels;
  - Vegetated buffer strips; and,
  - Evaporation ponds designed using the Alternative Method (refer to Section 5.7.2)

6.6 APPLICABILITY

The exemptions listed in the sections below are superseded by requirements set forth in any applicable Total Maximum Daily Load (TMDL) or other water cleanup plan. At the time of the writing of this Manual, no TMDLs exist for water bodies in Spokane County. Contact the local jurisdiction for current information on whether any TMDLs have been issued.

A.4 Storm Water Best Management Practices Catalogue, Idaho Department of Environmental Quality (IDEQ), 2005

Table 4-1. Selection Matrix for Best Management Practices	Targeted Pollutants					Physical Constraints							
	Sediment	Phosphorus	Trace Metals	Bacteria	Petroleum Hydrocarbons	Drainage area (acres)	Maximum slope (%)	Minimum depth to bedrock, ft	Depth to high water table, ft	SCS soil type[1]	Use with freeze/thaw cycle	Drainage/flood control	Expected life[2]
Stormwater Filters													
Vegetated swale	65%	15%	◖	○	◖	15	4	3	2	BCD	Fair	Yes	Permanent
Bioretention swale	75%	30%	●	◖	●	5	4	3	3	AB	Fair	Yes	Permanent
Vegetative filter strip	50%	40%	◖	◖	◖	5	6	5	3	BCD	Fair		Permanent
Sand filter	85%	55%	◖	◖	◖	5(inlets) 50 (basin)	6	3	3	NA	Fair	Yes	25 yrs
Compost filter	95%	40%	●	◖	●	1	6	NA	NA	NA	Fair		20+ yrs
Catchbasin insert	35%	5%	◖	○	◖	0.1	NA	NA	NA	NA	Fair		
Media filter	●	50%	●	◖	●	According to manufacturer's specifications				NA	Fair		20+ yrs
Infiltration Facilities													
Infiltration trench	75%	65%	●	●	●	10	15	3	3	AB	Fair		10 yrs
Bioretention basin	90%	75%	●	●	●	5	2	3	3	AB	Fair	Yes	25 yrs
Porous pavement	85%	64%	●	●	◖	0.25-10	2	2-5	2-5	AB	Fair	No	
Detention Facilities													
Wet pond (conventional pollutants)	80%	45%	●	◖	◖	15-20	10	3	2	CD	Good	Yes	Permanent
Wet pond (nutrient control)	80%	65%	●	◖	◖	5-20	5	3	2	CD	Fair	Yes	Permanent
Wet extended detention pond	80%	65%	●	◖	◖	10-50	10	3	2	CD	Good	Yes	Permanent
Dry extended detention pond	45%	25%	◖	○	◖	10-50	10	6	4	ABC	Good	Yes	Permanent

IDEQ Storm Water Best Management Practices Catalog
September 2005 1

Table 4 -1. Selection Matrix for Best Management Practices (cont.)	Targeted Pollutants					Physical Constraints							
	Sediment	Phosphorus	Trace Metals	Bacteria	Petroleum Hydrocarbons	Drainage area (acres)	Maximum slope (%)	Minimum depth to bedrock, ft	Depth to high water table, ft	SCS soil type[1]	Use with freeze/thaw cycle	Drainage/flood control	Expected life[2]
Biodetention basin	75%	45%	●	◖	●	25-50	5	3	2	CD	Fair	Yes	Permanent
Presettling/sedimentation basin	60%	30%	◖	○	○	10+	10	3	2	CD	Good		Permanent
Wet vault/tank	60%	30%	◖	○	○	5	15	12	12	ABC	Fair	Yes	Permanent
Other Structural Controls													
Oil/water separator	15%	5%	◖	○	●	1	15	8	8	ABC	Fair		20+ yrs
Swirl concentrator	35%	15-20%	◖	○	◖	According to manufacturer's specifications				NA	Fair		
Level spreader	NA	NA	○	○	○	5	1	NA	NA	ABCD	Fair	Yes	

● = very effective, removes > 70% of pollutant ◖ = moderately effective, removes 25-70% of pollutant ○ = least effective, removes < 25% of pollutant

N/A = Not applicable

[1] NRCS soil types (A,B,C,D) range from A = high infiltration to D = little or no infiltration

[2] Longevity data collected from various sources, including Panhandle Health District 1996, Boise City 1997, and EPA 1993. The numbers shown represent industry guidelines; the actual life expectancy is dependent on proper design, placement, and maintenance of BMPs.

The pollutant removal efficiencies given above are for planning purposes only. Actual removal rates are dependent on specific site characteristics, maintenance, and other factors. The following sources were used to determine the most likely average removal rate for conditions prevalent in

A.5 CALTRANS, 2010

Table 4.1 Concentration-based BMP Ranking for Target Design Constituents

	Concentration-Based Ranking[a]	
	Concentration-Based Regulation[b]	Load-based Regulation where Infiltration <20%[c]
TSS		
Tier 0	Infiltration basins[d] Infiltration trenches[d,e]	
Tier 1	Wet basin MCTT Delaware filter Austin filter Strip – HRT>5	Wet basin MCTT Delaware filter Austin filter Strip – HRT>5
Tier 2	Strip – HRT<5 EDB Swale	Strip – HRT<5 EDB Swale
Tier 3	EDB – lined	EDB – lined
Phosphorus (total) [f]		
Tier 0	Infiltration basins[d] Infiltration trenches[d,e]	
Tier 1	Delaware filter Austin filter EDB Strip – HRT<5	Delaware filter Austin filter EDB Strip – HRT<5
Tier 2	---	---
Tier 3	EDB – lined MCTT Wet basin Strip – HRT>5 Swale	EDB – lined MCTT Wet basin Strip – HRT>5 Swale
Nitrogen (total) [g]		
Tier 0	N.A.	
Tier 1	N.A.	---
Tier 2	N.A.	(Austin filter – both) EDB EDB – lined Wet basin
Tier 3	N.A.	Delaware MCTT Strip – all (Swale)

(Table 4.1 continued)

	Concentration-Based Ranking[a]	
	Concentration-Based Regulation[b]	Load-based Regulation where Infiltration <20%[c]
Copper (total)		
Tier 0	Infiltration basins[d] Infiltration trenches[d,e]	
Tier 1	Strip – HRT<5 Wet basin (MCTT) Delaware filter	Strip – HRT<5 Wet basin (MCTT) Delaware filter
Tier 2	Austin filter Strip – HRT>5 Swale EDB	Austin filter Strip – HRT>5 Swale EDB
Tier 3	---	---
Copper (dissolved)		
Tier 0	Infiltration basins[d] Infiltration trenches[d,e]	
Tier 1	Strip – HRT<5 (Delaware filter) (MCTT) Strip – HRT>5	Strip – HRT<5 (Delaware filter) (MCTT) Strip – HRT>5
Tier 2	Wet basin Swale	Wet basin Swale
Tier 3	EDB – lined Austin filter EDB	EDB – lined Austin filter EDB
Lead (total)		
Tier 0	Infiltration basins[d] Infiltration trenches[d,e]	
Tier 1	Wet basin Austin filter MCTT Delaware filter Strip – HRT<5 Strip – HRT>5	Wet basin Austin filter MCTT Delaware filter Strip – HRT<5 Strip – HRT>5
Tier 2	Swale EDB	Swale EDB
Tier 3	EDB – lined	EDB – lined

(Table 4.1 continued)

	Concentration-Based Ranking[a]	
	Concentration-Based Regulation[b]	**Load-based Regulation where Infiltration <20%[c]**
Lead (dissolved)		
Tier 0	Infiltration basins[d] Infiltration trenches[d,e]	
Tier 1	Delaware filter (MCTT) Strip – HRT<5 Austin filter Wet basin EDB Strip – HRT>5	Delaware filter (MCTT) Strip – HRT<5 Austin filter Wet basin EDB Strip – HRT>5
Tier 2	Swale	Swale
Tier 3	EDB – lined	EDB – lined
Zinc (total)		
Tier 0	Infiltration basins[d] Infiltration trenches[d,e]	
Tier 1	Delaware filter MCTT Wet basin Strip – HRT<5	Delaware filter MCTT Wet basin Strip – HRT<5
Tier 2	Swale Austin filter Strip – HRT>5 EDB	Swale Austin filter Strip – HRT>5 EDB
Tier 3	EDB – lined	EDB – lined
Zinc (dissolved)		
Tier 0	Infiltration basins[d] Infiltration trenches[d,e]	
Tier 1	MCTT Wet basin Austin filter	MCTT Wet basin Austin filter
Tier 2	Strip – HRT>5 Swale Strip – HRT<5 Delaware filter	Strip – HRT>5 Swale Strip – HRT<5 Delaware filter
Tier 3	EDB – lined EDB	EDB – lined EDB

(Table 4.1 continued)

	Concentration-Based Ranking[a]	
	Concentration-Based Regulation[b]	Load-based Regulation where Infiltration <20%[c]
Cadmium (total)[h]		
Tier 0	Infiltration basins[d] Infiltration trenches[d,e]	
Tier 1	Strip – HRT<5 Wet basin Austin filter Delaware filter Strip – HRT>5 Swale	Strip – HRT<5 Wet basin Austin filter Delaware filter Strip – HRT>5 Swale
Tier 2	EDB	EDB
Tier 3	EDB – lined MCTT	EDB – lined MCTT
Chromium (total)[h]		
Tier 0	Infiltration basins[d] Infiltration trenches[d,e]	
Tier 1	Wet basin (MCTT) Delaware filter Austin filter EDB Swale	Wet basin (MCTT) Delaware filter Austin filter EDB Swale
Tier 2	Strip – HRT>5	Strip – HRT>5
Tier 3	EDB – lined Strip – HRT<5	EDB – lined Strip – HRT<5

(Table 4.1 continued)

	Concentration-Based Ranking[a]	
	Concentration-Based Regulation[b]	Load-based Regulation where Infiltration <20%[c]
Nickel (total)[d]		
Tier 0	Infiltration basins[d] Infiltration trenches[d,e]	
Tier 1	Strip – HRT<5 (Delaware filter) EDB Wet basin Swale Strip – HRT>5	Strip – HRT<5 (Delaware filter) EDB Wet basin Swale Strip – HRT>5
Tier 2	(Austin filter)	(Austin filter)
Tier 3	EDB – lined MCTT	EDB – lined MCTT

a. Within tiers 1, 2, and 3, BMPs are sorted from lowest to highest average effluent concentration as estimated from the mixed-model statistical analysis.

b. This ranking is intended for concentration-based regulations that require maximum reduction of average discharge (effluent) concentration. If there is a not-to-exceed concentration standard, this analysis is not appropriate and a frequency analysis on exceedances may be more appropriate.

c. When there are no concentration-based standards, these rankings should only be consulted when there are no earthen BMPs that will achieve greater than 20% infiltration.

d. If minimizing average effluent concentrations is a regulatory requirement, infiltration BMPs should be considered first because complete elimination of a discharge will comply with concentration-based requirements.

e. Infiltration trenches often require pre-treatment to reduce the risk of clogging failures, unless site conditions show low sediment loads and large separation from normal high groundwater.

f. Strip classifications for phosphorus assume that salt grass is not planted. Pilot strips and swales planted with salt grass did not effectively reduce phosphorus.

g. For total nitrogen, there is no concentration-based ranking. The ranking shown for Infiltration < 20% is based on the sum of loads method.

h. Proposed New TDCs.

General Notes

- Strips are classified in two ways. For concentration-based rankings, the hydraulic residence time (HRT) was used because of its relationship to surface treatment processes, especially sedimentation. HRT<5 and HRT>5 mean hydraulic residence times less than and greater than 5 minutes.
- BMPs shown in parentheses involved either exceptions to these rules or other judgments that are explained in Table 3.1.

Table 4.2 Load-based BMP Ranking for Target Design Constituents

	Load-Based Ranking[a]	
	Infiltration 20 to 50%	**Infiltration >50%**
TSS		
Tier 0		Infiltration basins Infiltration trenches[b]
Tier 1	Austin filter – both[c] Delaware filter[c] EDB MCTT[c] Strip – all Swale Wet basin[c]	Austin filter – both[c] Delaware filter[c] EDB MCTT[c] Strip – A_S/A_D > 0.2 Strip 0.1 < A_S/A_D < 0.2 (Strip – A_S/A_D < 0.1) Swale Wet basin[c]
Tier 2	---	---
Tier 3	EDB – lined[c]	EDB – lined[c]
Phosphorus (total)[d]		
Tier 0		Infiltration basins Infiltration trenches[b]
Tier 1	Austin filter – earthen EDB	Austin filter – earthen EDB (Strip – A_S/A_D>0.2)
Tier 2	Austin filter – concrete[c] Delaware filter[c] Strip – A_S/A_D>0.2 Strip – 0.1<A_S/A_D<0.2 (Strip – A_S/A_D <0.1) (Swale) Wet basin[c]	Austin filter – concrete[c] Delaware filter[c] Strip – A_S/A_D<0.1 (Strip – 0.1<A_S/A_D<0.2) (Swale) Wet basin[c]
Tier 3	EDB – lined[c] (MCTT) [c]	EDB – lined[c] (MCTT) [c]
Nitrogen (total)		
Tier 0		Infiltration basins Infiltration trenches[b]
Tier 1	---	EDB Strip – all Swale
Tier 2	(Austin filter – concrete)[c] Austin filter – earthen EDB EDB – lined[c] Swale Wet basin[c]	(Austin filter – concrete)[c] Austin filter – earthen EDB – lined[c] Wet basin[c]
Tier 3	Delaware filter[c] MCTT[c] (Strip – all)	Delaware filter[c] MCTT[c]

(Table 4.2 continued)

	Load-Based Ranking[a]	
	Infiltration 20 to 50%	**Infiltration >50%**
Copper (total)		
Tier 0		Infiltration basins Infiltration trenches[b]
Tier 1	(Austin filter – earthen) EDB Strip – A_S/A_D >0.2 Swale Wet basin[c]	Austin filter – earthen EDB (Strip – A_S/A_D > 0.2) Strip – A_S/A_D < 0.1 Strip – 0.1<A_S/A_D<0.2 Swale Wet basin[c]
Tier 2	Austin filter – concrete[c] Delaware filter[c] EDB – lined[c] MCTT[c] Strip – A_S/A_D <0.1 Strip – 0.1<A_S/A_D<0.2	Austin filter – concrete[c] EDB – lined[c] Delaware filter[c] MCTT[c]
Tier 3	---	---
Copper (dissolved)		
Tier 0		Infiltration basins Infiltration trenches[b]
Tier 1	(Strip – A_S/A_D > 0.2)	Austin filter – earthen EDB Strip – all Swale
Tier 2	(Austin filter – earthen) Delaware filter[c] EDB (MCTT) [c] Strip – 0.1 < A_S/A_D < 0.2 (Strip – A_S/A_D < 0.1) Swale Wet basin[c]	Delaware filter[c] (MCTT) [c] Wet basin[c]
Tier 3	Austin filter – concrete[c] EDB – lined[c]	Austin filter – concrete[c] EDB – lined[c]

(Table 4.2 continued)

	Load-Based Ranking[a]	
	Infiltration 20 to 50%	**Infiltration >50%**
Lead (total)		
Tier 0		Infiltration basins Infiltration trenches[b]
Tier 1	Austin filter – concrete[c] (Austin filter – earthen) Delaware filter[c] EDB MCTT[c] Strip – $A_S/A_D > 0.2$ (Strip – $0.1 < A_S/A_D < 0.2$) Strip –$A_S/A_D < 0.1$ Swale Wet basin[c]	Austin filter – both[c] Delaware filter[c] EDB MCTT[c] Strip – all Swale Wet basin[c]
Tier 2	EDB – lined[c]	EDB – lined[c]
Tier 3	---	---
Lead (dissolved)		
Tier 0		Infiltration basins Infiltration trenches[b]
Tier 1	Swale Wet basin[c]	EDB (Strip – $A_S/A_D > 0.2$) Strip – $0.1 < A_S/A_D < 0.2$ Strip –$A_S/A_D < 0.1$ Swale
Tier 2	(Austin filter – concrete) [c] Austin filter – earthen Delaware filter[c] EDB (MCTT) [c] (Strip – $A_S/A_D > 0.2$) Strip – $0.1 < A_S/A_D < 0.2$ Strip –$A_S/A_D < 0.1$	(Austin filter – concrete) [c] Austin filter – earthen Delaware filter[c] (MCTT) [c] Wet basin[c]
Tier 3	EDB – lined[c]	EDB – lined[c]

(Table 4.2 continued)

	Load-Based Ranking[a]	
	Infiltration 20 to 50%	**Infiltration >50%**
Zinc (total)		
Tier 0		Infiltration basins Infiltration trenches[b]
Tier 1	Austin filter – both[c] Delaware filter[c] EDB MCTT[c] Strip – $A_S/A_D > 0.2$ (Strip – $0.1 < A_S/A_D < 0.2$) Strip –$A_S/A_D < 0.1$ Swale Wet basin[c]	Austin filter – both[c] Delaware filter[c] EDB MCTT[c] Strip – all Swale Wet basin[c]
Tier 2	EDB – lined[c]	EDB – lined[c]
Tier 3	---	---
Zinc (dissolved)		
Tier 0		Infiltration basins Infiltration trenches[b]
Tier 1	Austin filter – earthen Delaware filter[c] MCTT[c]	Austin filter – earthen Delaware filter[c] EDB MCTT[c] Strip – all Swale
Tier 2	Austin filter – concrete[c] EDB EDB – lined[c] (Strip – all) Swale	Austin filter – concrete[c] EDB – lined[c]
Tier 3	Wet basin[c]	Wet basin[c]

(Table 4.2 continued)

	Load-Based Ranking[a]	
	Infiltration 20 to 50%	**Infiltration >50%**
Cadmium (total)[e]		
Tier 0		Infiltration basins Infiltration trenches[b]
Tier 1	Delaware filter[c] EDB Swale Wet basin[c]	Austin filter – earthen Delaware filter[c] EDB Strip – all Swale Wet basin[c]
Tier 2	(Austin filter – concrete)[c] Austin filter – earthen Strips – all	(Austin filter – concrete)[c]
Tier 3	EDB – lined[c]	EDB – lined[c]
Chromium (total)[e]		
Tier 0		Infiltration basins Infiltration trenches[b]
Tier 1	Austin filter – earthen EDB (Strip – $A_S/A_D > 0.2$) Strip – $0.1 < A_S/A_D < 0.2$ Wet basin	Austin filter – earthen EDB Strip – all Swale Wet basin
Tier 2	(Austin filter – concrete)[c] Delaware filter[c] EDB – lined[c] MCTT[c] Strip – $A_S/A_D < 0.1$ Swale	(Austin filter – concrete)[c] Delaware filter[c] EDB – lined[c] MCTT[c]
Tier 3	---	---

(Table 4.2 continued)

	Load-Based Ranking[a]	
	Infiltration 20 to 50%	**Infiltration >50%**
Nickel (total)[e]		
Tier 0		Infiltration basins Infiltration trenches[b]
Tier 1	(Austin filter – earthen) EDB (Strip – all) Swale	Austin filter – earthen EDB Strip – all Swale
Tier 2	(Austin filter – concrete)[c] Delaware filter[c] Wet basin[c]	(Austin filter – concrete)[c] Delaware filter[c] Wet basin[c]
Tier 3	EDB – lined[c] MCTT[c]	EDB – lined[c] MCTT[c]

a. For load removal, Tier 1 = greater than 60% treatment efficiency; Tier 2 = 20-60% treatment efficiency; Tier 3 = less than 20% treatment efficiency (same as concentration alone). BMPs shown in parentheses involved either exceptions to these rules or other judgments that are explained in Table 3.1. Within tiers, BMPs are sorted alphabetically.

b. Infiltration trenches often requires pre-treatment to reduce the risk of clogging failures, unless site conditions show low sediment loads and large separation from normal high groundwater.

c. Lined BMPs are shown in the columns where substantial infiltration occurs for earthen BMPs. Though these BMPs never infiltrate, regardless of site conditions, they are shown in these columns solely to allow the user to more easily compare the load removal of lined BMPs to those that infiltrate.

d. Strip classifications for phosphorus assume that salt grass is not planted. Pilot strips and swales planted with salt grass did not effectively reduce phosphorus.

e. Proposed New TDCs

General Notes

- For load removal, the ratio of the strip area to the drainage area (A_S/A_D) was used to classify strips because of the relationship of the ratio to infiltration and because it is easy to calculate.

4.2 Qualifiers

4.2.1 BMP Selection Factor

The BMP rankings proposed in this document are based solely on constituent reduction performance. General factors that are not addressed in this analysis include safety, cost, and ease of maintenance.

4.2.2 Limitations in Statewide Interpretation of Water Quality Data

This report draws from the most comprehensive stormwater dataset directly collected by a single agency. Despite an unmatched BMP monitoring program, there is still difficulty in developing standard recommendations that are applicable for all project-specific circumstances in a state as large and diverse as California. The ranking methodologies presented here are based on comparing data collected from different places at different times. The validity of these comparisons is affected by the limited number of representative BMP test locations. For instance, several BMPs were not tested at highway locations as shown in Table 4.3.

Facility type can have a strong influence on whether the test location is relatively cleaner or dirtier than other locations. And even among highway locations, prior work by Caltrans has found that average annual daily traffic (AADT) and ecoregion play a significant role in highway runoff concentrations (Caltrans, 2009a). Besides influent concentrations, there are many other BMP test conditions that could affect performance, such as soil type, vegetation, and antecedent storm conditions.

It is unreasonable to expect that every BMP would be tested under all Caltrans conditions, because of limitations including time, budget, space constraints, safe access, construction conflicts, and space for monitoring equipment. Nevertheless, not testing BMPs for all conditions dictates the use of numeric methods and professional judgment to extrapolate certain observations to typical highway applications. From a statistical perspective, because the important site conditions were not sufficiently controlled among the BMP test locations, statistical tests could not always support these professional judgments. An improved mixed-model could be developed to handle the subjective adjustments needed in the sum of loads method.

Table 4.3 Select Site Characteristics for BMP Studies

	Facility Type[a]			Average Annual Rainfall		
BMP Type	**Hwy**	**P&R**	**MS**	**<15"**	**15 - 30"**	**>30"**
Austin Sand Filters, lined, full-sedimentation	✓			✓	✓	
Austin Sand Filters, unlined, partial-sedimentation	✓					✓
Austin Sand Filters, unlined, full-sedimentation			✓			✓
Delaware Sand Filters			✓	✓		
Detention Basins, lined	✓			✓		
Detention Basins, unlined	✓			✓		
Multi-Chambered Treatment Train (MCTT)		✓		✓	✓	
Strips	✓		✓	✓	✓	✓
Swales	✓			✓		
Wet basins	✓			✓		

[a] Facility Types: MS = maintenance station; P&R = park and ride; Hwy = highway

A factor limiting the precision of these rankings is the natural variability of the data from storm to storm. Because of these variations, the regressions that provided the basis of the performance comparisons are often not very tight, as evidenced by low r^2 values. This isn't failure to exercise care in collecting the data. It is, however, reflective of the fact that the data sets are inherently "noisy," and that relationships between influent and effluent values are not always linear.

A.6 BMP Performance Analysis, EPA, Region 1 (Northeast), 2008

4.1.4. BMPDSS Test Results

The calibrated BMPDSS models performances were tested by comparing the model simulated long-term pollutant removal for the 2004–2006 period to the UNHSC reported long-term BMP performances reported for the same period. The calibrated BMPDSS models were run for the 2004–2006 period, and the pollutant removal rates of each BMP were calculated and compared to the UNHSC-reported values (UNHSC 2007). It is important to note that the UNHSC-reported values represent the median pollutant removal of selected storms (approximately 17–20 storms) for each BMP. BMPDSS-simulated pollutant removal reports the cumulative pollutant removal of all storms (34 storms) that occurred during the selected period including those analyzed by UNHSC.

1. Infiltration system

The test results of the infiltration system BMPDSS model are shown in Table 4-8. As shown, the BMPDSS model simulation results for TSS, TP, and Zn removal are similar to the UNHSC-reported values.

Table 4-8. Test results of infiltration system removal efficiencies for 2004–2006

Total pollutant load	TSS (lbs)	TP (lbs)	Zn (lbs)
Inflow	279.29	2.81	0.45
Outflow	4.21	0.48	0.01
Pollutant removal	98%	83%	98%
UNHSC-report percentage	99%	81%	99%

2. Gravel wetland

The test results of the gravel wetland BMPDSS model are shown in Table 4-9. As shown, the BMPDSS model simulation results for TSS, TP, and Zn removal are similar to the UNHSC-reported values.

Table 4-9. Test results of gravel wetland removal efficiencies for 2004–2006

Total pollutant load	TSS (lbs)	TP (lbs)	Zn (lbs)
Inflow	279.29	2.81	0.45
Outflow	4.61	1.05	0.04
Pollutant removal	98%	63%	91%
UNHSC-report percentage	99%	55%	99%

3. Bioretention area

The test results of the bioretention area BMPDSS model are shown in Table 4-10. As shown, the BMPDSS model simulation results for TSS and Zn are similar (< 5 percent difference) to the UNHSC-reported values. However, the BMPDSS model simulated a much higher long-term pollutant removal rate for TP than the UNHSC-reported value. The bioretention system at UNHSC has gone through several design and construction related issues during the selected period. The observed data could have been influenced by these uncertainties. A review of bioretention performance data reported by others indicates that the UNHSC-reported TP removal of 5 percent is relatively low for a well-functioning bioretention type of BMP.

Consequently, the bioretention module in the existing BMPDSS, which was calibrated to bioretention performance data from the University of Maryland (Tetra Tech 2007) has resulted in a long-term TP removal of 64 percent. The BMPDSS model prediction for TP removal appears to be reasonable when compared to the pollutant removal percentages reported by EPA for bioretention systems (USEPA 1999), which is 70–83 percent.

Table 4-10. Test results of bioretention area removal efficiencies for 2004–2006

Total pollutant load	TSS (lbs)	TP (lbs)	Zn (lbs)
Inflow	279.29	2.81	0.45
Outflow	15.82	1.13	0.02
Pollutant removal	94%	60%	96%
UNHSC-reported percentage	99%	5%	99%

4. Porous pavement

The test results of the porous pavement BMPDSS model are shown in Table 4-11. As shown, the BMPDSS model simulation results for TSS, TP, and Zn removal are similar to the UNHSC-reported values.

Table 4-11. Test results of porous pavement removal efficiencies for 2004–2006

Total pollutant load	TSS (lbs)	TP (lbs)	Zn (lbs)
Inflow	279.29	2.81	0.45
Outflow	5.46	1.58	0.04
Pollutant removal	98%	43%	92%
UNHSC-reported percentage	99%	38%	96%

5. Grass swale

The test results of the grass swale BMPDSS model are shown in Table 4-12. As shown, the BMPDSS model simulation results for TSS, TP, and Zn removal are similar to the UNHSC-reported values.

Table 4-12. Test results of grass swale removal efficiencies for 2004–2006

Total pollutant load	TSS (lbs)	TP (lbs)	Zn (lbs)
Inflow	279.29	2.81	0.45
Outflow	87.87	2.01	0.08
Pollutant removal	69%	29%	83%
UNHSC-reported percentage	60%	NT	88%

6. Wet pond

The test results of the wet pond BMPDSS model are shown in Table 4-13. As shown, the BMPDSS model simulation results for TSS, TP, and Zn removal are similar to the UNHSC-reported values.

Table 4-13. Test results of wet pond removal efficiencies for 2004–2006

Total pollutant load	TSS (lbs)	TP (lbs)	Zn (lbs)
Inflow	279.29	2.81	0.45
Outflow	85.46	2.25	0.02
Pollutant removal	69%	20%	96%
UNHSC-reported percentage	72%	16%	93%

4.1.5. BMPDSS Calibration Summary

The BMPDSS model was calibrated and tested for six BMPs using observed data from UNHSC. Three events were selected for calibrating each BMP, and the BMP model performances were tested against the 2004–2006 pollutant reduction percentages documented in the UNHSC 2007 Annual Report.

Calibrations of the BMPDSS model indicate that the model is capable of simulating the hydraulic performances of BMPs, and the models test results show that the long-term prediction of BMP performances are in close agreement with the values reported by UNHSC.

The successful calibration and testing of the BMPDSS models with UNHSC data supports the use of the models to generate credible long-term BMP performance curves for the New England Region (Section 5).

4.2. BMPDSS Representation

In developing BMP performance curves, one important step is to represent the selected eight BMPs in the BMPDSS model with appropriate specifications. In this project, BMP specifications were represented by following the *Structural BMP Specifications for the Massachusetts Stormwater Handbook* (MassDEP 2008a). This section provides an overview of the eight BMPs that were represented in BMPDSS. A brief description of design specifications is provided for each BMP, followed by the modeling schematic of that BMP in BMPDSS.

4.2.1. Infiltration System

Infiltration trenches and infiltration basins are two common systems in use. Infiltration trenches are shallow excavations filled with stone. They can be designed to capture sheet flow or piped inflow. The stone and piping or storage units (if applicable) provide underground storage for stormwater runoff so that it can be gradually infiltrated through the bottom or sides of the trench into the subsoil. Infiltration basins are stormwater runoff impoundments that are constructed over permeable soils. Pretreatment is critical for effective performance of infiltration basins. Runoff from the design storm is stored until it infiltrates through the soil of the basin floor. The *Massachusetts Stormwater Handbook* requires 44 percent TSS removal through pretreatment in critical areas for infiltration basins. For developing BMP performance curves, infiltration trenches and infiltration basins were sized according to the Massachusetts standards.

A.7 International Stormwater BMP Database (ISBD), 2013

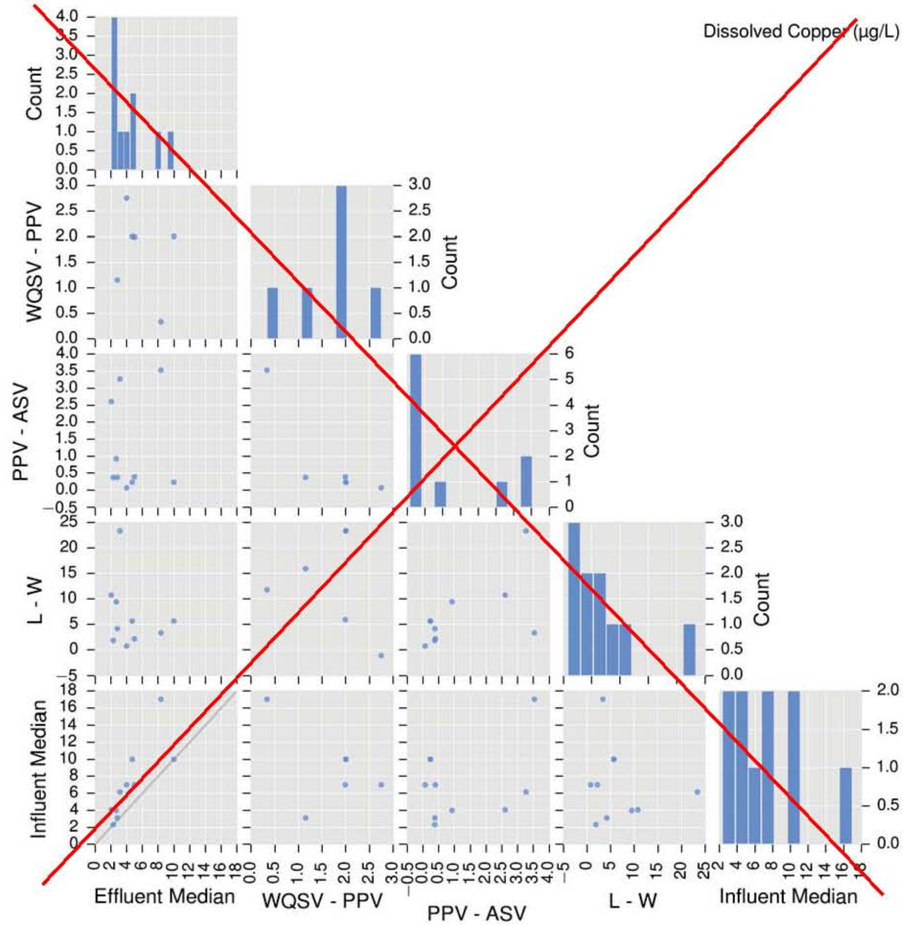


Figure 49. Scatter matrix of median dissolved copper concentration in the influent and effluent with selected design parameters for retention ponds.

3 SUMMARY AND CONCLUSIONS

The BMPDB is a long-term project that has steadily grown to over 530 BMPs and has resulted in improved understanding of performance of various BMP types. For the most part, analyses to date have focused on summarizing influent and effluent concentration statistics, along with some limited analysis of volume reduction. However, a long-term objective of the project has always been to provide a source of information to practitioners on the relationship between performance and various BMP design parameters. Given significant growth of the BMPDB, the Project Team reviewed the available design information stored in the BMPDB for various BMP types and evaluated potential relationships between selected design parameters and performance for a subset of water quality parameters. As a result of this evaluation, a few design-related findings emerged; however, for the most part, the design-related content of the BMP Database is still relatively limited for many BMP categories. Additionally, this analysis showed that most of the BMP design parameters that were significantly correlated with effluent concentration often displayed a similar correlation with influent concentration. This finding confounds conclusions that can be drawn regarding causal relationships between BMP design parameters and removal of constituents, without applying more advanced statistical methods, such as analysis of covariance and multi-parameter regression. Also, the analysis of nutrient removal is difficult since monitoring may not capture all influent sources, including leaves and grass clippings, which may result in apparent nutrient export due to an incomplete mass balance analysis. Primary observations and conclusions reached for each BMP category analyzed include:

1. Retention Ponds: The retention pond (wet pond) category is one of the larger data sets in the BMP database, both in terms of number of studies, water quality data and design parameters. Based on statistical analysis in this report, retention ponds provide statistically significant removal of all constituents evaluated (i.e., total suspended solids, total and dissolved copper, total phosphorus, NOx) except for dissolved phosphorus. Analysis of the relationships between selected design parameters and median effluent concentrations showed that higher permanent pool volume (PPV) to average storm volume (ASV) ratios are associated with lower concentrations of total suspended solids and possibly total phosphorus and nitrate, but the relationships for these two constituents are not quite statistically significant ($p=0.11$ and 0.14, respectively). Additionally, a higher water quality surcharge volume (WQSV) to permanent pool volume (PPV) ratio may result in lower effluent total phosphorus and dissolved phosphorus; however, hypothesis test results were not quite statistically significant for dissolved phosphorus ($p=0.15$) and the influent concentration may be confounding the results for total phosphorus. Lower total phosphorus concentrations were also identified for higher length to width ratios, but, again, the influent concentrations showed a similar relationship. No other statistically significant relationships between design parameters and effluent concentrations were identified based on the available data set.

2. Detention Basins: The detention pond (extended detention dry pond) category is also relatively large in terms of number of studies and water quality data; however, reporting of design parameters is less consistent. Based on statistical analyses in this report, detention ponds provide statistically significant removal of total suspended solids, total copper, and nearly significant removal of total phosphorus, but not dissolved phosphorus or NOx. Analysis conducted showed no explainable, significant relationships between design storm depth (DSD) to average storm depth (ASD) ratio, brimful emptying time (BFET), or length to width ratios based on the available data set.

3. Media Filters: Several different types of media filters are included in the BMP Database. This analysis focused on sand filters. Sand filters showed statistically significant reductions of total suspended solids, total copper, and total phosphorus; however, they did not significantly reduce dissolved phosphorus or dissolved copper. Statistically

significant increases in NOx were present. Analysis of the relationships between selected design parameters and median effluent concentrations did not result in identification of statistically significant causal relationships between design variables and effluent concentrations.

4. Bioretention: The bioretention category is growing data set in the BMPDB, which tends to include more consistent reporting of design parameters in newer studies, but the data set overall remains smaller in terms of numbers of BMPs and constituents available. Additionally, this analysis focused on designs with underdrains, which further narrows the number of studies evaluated. Based on statistical analysis in this report, bioretention facilities with underdrains provide statistically significant removal of total suspended solids, but not total phosphorus or NOx. (Inadequate studies with design data were available to evaluate dissolved phosphorus and copper in this report.) The scatterplot matrices indicate that the combination of a large footprint to drainage area ratio and deep media bed may provide a higher water quality benefit than a smaller area ratio and shallower media bed, but additional data and research is needed to evaluate this relationship statistically. The composition of the media mix also is expected to play a significant role in pollutant removal, but with the variety of mixes reported in the BMPDB there currently are too few studies to meaningfully analyze this design parameter. Analysis of the relationships between selected design parameters and median effluent concentrations did not result in identification of statistically significant causal relationships between design variables and effluent concentrations. An important caveat for the bioretention findings is that volume reduction is typically a primary design objective and process for reducing pollutant loads. The analyses in this particular report do not consider volume reduction; however, bioretention has been shown to provide significant volume reduction in studies by other researchers, as well as in previous BMPDB analyses (see Geosyntec and WWE 2012c).

5. Grass Strips: Grass strips showed statistically significant reductions of total suspended solids, NOx, and total copper. Nearly significant reductions for dissolved copper were identified. A statistically significant increase in total phosphorus was noted. Volume reduction benefits may be present for grass strips, but were not addressed in this report. Analysis of the relationships between selected design parameters (length and slope) and median effluent concentrations did not result in identification of any statistically significant causal relationships. However, research by others (e.g., Caltrans, 2003) indicates that there may be an optimum length for any given slope and vegetation density to achieve consistently low effluent concentrations. Multi-regression analyses on the available BMPDB data could be used to better evaluate the effects these design parameters may have on performance.

6. Grass Swales: Grass swales showed statistically significant reductions of total suspended solids and total copper, but not NOx, total phosphorus or dissolved copper. However, dissolved copper removals were nearly statistically significant ($p=0.13$). Volume reduction benefits may also be present for grass swales, but were not addressed in this report. Analysis of the relationships between selected design parameters and median effluent concentrations showed that increasing swale lengths corresponded to better

THIS PAGE INTENTIONALLY LEFT BLANK

Regional Stormwater/Wetland Management Master Plan

AUGUST 2016

Prepared by:

PACIFIC ENGINEERING

Grette Associates LLC
ENVIRONMENTAL CONSULTANTS