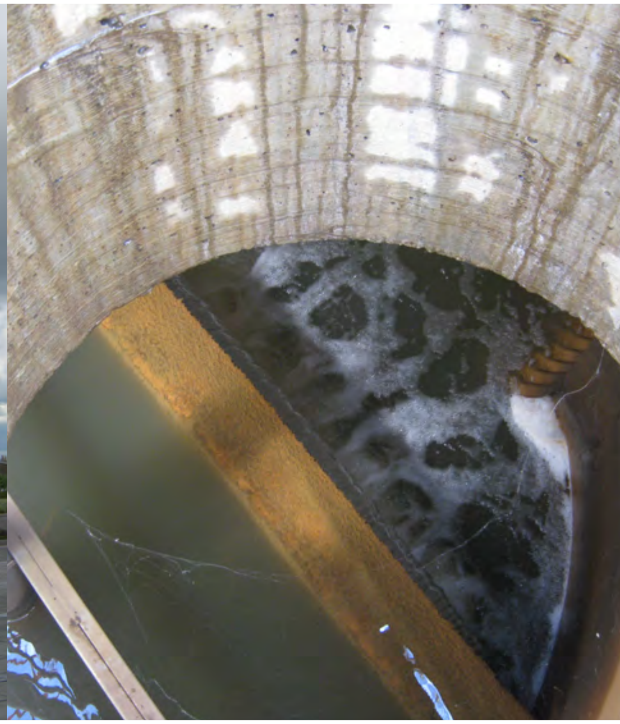

Port of Portland
Stormwater Design Standards Manual

2017

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QUICK START GUIDE

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ACRONYMS AND ABBREVIATIONS

AASHTO	American Association of State Highway and Transportation Officials
ACRP	Airport Cooperative Research Program
AC	advisory circulars
ALP	Airport Layout Plan
API	American Petroleum Institute
AREMA	American Railway Engineering and Maintenance-of-Way Association
BDS	Bureau of Development Services
BES	Bureau of Environmental Services
BMPs	Best Management Practices
BOD	biochemical oxygen demand
CAS	Cascade Station
CFR	Code of Federal Regulations
cfs	cubic feet per second
City	City of Portland
CO_2	carbon dioxide
CP	coalescing plate
CST	concentrated storage tanks
cu-ft	cubic foot (feet)
CWA	Clean Water Act
DDE	1,1-Dichloro-2,2-bis(p-chlorophenyl) ethylene
DDT	Dichloro-diphenyl-trichloroethane
DEQ	Department of Environmental Quality
DMS	Deicer Management System
DSM	Design Standards Manual
E. coli	Escherichia coli
ED	extended detention
EPA	Environmental Protection Agency
ESCP	Erosion and Sediment Control Plan (DEQ)
ESPCP	Erosion, Sediment and Pollution Control Plan (City)
FAA	Federal Aviation Administration
FEMA	Federal Emergency Management Agency
ft	foot (feet)
ft/sec	feet per second
GI	green infrastructure
GIS	Geographic Information System
HCB	hexachlorobenzene
HDPE	high density polyethylene
HEC-HMS	Hydrologic Engineering Center- Hydrologic Modeling System
HGL	Hydraulic Grade Line

ACRONYMS AND ABBREVIATIONS

hr	hour
HRT	hydraulic residence time
HSG	Hydrologic Soil Group
HUC	hydrologic unit code
IDF	intensity duration frequency
IGA	Intergovernmental Agreement
IMP	impervious area fraction
in/hr	inches per hour
i_{WQF}	water quality storm intensity
LID	low-impact development
MCDD	Multnomah County Drainage District
mg/L	milligrams per liter
MS4 Permit	Municipal Separate Storm Sewer System (MS4) Permit No. 101314
MWSE	maximum water surface elevations
NMFS	National Marine Fisheries Service
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resource Conservation Service
O&M	Operations and Maintenance
ODOT	Oregon Department of Transportation
ORS	Oregon Revised Statute
PA/SI	Preliminary Assessment and Site Inspection
PCBs	Polychlorinated biphenyls
PCP	Pentachlorophenol
PDX	Portland International Airport (which includes the Air Cargo facilities)
PE	Professional Engineer
pH	Hydrogen Ion Activity of Water
PIC	Portland International Center
POC	pollutants of concern
Port	Port of Portland
ppm	parts per million
PVC	polyvinyl chloride
R_v	runoff coefficient
SBUH	Santa Barbara Urban Hydrograph
SCS	Soil Conservation Service
SDFDM	Sewer and Drainage Facilities Design Manual
SPCC	Spill Prevention, Control and Countermeasure
sq ft	square feet
SSF	subsurface flow

ACRONYMS AND ABBREVIATIONS

State	State of Oregon
SWM	Stormwater Management
SWMM	Stormwater Management Manual
SWMP	Stormwater Management Plan
SWPCP	Stormwater Pollution Control Plan
T2	Marine Terminal 2
T4	Marine Terminal 4
T5	Marine Terminal 5
T6	Marine Terminal 6
TMDLs	Total Maximum Daily Loads
TRC	Technical Reference Center
TSS	total suspended solids
UIC	underground injection control
USB	urban services boundary
USCF	underground stormwater control facilities
USGS	U.S. Geologic Survey
WHMP	Wildlife Hazard Management Plan
WHPA	Wellhead Protection Area
WQ_V	water quality volume
WQ_F	water quality flow
WSDOT	Washington Department of Transportation

Record of Revisions

Date	Revision	Person or Group Making Revision
7/31/2017	▪ Clarified that treatment requirements are not applicable to replacement roofs (Section 1.5.2). ▪ Clarified variance request process within Section 3.3.3 and within Appendix E and F. ▪ Clarified that areas with pervious pavement may be excluded from volumetric runoff coefficient calculations (Section 4.5.2.3). ▪ Clarified source control requirements within Section 4 and within Appendix E. ▪ Updated Table 6-1 target pollutants for pervious pavement to match Fact Sheet 10. ▪ Removed Appendix M. ▪ Clarified the definition of best management practices as “postconstruction” best management practices and added the definition of source controls within the Glossary. ▪ Updated references to the Stormwater Master Plan. ▪ Updated header date from “May 2014” to “2017”. ▪ Updated references to City Stormwater Management Manual (SWMM) and added references to City Source Control Manual (SCM). ▪ Updated figures that show DSM applicability areas (Figures 1-1, 1-2, and 4-1) and added in zoomed in views of Figure 1-2 (Figures 1-2A, 1-2B, and 1-2C). ▪ Updated Appendix	Gresham Smith
11/05/2019	Appendix F Variance form updated to add detail about acreage and local treatment	POP Stormwater Amp Team
11/05/2019	Appendix E updated to add total area disturbed to E.1.	POP Stormwater Amp Team
11/05/2019	Figure1-2: DSM Applicability Area at PDX updated to better show applicability boundaries.	POP Stormwater Amp Team
7/1/2020	Revisions throughout to reflect that DSM is applicable to select areas at T6.	Gresham Smith
9/27/2022	Revisions throughout to reflect additional drainage areas at T6 in which the DSM is applicable.	Gresham Smith

EXECUTIVE SUMMARY

This Port of Portland (Port) Stormwater Design Standards Manual (DSM) became effective on January 1, 2014, in accordance with the requirements of Municipal Separate Storm Sewer System Permit No. 101314 (MS4 permit). Any development or redevelopment project that occurs at applicable Port facilities after this date and meets the applicability threshold described below must comply with DSM requirements, unless otherwise notified by the Port. The DSM is the central component of the Post-Construction Stormwater Pollutant and Runoff Control Program that is required under Schedule A.4.f of the MS4 permit. In accordance with this permit, the Port has the authority to define stormwater management requirements at Port-owned properties.

The DSM is currently applicable within select areas at Portland International Airport (PDX) and Marine Terminal 6 (T6). Detailed information on DSM applicability and exemptions is provided in Chapter 1. At applicable sites, the Port will be enforcing the DSM on "any new development or redevelopment project that creates or replaces 500 square feet or more of impervious surface" (with consideration for the larger common plan of development for the project site). For applicable projects, stormwater management designs shall comply with the DSM and Port stormwater review process in place of the latest version of the City *Storm Water Management Manual* and City stormwater review process. Outside of applicable areas shall comply with the local jurisdiction's stormwater management requirements and review process (e.g., City SWMM outside of DSM-applicable areas within the City of Portland).

The DSM establishes requirements for stormwater management that are consistent with MS4 permit "Post-Construction Site Runoff Control"[1] requirements, and requires coordination with other regulatory requirements that are potentially pertinent to stormwater management at Port facilities. The DSM does not incorporate all of the regulatory requirements that are potentially applicable to a project, and thus compliance with the Port DSM does not necessarily imply compliance with all applicable City, State of Oregon (State), and federal regulations or review processes. DSM requirements include stormwater management (SWM) standards for runoff control and regulatory coordination (Chapter 4, and stormwater drainage system and best management practice (BMP) selection and design criteria (Chapters 5, 6, and BMP fact sheets).

The DSM is enforced through the Port's design review and approval process for applicable projects and facilities (Chapter 3). Projects subject to the DSM are required to obtain Port approval of the stormwater management design through submission of documentation on the proposed measures for complying with the DSM before the project will be allowed to proceed from design to construction. Deviations from DSM requirements are not permitted unless they fall within a select list of potentially acceptable variances and are approved by the Port through the DSM variance request process.

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[1] MS4 permit A.4.f."

1 OVERVIEW

1.1 About the Port of Portland

The Port is a regional government agency authorized by the State of Oregon. The Port owns facilities residing within Clackamas, Multnomah, and Washington Counties in Oregon. The Port operates marine, airport, and industrial facilities under the direction of commissioners appointed by the Oregon Governor and confirmed by the legislature. The mission of the Port is to enhance the region's economy and quality of life by providing efficient cargo and air passenger access to national and global markets (Port 2013a).

The Port is a co-permittee with the City of Portland (City) on Municipal Separate Storm Sewer System (MS4) Permit No. 101314 (MS4 permit), which was issued by the Oregon Department of Environmental Quality (DEQ) in 2011. Please refer to Appendix **A** for a copy of the current MS4 permit. The City and Port both own and operate separate storm sewer systems within the City urban services boundary (USB). The Port is responsible for implementing the requirements of the MS4 permit within the Port MS4 permit area, which includes all Port-owned property within the City USB (Port 2011).

In accordance with Port MS4 permit area responsibilities, the Port has the authority to regulate stormwater discharges and define stormwater management requirements at Port-owned properties. Under the MS4 permit, the Port has developed several enforcement mechanisms, as summarized in the Port MS4 Stormwater Management Plan (SWMP). These enforcement mechanisms include contractual methods such as lease agreements with tenants and contracts with contractors, as well as regulatory methods such as permits and stormwater ordinances. The lease agreements require the lessees to comply with the MS4 permit. Port Ordinance No. 361 "Storm Water Regulation" provides the Port with legal authority to conduct inspections of Port-owned land and storm sewers, and prohibits illicit discharges or connections into a Port-owned storm sewer. From the enforcement mechanisms in place, the Port has the authority to prevent a project from proceeding to construction if it is determined that the project design is not sufficiently compliant with Port's stormwater management requirements. The Port's requirements for stormwater management design, review, and approval have been incorporated into this Stormwater DSM, as described below.

1.2 Introduction to the Stormwater Design Standards Manual

The DSM is the central component of the Post-Construction Stormwater Pollutant and Runoff Control Program that is required under Schedule A.4.f of the MS4 permit. The development of the DSM is intended to satisfy the requirement for the Port to "develop or reference an enforceable post-construction stormwater quality management manual by January 1, 2014."[2]

[2] MS4 permit A.4.f.iii.

The DSM defines the following types of stormwater management requirements:

- SWM standards, which are the requirements for managing the quantity and quality of post-construction stormwater runoff from new development and ***redevelopment***[3] sites at applicable Port facilities, in coordination with applicable water resource regulations.
- Design criteria for drainage systems, including stormwater collection and conveyance infrastructure and features.
- Design criteria for structural stormwater ***best management practices*** (BMPs) for controlling the quantity and quality of stormwater discharges from applicable Port facilities in compliance with the SWM standards.

Appendix **B** provides a detailed summary of permit requirements and how they were incorporated into the DSM. While developing the DSM requirements, it was pertinent to coordinate with other relevant regulations that have the potential to govern post-construction stormwater management. Compliance with the Port DSM does not necessarily imply compliance with all applicable City, State of Oregon (State), and federal regulations or regulatory review processes. The DSM requirements and guidance were also developed with consideration for the unique site constraints and operational and maintenance (O&M) considerations applicable to Port facilities.

1.3 Enforcement of the Manual

Compliance with the DSM is enforced through the Port's design review and approval process for applicable projects and facilities. Projects subject to the DSM are required to obtain Port approval of the stormwater management design before the project will be allowed to proceed from design to construction. Any deviation from DSM requirements must be previously approved by the Port through the ***variance request*** process. See Chapter 3 for more information on the ***stormwater management submittal***, variance requests, and other required submittals and coordination steps between designers and the Port. Port approval of the SWM submittal does not replace the need for other potentially required Port, City, or governmental agency reviews, permits, or approvals.

The Port also has programs in place that allow for the review and inspection of stormwater controls and discharges, including environmental inspections during the construction phase as well as regular O&M inspections of constructed BMPs and drainage infrastructure. Additional stormwater inspections and enforcement requirements may be implemented at the Port's discretion to comply with the terms of the MS4 permit, in accordance with Port Ordinance No. 361 "Storm Water Regulation."

1.4 Objectives of the Manual

The DSM is intended to establish requirements for stormwater management at applicable Port facilities in accordance with MS4 permit "Post-Construction Site Runoff Control"[4] requirements. The DSM also incorporates additional stormwater management requirements that are unique to Port operations, such as hazardous wildlife management. The DSM is not comprehensive of all necessary requirements to meet regulations outside of the DSM and the MS4 permit Post-Construction Site Runoff Control requirements. There may be unique circumstances that require

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[3] Terms defined in the glossary (Chapter 8) are shown in ***bold, italicized*** typeface the first time they are used.
[4] MS4 permit A.4.f.

the consultation of additional resources. Additionally, the Port has the option to define project-specific requirements beyond those in the DSM, as identified within a project scope.

Implementation of the DSM has the following objectives:

- Incorporate additional flexibility into the post-construction stormwater review and compliance process to account for operational and site-specific development constraints that are unique to the Port.
- Promote coordination with Port stormwater management initiatives, including the Port's Stormwater Management Plan (as introduced within Chapter 2).
- Promote coordination with anticipated long-term development and recommendations of the Stormwater Master Plan (as introduced within Chapter 2).
- Promote consideration of the facility-wide impacts of stormwater management decisions associated with individual projects.
- Facilitate communication about stormwater management decision-making between designers of stormwater management facilities and the Port at various phases of project planning and design.
- Facilitate consistency in stormwater management approaches for new and redevelopment projects.
- Promote compatibility of stormwater management designs with aviation safety requirements.

1.5 Applicability to Port Facilities and Projects

1.5.1 Facility Applicability

The Port owns a variety of properties, including undeveloped areas as well as properties with active facilities such as airports, marine terminals, and industrial parks. Several of the Port properties do not fall within the City USB, and therefore do not fall within the boundaries of the Port MS4 permit area. The Port has selected the Port facilities that are currently subject to the requirements of the DSM, as identified in Table 1-1 and illustrated on Figure 1-1. For purposes of the DSM, the term "Port facilities" is defined as Port property within the identified facilities. The DSM is currently applicable within select areas at PDX and T6. Applicable areas at each facility are described in further detail below. The Port is considering the benefits of future implementation of the DSM at other Port facilities within the Port MS4 permit area, as well as future reference of the DSM at Port facilities outside of the City USB.

DSM-applicable areas at PDX include all "airside" areas within the airport fence (including Air Cargo facilities and Oregon Air National Guard), as well as Port-owned and operated "landside" properties outside the fence that are adjacent to the airport. DSM applicability areas at PDX do not currently include landside Port properties that are leased to tenants or have the potential to be leased in the future, such as Portland International Center (PIC) and Cascade Station (CAS). Figure 1-2 displays the areas included at PDX. Designers of projects at these facilities shall coordinate with the Port to confirm current applicability requirements.

DSM-applicable areas at T6 are limited to Drainage Basins C, D, F, G, H, I, J, K, L, M, O, and T. Applicable areas at T6 are illustrated on Figure 1-3.

Design of stormwater management systems for applicable projects within the DSM-applicable areas (see below for information on project applicability) shall comply with the DSM requirements and the Port stormwater review process, in place of the City *Storm Water Management Manual* (SWMM) (City of Portland 2016) and City stormwater review process. Stormwater management designs outside of DSM-applicable areas shall comply with the local jurisdiction's stormwater management requirements and review process (e.g., City SWMM outside of DSM-applicable areas within the City of Portland).

Table 1-1: Summary of DSM Applicability to Port Facilities[1]

Port Division	Facility	Port MS4 Permit Area?	DSM Applicable?
Airports	Hillsboro Airport	*No*	*No*
	Portland International Airport (PDX)	**Yes**	**Yes**
	Troutdale Airport	*No*	*No*
Marine Terminals	Marine Terminal 2 (T2)	**Yes**	*No*
	Marine Terminal 4 (T4)	**Yes**	*No*
	Marine Terminal 5 (T5)	**Yes**	*No*
	Marine Terminal 6 (T6)	**Yes**	**Yes**
Industrial Parks and Facilities	Air Cargo (Air Trans Center, PDX Cargo Center, North Cargo Complex) (Considered to be part of PDX)	**Yes**	**Yes**
	Cascade Station (CAS)	**Yes**	*No*
	Gresham Vista Business Park	*No*	*No*
	Mock's Bottom	**Yes**	*No*
	Navigation Base	**Yes**	*No*
	Portland International Center (PIC)	**Yes**	*No*
	Rivergate Industrial District	**Yes**	*No*
	Swan Island Industrial Park	**Yes**	*No*
	Troutdale Reynolds Industrial Park	*No*	*No*

[1] Table includes active facilities listed on the Port's website (http://www.portofportland.com). The Port owns properties without active facilities that are not listed in this table and are not being considered for implementation of the DSM.

1.5.2 Project Applicability and Exemptions

In accordance with the MS4 permit (Schedule A.4.f.i), the Port is required to enforce the DSM, as part of their post-construction stormwater pollutant and runoff control program, on "any new development or redevelopment project that creates or replaces 500 square feet or more of impervious surface." The DSM shall also apply if there is a larger common plan of development for the project site that meets these thresholds. Key terms pertaining to applicability are defined below:

- ***Disturbance Area*** – The area where soil is exposed during construction of the development or redevelopment project.
- ***Development*** – The addition of any impervious surface to a project site where the existing land cover is less than 35 percent impervious prior to the addition of the new impervious surface. Compare to the definition for redevelopment.

- ***Impervious Surface*** – The MS4 permit defines this term as "any surface resulting from development activities that prevents the infiltration of water or results in more runoff than in the undeveloped condition. Common impervious surfaces include building roofs, traditional concrete or asphalt paving on walkways, driveways, parking lots, gravel roads, and packed earthen materials."[5] For consistency with the City SWMM, surfaces such as gravel roads and packed earthen materials will be considered impervious when the runoff coefficient is greater than 0.8, and otherwise will be considered to be pervious.
- ***Project Site*** – The site that is selected for land development and redevelopment activities, including the functional project area, as well as areas used for stormwater management within the project limits of construction. The site also encompasses the full disturbance area, including areas that will ultimately be pervious and impervious.
- ***Redevelopment*** – The MS4 permit defines this term as "a project on a previously developed site that results in the addition or replacement of impervious surface."[6] For purposes of the DSM, a project is considered to be redevelopment if the existing land cover at the project site is greater than or equal to 35 percent impervious prior to the addition or replacement of impervious surface.
- ***Replacement*** – The MS4 permit defines this term as "the removal of an impervious surface that exposes soil followed by the placement of an impervious surface.
- ***Larger Common Plan of Development*** – The United States Environmental Protection Agency (EPA) defines this term as "a contiguous area where multiple separate (development) activities may be taking place at different times… under one plan." (EPA 2013a)

In accordance with the definitions above and with MS4 permit language, select activities and portions of projects are potentially considered to be exempt from DSM requirements associated with post-construction runoff control. This potential exemption applies only to the portions of the project that fall within one of the categories below, and does not entail exemption from other regulatory requirements such as construction-phase sediment and erosion control measures that are required by City code and DEQ permits. The potential exemption is predicated on the assumption that the activities below will have negligible impact to post-construction hydrologic conditions or water quality. If the Port identifies that a project falling within one of the categories below may have a hydrologic or water quality impact, they have the option to waive this exemption and require treatment as appropriate to comply with permit requirements. Designers shall coordinate with the Port to confirm potentially-exempted areas early in the project planning process. Potentially exempt activities include:

- Repair and Maintenance – The MS4 permit states that "replacement does not include repair or maintenance activities on structures or facilities taken to prevent decline, lapse, or cessation in the use of the existing impervious surface" as long as those activities do not have "additional hydrologic impact results."[7] For the purpose of the DSM, activities that are exempt from DSM requirements include, but may not be limited to, mill and overlay, microsurfacing, slurry seal, crack sealing, and roof repair or replacement.
- Linear Construction – Linear construction work (e.g., construction within a narrow corridor for the purpose of installing buried infrastructure such as sewers and utilities) are exempt from

[5] MS4 permit D.7.g
[6] MS4 permit D.7.k
[7] MS4 permit D.7.l

DSM requirements as long as the disturbed surface from such activities are restored and replaced in kind, and the work does not result in any additional impervious surface.

- Removal of Existing Impervious Surface – Activities that consist of removal of existing impervious surface that is replaced with a pervious area, provided that the areas achieve final stabilization after construction, are exempt from DSM requirements.
- Projects Creating or Replacing Less Than 500 Square Feet – In accordance with the MS4 permit applicability threshold, projects are exempt from DSM requirements if they create or replace less than 500 square feet of impervious surface. When considering applicability based on this threshold, the entire project site and larger common plan of development must be considered.

Applicability of the DSM to a proposed development or redevelopment project (or portions thereof) will be determined initially by the Port at the start of the project, in accordance with these definitions. Should the nature of the project change substantially with respect to DSM applicability or exemption eligibility, the Port reserves the right to update their determination of DSM applicability to the project accordingly.

Designers of stormwater management systems at Port facilities where the DSM is applicable are required to adhere to SWM standards (Chapter 4) and design criteria described in the DSM (Chapters 5, 6, and ***BMP fact sheets***), as well as follow required compliance and Port review processes (Chapters 3 and 4). The Port review processes require that project designers submit documentation on proposed measures for complying with the DSM to the Port and obtain approval from the Port prior to finalization of the design, as described further in Chapter 3. The Port recognizes that project-specific and site-specific constraints may interfere with the ability to fully meet the requirements of the DSM. As such, the DSM allows for the possibility of a variance from the DSM SWM standards and design criteria, with Port approval. Although the DSM standards, criteria, and compliance approaches incorporate some flexibility to account for these constraints, designers may coordinate with the Port and follow the official variance request process (Chapter 3) in cases where additional flexibility is required.

This manual is effective as of January 1, 2014, in accordance with MS4 permit requirements. Any development or redevelopment project that occurs at applicable facilities after this date must comply with the DSM, unless otherwise notified by the Port.

1.6 Coordination with Regulatory Agency Requirements

Compliance with the DSM does not eliminate the need for designers to comply with other applicable local, state, and federal regulatory requirements (See Appendix **C** for an overview of potentially applicable regulations). Although the DSM is intended to be used in place of the City's SWMM and stormwater review process at applicable Port facilities, designers are responsible for complying with all applicable City codes and ordinances that are outside the scope of the City SWMM. Additionally, Port projects may need to comply with City review and approval processes and applicable design standards if they meet specific City review triggers. Potential City review triggers may include, but are not limited to:

- Projects sited within City-defined zones protecting natural resource areas (e.g., ***greenway overlay zones***), ***environmental overlay zones***, Columbia South Shore Well Field ***Wellhead Protection Area*** (WHPA), ***flood hazard areas***) – These projects typically require review by the City for compliance with zone-specific City design standards.

- Projects requiring a building permit – These projects trigger a review by the City Bureau of Development Services (BDS) for compliance with applicable building codes. For airside projects at PDX, projects requiring a building permit are limited to those with structures or providing a life-saving function.
- Projects interfacing with city stormwater infrastructure or drainage facilities (e.g., Port sewers crossing city roads or other public facilities, Port projects discharging into city MS4 infrastructure) – These projects may require coordination with City Bureau of Environmental Services (BES) to determine what, if any, city stormwater standards may be applicable, including portions of the City's Sewer and Drainage Facilities Design Manual (SDFDM) for the design of public sewers, or portions of the City SWMM for discharge to the City MS4.

Regulatory requirements that are summarized in the DSM are provided for coordination purposes only, and do not supersede the regulations that are effective at the time of development. Federal, state, and local regulatory authorities with jurisdiction over a potential project environmental impact (e.g., DEQ, United States Army Corps of Engineers, EPA, National Marine Fisheries Service [NMFS], etc.) may require more stringent measures than the DSM, depending on applicable project-specific regulatory or permitting requirements. Designers will coordinate with the Port to identify regulatory agencies that may require coordination or review of the project design.

In cases where there is a discrepancy between the DSM and applicable regulatory requirements, the more stringent requirements apply. Outside of the DSM compliance process, designers are responsible for designing their project to meet other applicable regulatory requirements, as well as acquiring applicable permits and approvals associated with the proposed project. All anticipated non-DSM regulatory submittals are required to be coordinated in advance with the Port as part of the DSM coordination process.

1.7 Considerations for Use of the Manual

The DSM is intended primarily to be used by designers (Port, tenant staff, or consultants) of stormwater management facilities, infrastructure, strategies, and controls for Port or Port tenant development projects. The DSM may also serve as a reference manual for Port or tenant staff involved in stormwater management planning and design review and approval.

It is recommended that the DSM be reviewed during the early stages of a project, allowing for timely consideration of the SWM standards and design criteria. As described in Chapter 3, the DSM should also be referenced throughout the design process to ensure the project is complying with the SWM standards or, where applicable, variance requests are being coordinated with the Port. Design review milestones provide a means for designers and the Port to communicate about DSM requirements and strategies for complying with the SWM standards.

1.8 Contents and Organization of the Manual

The DSM is organized in a series of chapters that describe varying aspects of Port stormwater management requirements and DSM compliance. Topics include stormwater runoff control requirements, ***drainage system*** evaluation and design, BMP selection and design, and requirements for coordinating the stormwater management design with the Port. The organization is intended to assist designers with accessing DSM requirements at a glance, while also providing the necessary context and guidance for compliance where further details are required. The electronic version of the document contains hyperlinks for easy navigation. The summary below explains the contents and purpose of the major sections of the DSM, and serves as a guide for finding particular types of stormwater management information.

Chapter 1 – Introduction to the DSM: Chapter 1 provides an introduction to the DSM and explains why the manual was developed, applicability of DSM requirements toward Port facilities and projects, considerations for manual use, and an overview of manual content.

Chapter 2 – Port Stormwater Management Context: Chapter 2 provides context and background for stormwater management systems at Port facilities. This chapter also identifies potential Port resources related to Port future planning, stormwater infrastructure, site and geotechnical information, and past projects This background information is intended for reference on new and redevelopment projects and to assist the designer with effectively initiating information requests.

Chapter 3 – Design Compliance Process: Chapter 3 highlights the design process and submittal requirements for developing and designing a stormwater management system that complies with DSM requirements. This chapter also describes coordination of stormwater management decisions with the Port, as well as submitting the stormwater design for review and approval by the Port. Designers should reference this chapter at the start of any stormwater management design, throughout the design process, and in preparation for the stormwater submittal.

Chapter 4 – ***Stormwater Management Standards***: Chapter 4 identifies the set of SWM standards that drive the need and design basis for stormwater management BMPs and strategies to control the quantity and quality of stormwater discharges. These standards emphasize minimizing the potential effects of development on stormwater discharges and mimicking predevelopment drainage conditions. The SWM standards are also intended to align stormwater management approaches with Port stormwater management initiatives and regulatory requirements, including the post-construction runoff control requirements in the MS4 permit.

Chapter 5 – Drainage System Design: Chapter 5 describes key design criteria for the design of stormwater collection and conveyance infrastructure at applicable Port facilities. Major topics include hydrology, open channels, culverts, storm sewer pipes, and drainage structures. These design criteria were selected to promote compliance with applicable drainage system regulatory requirements, as well as align with Port goals for the performance of facility drainage systems.

Chapter 6 – BMP Selection, Design, and Implementation: Chapter 6 provides an overview of potential stormwater quantity and quality treatment BMP options that may be implemented on a project for the purpose of complying with the SWM standards in Chapter 4 and other potentially applicable regulatory requirements. This chapter identifies considerations and a methodology for the selection of appropriate site-specific BMPs. Chapter 6 also describes BMP design criteria and considerations, including siting, components, ***pretreatment***, and other key design decisions. The general information in Chapter 6 is intended to be coordinated with the BMP-specific selection and design guidance and criteria described in a series of BMP fact sheets.

BMP Fact Sheets – The BMP fact sheets provide selection and design guidance and criteria for individual stormwater management BMPs. The fact sheets include the functional description, cost considerations, site suitability and limitations, footprint considerations, general O&M requirements, and specific BMP design and implementation requirements.

Chapter 7 – References: Chapter 7 provides a list of reference materials cited in the DSM.

Chapter 8 – Glossary: Chapter 8 provides a list of terms and definitions that are used within the DSM that may not be familiar to the reader.

Figures – The figures provide further detail on location of Port facilities, Port MS4 permit area, certain regulated areas, and site characteristics. DSM figures are listed in the Table of Contents.

Appendices – The appendices provide additional details supporting the DSM requirements, including additional background on the origin of particular DSM requirements, guidance on testing and analysis requirements, and submittal checklists and forms. DSM appendices are listed in the Table of Contents.

2 PORT STORMWATER MANAGEMENT CONTEXT

2.1 Introduction

2.1.1 Objectives

- Provide context for stormwater management systems and processes at Port facilities that need to be understood and coordinated during the course of a stormwater design.
- Identify potential sources of information related to Port future planning, stormwater infrastructure, site and geotechnical information, and past projects, for reference on new and redevelopment projects.

2.1.2 Chapter Contents

The contents of this chapter provide additional background information pertaining to stormwater management at Port facilities. This chapter is intended to make the designer aware of existing facility information (for facilities currently following the DSM), infrastructure, and drainage features that may require coordination on stormwater management design. Additional relevant background information can be found in Appendix **C**, which describes a variety of existing regulatory requirements.

2.2 Port Facility Receiving Waters

An understanding of Port facility receiving waters is necessary to understand applicable water resource regulations (Appendix **C**) and stormwater management design requirements, especially pertaining to water quantity controls and water quality protection. The U.S. Geological Survey (USGS) has defined areas or “hydrologic units” draining to the water systems in the United States in varying levels of detail. The hydrologic units are given a hydrologic unit code (HUC) with increasing digits corresponding to the level of detail (USGS 2013).

The Portland metropolitan area is located within the Lower Willamette Subbasin, which is defined as a 4th-level hydrologic unit by the USGS, corresponding to the 8-digit HUC (HUC8) #17090012. This subbasin consists of the area draining to the Columbia River northwest of Troutdale and southeast of St. Helens. It includes tributaries draining to the Columbia River in this region, including the entire Columbia Slough and the lower portion of the Willamette River upstream (southeast) of the Columbia River to Bolton. The Columbia Slough drains into the Willamette River just upstream of its confluence with the Columbia River. Downstream of the Lower Willamette Subbasin, the Columbia River continues approximately 80 miles northwest through two additional HUC8 subbasins before it discharges into the Pacific Ocean.

Along the Columbia River and Columbia Slough, natural drainage has been altered to protect development and provide flood control through a system of levees. Additional flood control is provided within the Columbia Slough through pump stations maintained and operated by the Multnomah County Drainage District (MCDD).

The Lower Willamette Subbasin is further divided into smaller hydrologic units corresponding to 6th-level or 12-digit HUC (HUC12) watersheds along the receiving waters. Within the Port MS4 permit area, Port facility locations relative to receiving waters and HUC12 watershed boundaries are displayed on Figure 2-1. T2, T4, and T5 and the industrial parks Mock’s Bottom, Rivergate, and Swan Island are located along the Willamette River within the Willamette River Watershed

(HUC12 #170900120202). T6, PDX, CAS, and PIC are located between the Columbia Slough and Columbia River, east of the Willamette River. These facilities are defined within the boundaries of the Columbia Slough Watershed (HUC12 #170900120201). PDX and T6 have outfalls to both the Columbia Slough and Columbia River. Table 2-1 summarizes the receiving waters for drainage from each of the Port facilities within the Port MS4 permit area.

Table 2-1: Receiving Waters for Facilities Within the Port MS4 Permit Area

Port Facility	Columbia Slough	Willamette River	Columbia River
Portland International Airport	X		X
T2		X	
T4		X	
T5		X	
T6	X		X
CAS	X		
Mock's Bottom		X	
Navigation Base		X	
Rivergate	X	X	
PIC	X		
Swan Island		X	

2.3 Stormwater Management at Port Facilities

This section provides an overview of Port facilities within the MS4 permit area, including existing development, industrial activities, regulatory permits, and stormwater infrastructure. This information may help to inform designers about features and activities to be considered and coordinated on the project stormwater management design. The information in this section focuses on the facilities where the DSM is currently applicable (currently only PDX).

2.3.1 Portland International Airport

2.3.1.1 Industrial Activities and National Pollutant Discharge Elimination System (NPDES) Permits

PDX provides services to accommodate passenger airline and cargo carrier operations. Services performed within the inclusive PDX facility (as described in Chapter 1) include car rental companies, fueling stations, and other supportive services. The industrial activities that take place at PDX include:

- Fueling
- Aircraft, equipment, vehicle, and building Maintenance
- Aircraft and pavement deicing
- Airport maintenance and operations
- Material storage and handling
- Food services

- Garbage and recycling storage
- Fire station operations and training
- Aircraft, vehicle, and equipment washing
- Rental car fueling, maintenance, and washing
- Aircraft and ground services equipment painting
- Vehicle and equipment storage

The Port and associated co-permittees hold an individual industrial NPDES permit (#101647) for stormwater discharges to the Columbia Slough and Columbia River associated with aircraft and pavement deicing activities and the Deicer Management System (DMS) at PDX. The 1200-Z NPDES permit is included as an attachment to permit 101647 and covers airport discharges for non-deicing industrial stormwater discharges to the Columbia Slough. The Port maintains a Stormwater Pollution Control Plan (SWPCP) that details industrial activities and stormwater management at PDX. Additionally, the Port holds the following permits at PDX:

- City of Portland Pretreatment Permit
- Water Pollution Control Facility 1700-B Wastewater Permit

2.3.1.2 PDX Stormwater Management System

As previously described, the Columbia Slough is the primary receiving water for stormwater drainage from PDX. PDX is divided into nine major drainage basins from west to east, each corresponding to an outfall at the Columbia Slough. Stormwater runoff from the facility generally drains south across the facility by gravity through a series of storm sewers and channels before it reaches an outfall at the Columbia Slough. Stormwater from Drainage Basins 3, 4, 5, 7, 8, and 9 drains to the Columbia Slough through gravity systems, while stormwater from Drainage Basins 1, 2, and 6 is pumped to the Columbia Slough through pump stations. MCDD operates and manages the pump station within Drainage Basin 1 (MCDD Pump Station #2), as well as the pump station within Drainage Basin 2 (Broadmoor Pump Station). The Port operates and manages the pump station within Drainage Basin 6 (PS-6).

The following stormwater BMPs are implemented at PDX:

- East Quiescent Basin
- East Detention Basin
- Central Quiescent Basin
- West Quiescent Basin
- West Detention Basin
- Proprietary Device BMPs
  - Hydrodynamic Separators
  - Oil/Water Separators
  - Storm Filters
  - Sedimentation Manholes
- Sand Filters (used at CAS)
- Vegetated Swales
- Rocky Swales
- Filter Strips
- DMS (described in section below)

- PDX also implements source controls for various activities such as storing fuel in order to comply with Spill, Prevention, Control, and Countermeasure (SPCC) regulations. The Source Controls SWM Standard in Chapter 4 provides key requirements for source controls at PDX.

Designers are encouraged to coordinate with the Port to collect more detailed information on the existing BMPs as applicable to their projects.

2.3.1.3 PDX Deicer Management System

The PDX DMS is used to manage the collection, storage, treatment, and discharge of stormwater containing applied deicing chemicals, in accordance with the individual industrial NPDES permit #101647. During the deicing season, stormwater runoff is monitored for total organic carbon concentrations (as a surrogate for biochemical oxygen demand [BOD]) in deicer-impacted stormwater runoff at key locations around the airport through online meters. Through a computer control system, stormwater is routed either to storage structures or to the Columbia Slough outfalls, based on how the measured total organic carbon concentrations compare to total organic carbon diversion concentration setpoints. Deicer-impacted stormwater that requires collection (to meet wasteload allocations for total organic carbon in the deicing NPDES permit) is pumped across the airport to on-site storage facilities that hold dilute or concentrated runoff.

The dilute stormwater runoff may be collected within the dilute ***detention*** basin, which historically metered dilute deicer laden discharge to the Columbia Slough. While there is a manual valve to direct discharge to the Columbia Slough in an emergency situation, the design of the system is to have all collected dilute stormwater pump to the dilute storage tanks and discharged through controlled release to an outfall in the Columbia River, in compliance with permit requirements for total organic carbon mass loading. Concentrated stormwater is pumped to the concentrated storage tanks (CSTs) and then directed to an on-site deicer treatment system or directed to the sanitary sewer. Treated effluent is typically discharged to the sanitary sewer, but it can be routed to the Columbia River.

The DMS infrastructure was specifically designed to accommodate anticipated deicing stormwater flows in accordance with permit conditions and anticipated deicing activities and is not available to be used for non-deicing applications. Any new stormwater management infrastructure that will be built in the vicinity of DMS infrastructure, or that may affect stormwater routing in the DMS, must be coordinated with the Port to minimize the potential for interference with DMS operations or permit compliance. The DMS is typically operational from October through the end of May.

2.3.2 Marine Terminals

As described in Chapter 1, the Port owns four marine terminals within the MS4 permit area, including T2, T4, T5, and T6. The Port and tenants at these facilities manage operations that transport bulk materials, grains, or cars using ships, railways, and trucks. The DSM is currently applicable only to Port operated areas of T6. T2, T4, and T5 may be considered for DSM implementation in the future. These facilities, as well as areas outside of DSM-applicable areas at T6, are currently required to comply with the City SWMM.

T6 is primarily used for importing and exporting shipping containers and includes a container storage area with seven container cranes, a multipurpose area serving oversized breakbulk cargo, and an intermodal yard that allows transfers between trucks, ships, and rail. The Port operated area of T6 is approximately 196 acres.

The Port-operated drainage system at T6 is divided into drainage basins, each of which has a letter designation. Drainage basins (I, J, K, L, M, O, and a portion of H) are subject to compliance with the Port's MS4 permit and the Port's 1200-Z general permit. Other Port-operated drainage basins (C, D, F, G, T, and a portion of H) are subject to compliance with the MS4 permit only. The Port is applying the DSM to these 12 drainage basins. All other drainage basins at T6 shall follow the City SWMM for stormwater management requirements, see Figure 1-3 for the T6 applicability area.

A variety of stormwater BMPs are used at T6 to improve water quality. Installed BMPs include proprietary devices such as oil/water separators, StormFilters, and a sedimentation manhole. Additionally, the site has an infiltration facility near the facility entrance. Infiltration and filtration-based practices were recommended as BMPs to be considered for future implementation at T6, to address pollutants of concern. Designers are encouraged to coordinate with the Port to collect more detailed information on the existing BMPs as applicable to their projects.

2.3.3 Industrial Parks and Facilities

As described in Chapter 1, the Port owns properties in a series of industrial parks and facilities within the MS4 permit area, including Cascade Station, Portland International Center, Swan Island, Navigation Base, Mock's Bottom, and Rivergate. Stormwater management at these facilities is not subject to as many unique operational constraints as airports and marine terminals. Drainage from these facilities combines with drainage from non-Port facilities as it enters municipal stormwater conveyance systems. The Port is not currently considering implementation of the DSM at the industrial facilities, so these facilities must continue to comply with the City's SWMM and review process for stormwater management design.

2.4 Relevant Port Information Sources

The Port has a series of technical resources that may be useful to designers as they design stormwater management systems in accordance with the requirements of the DSM. Designers are strongly encouraged to coordinate with the Port to identify existing information sources that may be pertinent to the specific development or redevelopment project or site. Information sources may include, but are not necessarily limited to, the following:

- Stormwater Master Plan: The Port developed a PDX-specific Stormwater Master Plan in 2015, which identified stormwater management recommendations and strategies associated with facility long-term development plans. Projects at PDX should coordinate with the Stormwater Master Plan to make sure that stormwater management is effectively working toward Port goals and projects.
- Other Port Stormwater Plans: The Port develops and maintains other stormwater plans for compliance with associated permits and regulatory requirements as applicable at each facility. Such plans include SWMP, SWPCPs, and SPCC.
- Port Geographic Information System (GIS) Database: The Port stores and updates various GIS data that relate to select stormwater assets (e.g., structures, pipes and BMPs). There is also data on GIS impervious areas and drainage basins. In addition to the Port GIS, designers

may also look to the City and Metro GIS databases to obtain information on zoning and floodplains.

- Port Technical Reference Center (TRC): The Port's TRC stores project record information as well as geotechnical and site data and reports.
- Port Design Consultant Manual: The Port has detailed requirements for design drawings, specifications, and other electronic files. Designers are required to follow the standards set within the Design Consultant Manual for all design submittals.
- Port Stormwater Models: Coordinate with the Port on existing modeling information that may be available for reference.
- Standard CAD Drawings: Coordinate with the Port on available drawing templates and standard drawings to be incorporated into design submittals.
- Standard Design Specifications: Coordinate with the Port on available specification templates and standard specifications to be incorporated into design submittals.
- Washington State Department of Transportation (WSDOT) Aviation Stormwater Design Manual – Managing Wildlife Hazards Near Airports: Technical manual with additional guidance on managing stormwater at airports, with consideration for ***hazardous wildlife attractants***.
- PDX Wildlife Hazard Management Plan (WHMP): The Port maintains a copy of the WHMP to document practices and standards that the Port takes to manage wildlife hazards affecting flight operations at PDX.

3 DSM COMPLIANCE PROCESS

3.1 Introduction

3.1.1 Objectives

- Identify key points of coordination between designers, tenants, and the Port during planning, design, review, and construction of stormwater management features.
- Describe the required components of the DSM SWM submittal to the Port (as described in Section 3.3.4).

3.1.2 Chapter Contents

Compliance with the DSM requires that project designers obtain formal Port approval of their stormwater management design, as documented in their SWM submittal. Designers are required to submit the SWM submittal to the Port along with final design documents at the final design phase. This chapter describes requirements of the SWM submittal, as well as other required intermediate stormwater submittals to the Port. Additionally, the chapter provides recommendations for stormwater design development and coordination with the Port at key project milestones, to facilitate timely Port review and approval. The requirements in this chapter are applicable to designers of both Port and tenant-driven projects that are required to follow the DSM, as described in Chapter 1.

3.1.3 Coordination with Other DSM Chapters and Appendices

- Chapter 4 – SWM standards for which designers are required to demonstrate compliance in their SWM submittal.
- Chapter 5 – Drainage system design criteria required to be incorporated into the design of stormwater collection and conveyance systems and reflected in the SWM submittal.
- Chapter 6 and BMP Fact Sheets – Design criteria and guidance for the selection, design, and implementation of site-specific stormwater management BMPs that comply with the DSM, to be reflected in the design and in the SWM submittal.

3.2 Overview of the Design Coordination and Review Process

This section provides a recommended process for designers to coordinate with the Port to develop a stormwater management design that complies with the requirements of the DSM and facilitates the exchange of information, decision-making, and approvals between the Port and designers at key milestones. Coordination on the stormwater management design between designers and the Port is intended to support the following objectives:

- Promote designers' understanding of applicable SWM standards, design criteria for stormwater management BMPs and drainage systems, and submittal requirements.
- Allow for collaborative development of a stormwater management design that aligns with project objectives and Port stormwater management needs.
- Facilitate communication of project constraints and site information.
- Minimize the potential for schedule delays due to lengthy reviews or unforeseen regulatory/permit requirements.

The Port generally establishes a design milestone structure for each project, defining key points in the design process where the Port has the opportunity to review design progress. Each design phase typically involves the development of design documents to be submitted to the Port, followed by a Port review period, and then a subsequent coordination meeting to discuss design review comments and the design. The number of design milestones may vary between projects, depending on project complexity, scope, and schedule. Coordination with the Port on DSM or stormwater-specific design decisions is generally intended to be performed within this existing design review structure, although there may be a need to set up additional meetings to discuss particular topics as needed. Typical major design phases and milestones are summarized in the sections below, including recommendations for information collection and design development to be completed along the way to facilitate the review process.

3.2.1 Project Kickoff Meeting

The Port will hold a ***project kickoff meeting*** with designers at the start of each design project to review project goals and objectives as identified in the project scope of work, as well as project schedule, logistics for coordination, Port information resources, and submittal requirements. As it relates to DSM compliance, the meeting provides an opportunity to discuss preliminary site and project information that may support development of the stormwater management approach on the project. To support this objective, meeting attendees should be familiar with the DSM requirements, including design criteria and SWM standards.

At and following the meeting, designers may begin collecting site and project information to support the stormwater management design, including the following as applicable:

- Existing and proposed site activities and operations at the project site.
- Considerations for project footprint and placement based on access requirements, operations, and connections to infrastructure.
- Site location and characteristics, including receiving waters and natural resources.
- Historic environmental data from the site, including soil analyses and geotechnical reports, groundwater elevations, and historic land uses or site contamination from environmental reports.
- Existing infrastructure near the site, based on Port base maps, as-built drawings, aerial photography, GIS data, and stormwater models, as applicable.
- Existing and planned Port regional BMPs.

Additionally, designers should coordinate with the Port on preliminary planning-level considerations for the stormwater management approach, based on Port experience and ongoing stormwater management initiatives. Topics for discussion may include, but are not necessarily limited to:

- Coordination with regional BMPs, other projects, and facility Stormwater Master Plan.
- Coordination with MS4 SMP compliance initiatives.
- ***Low-impact development (LID) practices*** currently considered by the Port.
- Applicable regulations and regulatory activities.
- Pollutants of concern requiring treatment and potentially required ***source controls***.
- Infrastructure tie-in locations for project discharges.
- Potentially applicable regulatory requirements, including existing permit coverage as well as potentially required permit modifications or new permit coverage.

- Existing drainage system capacity or flooding issues and asset management concerns to be addressed as part of the project.
- Applicability of existing or planned regional BMPs to address project needs.

3.2.2 Preliminary Design Phase

The preliminary design phase begins following the project kickoff meeting, and may include one or more preliminary design milestone(s), each including a submittal and meeting with the Port. To facilitate compliance with the DSM, designers should begin development of the stormwater management design during the preliminary design phase, and be prepared to discuss key DSM compliance issues with the Port at the preliminary design milestone(s).

3.2.2.1 Preliminary Project Design

The preliminary project design involves the initial development of the stormwater management design in preparation for the preliminary design milestone(s). During this phase, it is critical that designers develop, at minimum, the following elements of the stormwater system design to allow the Port to review and provide feedback before the final design phase:

- LID practices that are planned to be implemented on the project, in accordance with the LID SWM standard in Section 4.2.
- Approach to meeting each of the SWM standards in Chapter 4.
- Stormwater discharge tie-in points.
- Development of preliminary water quality treatment BMP approach, including applicable BMPs, and potentially required pretreatment and source control measures.
- Preliminary sizing of BMPs to meet SWM standards and design criteria in Chapter 6 and BMP fact sheets.
- Potential hazardous wildlife attractant mitigation approach, as described in Chapter 4.
- Preliminary layout, sizing, and characteristics of collection and conveyance infrastructure to meet design criteria in Chapter 5.
- Variance requests for deviations from DSM requirements, in accordance with Section 3.3.3.
- Anticipated regulatory reviews, permits, and approvals by regulatory agencies.
- Potential asset management concerns associated with existing pipe conditions and age, and recommendations for replacing or upgrading existing pipe.
- Compliance with water quantity control objectives and potentially required water quantity controls.

The initial stormwater management design should be based on the historic information collected as described above, as well as site-specific field data. Field data collected during this phase may include the following, as required:

- Topographical and infrastructure surveys.
- Soil and groundwater analyses, as described in Appendix **D**, to support infiltration strategies.
- Geotechnical investigations.
- Utility location services.
- Environmental assessments or other environmental investigations.
- Wetlands, wildlife, and other natural resources surveys.

3.2.2.2 Preliminary Design Milestones

Projects may include one or more preliminary design milestone(s) between the project kickoff meeting and ***final design milestone***. The preliminary design milestone meeting(s) generally allow(s) coordination between designers and the Port on design progress, findings from field investigations, technical design decisions, information needs, and document quality. For purposes of the DSM, these meetings provide an opportunity for designers and the Port to coordinate on stormwater design elements described in the previous section, and the design approach for compliance with the DSM. In addition to the typical design document submittals at the preliminary design milestone(s), designers are required to submit completed variance requests to the Port, as applicable. This allows the Port to review discrepancies from DSM requirements, provide feedback to designers, and adjust project course as needed before proceeding to the final design phase. See Section 3.3 for more information on required submittals to the Port.

3.2.3 Final Design Phase

The final design phase begins following the preliminary design milestone(s). The final design phase includes a final design milestone, which involves submittal of the final design documents to the Port for review and approval, and a meeting with the Port to discuss review comments. To comply with the DSM, designers need to complete and submit the SWM submittal as part of the final design documents submittal, for review and approval by the Port. The SWM submittal demonstrates how the final stormwater management design complies with the requirements of the DSM.

3.2.3.1 Final Design

During the final design, the designer proceeds with finalizing the design based on the stormwater management approach agreed on with the Port at the preliminary design milestone(s). In the time leading up to the final design milestone, the designer should be making final adjustments to the design based on comments received during the preliminary design phase, performing final calculations and analyses, and finalizing the development of the design documents. Also during this time, the designer should prepare the SWM submittal, which is due to the Port at the final design milestone.

3.2.3.2 Final Design Milestone

The final design milestone allows the Port to review the completed stormwater management design for alignment with Port standards, project objectives, and compliance with the DSM. Design submittals at this milestone include the full set of completed design documents (as defined in the project scope), as well as the SWM submittal. The SWM submittal, which is described in detail in Section 3.3.4, is required to include a narrative and supporting information that documents the final stormwater management design and demonstrates compliance with the DSM. After the Port's review of the required submittals, the final design meeting is held to discuss review comments with designers. Designers are then required to revise the design documents to incorporate Port comments, and resubmit for Port approval to proceed to construction. On tenant projects, Port approval of the design will involve the issuance of a Port construction permit.

3.3 Submittals to the Port

3.3.1 General Design Submittals

Designers are typically required to submit design documents to the Port for an opportunity to review design progress and decisions prior to the preliminary and final design milestones. As part of the standard Port design review process, the Port will review the stormwater management design elements that appear on the project design documents submitted at that milestone. Design documents typically include design drawings, specifications, cost opinions, design or engineering reports, and other items as identified by the Port. Designers shall coordinate with the Port at the project kickoff meeting to determine specific design submittal requirements and timing.

Design documents are required to comply with Port standards manuals for design documents, as provided by the Port or as specified on their "Master Specifications and Standard Details" webpage, including their Specifications Standards Manual, CAD Standards Manual, and Engineering Consultant Handbook. Design documents shall also comply with Port-identified technical standards and requirements such as HVAC standards for IT rooms, PDX landscaping standards, and design requirements in the WHMP (Port 2013b).

3.3.2 DSM Coordination Checklist

The DSM coordination checklist (Appendix **E**) provides a means for designers to document how the project stormwater management design is complying with major requirements of the DSM. This checklist is required to be submitted as part of each design document submittal to facilitate coordination and review by the Port. The DSM coordination checklist encompasses the following categories of information:

- Applicability of and approach to meeting the SWM standards (Chapter 4).
- Implementation of LID practices as applicable (Section 4.2, LID SWM standard).
- Potential variance requests and justification.
- Compliance with drainage system design criteria (Chapter 5).
- Compliance with the BMP design criteria (Chapter 6 and BMP fact sheets).

The checklist should be initially completed to reflect preliminary stormwater management considerations resulting from the project kickoff meeting (Section 3.2.1) with the Port and subsequent information gathering and project planning. As the design approach evolves over the course of the design, the checklist is required to be maintained, updated, and incorporated into design submittals and milestone meetings with the Port.

3.3.3 Variance Requests

Although the DSM requirements were developed to build in flexibility to account for potential site constraints, there may be some instances where further flexibility is warranted on a particular project. The variance request process provides a means for designers to request a design deviation from a few limited types of DSM requirements, pending Port review and approval. The need for a variance request must be driven either by a site constraint that makes a particular requirement impracticable or an opportunity to enhance the design and improve system performance. Potential variance requests that will be considered for acceptability are limited to the following:

- Variance request for ***off-site mitigation*** to meet water quality SWM standard (Chapter 4).
- Variance request to implement a new ***underground injection control*** (UIC) system serving non-roof areas (Chapter 4).
- Variance request to use a modified structural source control standard (Chapter 4).
- Variance request to deviate from conveyance or BMP design criteria in Chapter 5, Chapter 6, or the BMP fact sheets.
- Variance request to implement a BMP type other than those defined in the BMP fact sheets (BMPs must be certified under the Washington State Department of Ecology Technology Assessment Protocol program or an equivalent review system approved by the Port).

The DSM requirements were selected specifically to meet Port objectives for stormwater management; for that reason, designers are not permitted to deviate from DSM requirements unless they have received formal approval from the Port through the variance request process. Approval from the Port confirms that the stormwater management objectives are still able to be met with the variance request. Outside of any approved variance requests, designers of applicable projects are required to comply with all other DSM requirements.

The Port holds the authority to formally approve variance requests associated with post-construction stormwater management but does not have the authority to approve or deny external variance requests for criteria that are regulated by outside entities. These include variances associated with UICs, which are regulated by DEQ, or structural source controls that tie into the sanitary sewer, which are regulated by the City of Portland. Designers that are planning to pursue an external variance request are required to coordinate in advance with the Port on reviews of the variance request before it is submitted to an outside entity. The Port reserves the right to deny the pursuit of a designer’s variance request, or require that it be modified and resubmitted for any reason. If the Port allows an external variance request to proceed, the designer may then move forward with DEQ (UIC) and/or City submittals (source controls tied to sanitary sewer). The Port does not guarantee that approval by the Port to submit an external variance request will result in a final approval of the variance request by the regulatory authority. Unless an external variance request is allowed to proceed by the Port and formally approved by the regulatory authority, designers are required to follow all requirements stated within the DSM and all applicable regulations.

Designers that are submitting a variance request are required to comply with the process described in the steps below:

1. Within the preliminary design phase, determine if site constraints may make it impracticable to comply with a particular DSM requirement, and determine if any of the above variance request types may be justified.
2. Characterize how the design deviation from the DSM may impact system performance, O&M, costs, constructability, regulatory compliance, and other Port or project objectives.
3. Characterize potential project or stormwater management benefits associated with the deviation.
4. Notify the Port of potential variance requests being considered as soon as possible to minimize schedule impacts.

5. Fill out the variance request form template provided in Appendix **F** and develop required supporting documentation. Documentation is required to describe how the design deviates from DSM requirements, provide justification for the deviation based on project constraints or potential benefits, and summarize potential impacts on the ability to meet Port or project objectives.
6. Submit all completed variance request(s) to the Port as part of the design document submittal at the preliminary design milestone(s). The Port will review all requests simultaneously with consideration for cumulative impacts. At completion of Port review, the Port will return review comments to the designer, including a formal approval or denial, as well as conditions for approval, as applicable.
7. Discuss Port review comments on the submitted variance request at the preliminary design milestone meeting.
8. Adjust design to incorporate Port feedback as part of the final design phase.
9. Submit finalized variance request approval documentation to the Port as an attachment to the SWM submittal at the final design milestone. Final design documents must be consistent with any variance requests as approved by the Port. New variance requests will not be accepted at this time.

The Port reserves the right to deny variance requests if they are expected to result in significant impacts to the project or conflicts with Port stormwater management objectives, or if there is a possibility that a design change may allow the deviation to be avoided. The Port also has the option to provide conditional approvals of variance requests, which require that designers take additional measures or incorporate additional features into the design to mitigate for potential project impacts. If a variance request has the potential to offer positive benefits to the project or to the ability to meet Port or project objectives, designers shall document potential benefits in the variance request, and the Port may consider if there is a need to revise future installments of the DSM accordingly.

3.3.4 Stormwater Management Submittal

The SWM submittal is required to be submitted at the final detailed design review milestone to document compliance with DSM **stormwater** management requirements. The Port construction permit cannot be issued until this submittal has been completed, reviewed, and approved by the Port. The list of required components of the SWM submittal are summarized in Appendix **G** for ease of reference by designers and Port reviewers during the submittal process. Further details are provided in the subsections below.

3.3.4.1 Narrative

A narrative is required to be included in the SWM submittal to clearly demonstrate how DSM compliance is being achieved through the project design and selected SWM Strategy. Demonstrating compliance with the SWM standards may require the explanation of stormwater management decisions, considerations, and constraints affecting the design development process that may not be apparent from the design documents. A well-written narrative will allow the Port to clearly identify how the project complies with each applicable SWM standard, as well as reasoning behind any variance from the SWM standards or design criteria, facilitating an expeditious review. The narrative may also be referenced long-term by the Port as needed to protect the design and function of the system during operations and future development.

Although the format of the narrative may vary, the Port requires that each narrative include the following components:

- Overview of the project design and function.
- Overview of the project site.
- Description of the SWM strategy, including applicability of each of the SWM standards in Chapter 4, and measures taken to comply with them.
- Description of stormwater management BMPs.
- Description of the project drainage system.
- Description of variance requests.
- Description of applicable regulatory reviews and approvals associated with stormwater or DSM requirements.

Please refer to Appendix **G** for the specific items to be included under each component.

3.3.4.2 DSM Coordination Checklist

Each design submittal to the Port, including the SWM submittal, is required to include a DSM coordination checklist that has been completed by the designer. This checklist provides a place for the designer to provide a high level summary of the stormwater management approach, as described in Section 3.3.2 and provided in Appendix **E**.

3.3.4.3 Calculations

Calculations supporting the design of stormwater management features and demonstrating compliance with SWM standards are required to be included in the SWM submittal for review by the Port. These calculations should clearly indicate the methodology used, as well as assumptions and information sources. In cases where these calculations were performed using modeling software, the requirements below must still be met, but may be provided as part of the model report described in the following section. Where applicable, calculations should include those supporting the sizing or design of conveyance and BMPs, which may include the following:

- Calculation of maximum ponding and flow elevations within conveyance, BMPs, and surface drainage areas, and demonstration that elevations meet water quantity control objectives in Chapter 4 and ponding allowances in Chapter 5.
- Inlet and pipe sizing analyses that comply with the design storms in Chapter 5.
- Stage versus discharge or outlet rating curves for volume-based facilities.
- Inflow and outflow hydrographs for BMPs (flow-based and volume-based, as described in Chapter 4).
- Calculation of water quality volume or water quality flow, as detailed in Section 4.5, Water Quality – Capture and Treat.
- Calculation of infiltration volume corresponding to the applicable ***infiltration strategy***, as detailed in Section 4.3, Infiltration.

3.3.4.4 Modeling Reports

The SWM submittal must include a modeling report for each hydrologic and hydraulic stormwater model used in support of the stormwater management design. Models may include those used to design conveyance, surface drainage, and stormwater BMPs. Required components of each modeling report are documented in Appendix **H**.

3.3.4.5 Erosion, Sediment and Pollution Control Plan

Attach the ***Erosion, Sediment and Pollution Control Plan*** (ESPCP), if required to be developed and submitted to the City. For projects that require coverage under the 1200-C permit, the ESPCP may also need to be submitted to DEQ as part of the permit application. For the projects that are applicable for coverage under the 1200-CA permit, an ongoing construction permit for the Port, the ESPCP must be developed and readily available to DEQ on request. See Appendix **C** for background on erosion and sediment control regulations and Section 4.9, Erosion and Sediment Control, for a summary of compliance requirements and applicability.

3.3.4.6 Soil and Groundwater Analyses Report

In support of a stormwater management approach that involves infiltration, designers are required to perform site-specific soil and groundwater analyses to determine the field and design infiltration rates and seasonally-high groundwater elevations. These analyses may be part of a standard design geotechnical report. Designers are required to submit documentation of these analyses, where applicable, as part of the SWM submittal. Appendix **D** provides detailed requirements for these analyses.

3.3.4.7 Operations and Maintenance Plan

An O&M Plan is required to be developed to identify operations and maintenance requirements (O&M strategies) for all stormwater management facilities within the stormwater management design. The O&M Plan should provide the Port with specific O&M actions for the designed facilities such that the facilities will function as designed for their useful life. The O&M Plan submittal is required to include a completed O&M form (included in Appendix **I**), as well as a narrative, and other attachments as needed to document O&M procedures and considerations. Designers shall coordinate with the Port on project-specific requirements for the O&M Plan.

The O&M form requires designers to fill out basic project information, a summary of project stormwater management BMPs and facilities, and provides a checklist for documenting required components of the narrative. The form also includes several tables that shall be used to summarize O&M procedures, including specific tasks and frequencies.

O&M information provided by any applicable vendors must be attached to the submitted O&M Plan and called out on the O&M form. Any O&M Plan items not covered within the vendor-supplied information must be supplemented by the designer and incorporated into the submitted O&M Plan. Coordinate with Chapter 6 and the BMP fact sheets for guidance on stormwater management BMP O&M. For maintenance of other stormwater management facilities (e.g., pump stations) coordinate with the Port on existing stormwater management facilities and maintenance plans to determine what should be included in the O&M Plan for the stormwater management facility within the stormwater management design.

3.3.4.8 Supporting Drawings

The Stormwater Management Submittal must include drawings that illustrate site hydrology (pre- and post-development), as well as the stormwater management design, including site grading, conveyance, and BMPs. These drawings may be within the design drawing set provided that copies of those drawings are submitted along with the SWM submittal, or may be developed separately in support of the SWM submittal. All drawings must comply with the Port's design documents requirements, as described in Section 3.3.4. At minimum, SWM submittal supporting drawings must include:

- Drainage maps
  - ***Pre-development site conditions*** and post-development site conditions (including wetlands)
- Runoff assumptions for calculations
  - Delineated drainage catchments and drainage catchment characteristics (hand calculated or model derived) for pre-development and post-development site conditions
- BMP reference numbers
- Pipe and structure reference numbers
- Plan and profile of conveyance features
- BMP plan and sections

4 STORMWATER MANAGEMENT STANDARDS

4.1 Introduction–Overview of Chapter

4.1.1 Objective

The objective of this chapter is to describe the SWM standards, including standards for managing the quantity and quality of post-construction stormwater runoff from new development and redevelopment sites at applicable Port facilities (***Runoff Control SWM Standards***), as well as standards for coordinating stormwater management with applicable water resource regulations (***Regulatory Coordination SWM Standards***).

4.1.2 Chapter Contents

This chapter includes sections describing the eight required SWM standards governing design of stormwater management infrastructure at Port facilities. Each standard includes specific requirements for stormwater management, a required compliance approach, and potential implementation considerations. Designers of stormwater management infrastructure are required to comply with each of the SWM standards as part of their stormwater management design. The SWM standards are divided into runoff control SWM standards and regulatory coordination SWM standards, as described below.

4.1.2.1 Runoff Control SWM Standards

The runoff control SWM standards establish requirements for controlling the quality and quantity of post-construction stormwater runoff from applicable development and redevelopment projects at Port facilities subject to this DSM. These requirements are largely driven by MS4 permit requirements for post-construction site runoff,[8] which are aimed at minimizing the potential for runoff from impervious surfaces to impact receiving waters. These standards may drive the need for BMPs to be incorporated into the stormwater management design, in accordance with the BMP design criteria and selection guidance provided in Chapter 6 and the BMP fact sheets. The runoff control SWM standards are as follows:

1. Low-impact Development (Section 4.2) – Identifies strategies and practices for ***low-impact development*** (LID) that must be considered on each project.
2. Infiltration (Section 4.3) – Defines a series of infiltration strategies, one of which must be implemented on a project depending on project and site conditions.
3. Water Quantity Control (Section 4.2) – Establishes water quantity control objectives for flooding, and requires stormwater modeling to evaluate project compliance. Additional controls may be determined on a project-by-project basis, depending on results of the analysis and historic drainage system capacity issues near the project site.
4. Water Quality – Capture and Treat (Section 4.5) – Defines the minimum water quality BMP design treatment capacity that must be provided to meet MS4 permit capture and treat requirements.

[8] MS4 permit A.4.f.

5. Source Controls (Section 4.6) – Identifies the need for source controls to be implemented within project designs based on a set of standards adopted from the City. Additional source controls may be required at the discretion of the Port to manage pollutants of concern (POCs).

4.1.2.2 Regulatory Coordination SWM Standards

The regulatory coordination SWM standards identify the need for designers to coordinate their design with key regulatory requirements. Although designers are responsible for designing to all applicable regulatory requirements, the requirements called out in these SWM standards are those that may be especially pertinent to stormwater management at Port facilities. These requirements are largely driven by regulatory sources other than the MS4 permit, as described below:

1. Hazardous Wildlife Attractants (Section 4.7) – Summarizes key requirements for the siting and design of stormwater management BMPs to minimize the attraction of hazardous wildlife, in accordance with Federal Aviation Administration (FAA) Advisory Circular (AC) 150/5200-33: *Hazardous Wildlife Attractants On or Near Airports* (FAA 2007), PDX WHMP, and Oregon Revised Statute (ORS) 836.623.
2. Floodway and Natural Resource Protection (Section 4.8) – Requires designers to comply with the local, state, and federal regulations that protect natural resources and floodways. These regulations may limit or restrict development in regulated areas and may require coordination during the siting of BMPs and drainage systems.
3. Erosion and Sediment Control (Section 4.9) – Requires designers to comply with the City, Oregon DEQ, and Port requirements for erosion and sediment control on project sites with stormwater discharges from construction activities.

4.1.3 Coordination with Other DSM Chapters

- Chapter 1 – Facility and project applicability of DSM requirements.
- Chapter 3 – SWM submittal requirements as well as an overview of the design and review process and variance request requirements.
- Chapter 5 – Drainage system design criteria related to the design of stormwater collection and conveyance systems.
- Chapter 6 and BMP Fact Sheets – Guidance on selecting and siting appropriate BMPs to meet the SWM standards presented in this chapter, as well as detailed BMP design criteria.

4.2 Low-Impact Development

4.2.1 Introduction

On an undeveloped natural site, the rate that precipitation runs off the surface is slowed by vegetation and rough terrain with depressions that promote on-site ***retention*** as well as infiltration and evapotranspiration. Land development and redevelopment activities typically result in increased imperviousness, compacted soils, and smoothly graded surfaces that are designed to rapidly drain through conveyance systems such as storm sewers and engineered channels. Development projects therefore typically result in an increase in the percentage of rainfall that contributes directly to runoff (increased runoff volume), a decrease in the travel time for stormwater runoff to reach the discharge point (decreased time of concentration), and an increase in the rate of stormwater discharges (increased peak flow rates).

The MS4 permit requires that LID, ***green infrastructure*** (GI), or equivalent design and construction approaches are prioritized for managing post-construction site runoff, and that site-specific management practices that target natural hydrologic functions are implemented "as much as practicable."[9] LID, as defined by the EPA, is "an approach to land development (or re-development) that works with nature to manage stormwater as close to its source as possible," and "employs principles such as preserving and recreating natural landscape features (and) minimizing effective imperviousness to create functional and appealing site drainage that treat(s) stormwater as a resource rather than a waste product." (EPA 2013c)

GI is defined by the EPA as including "systems and practices that use or mimic natural processes to infiltrate, evapotranspirate, or reuse stormwater" on-site and "support the principles of LID" (EPA 2013c). For the purposes of the DSM, the term GI refers to structural stormwater BMPs that meet these goals, and the use of GI BMPs is one of many potential LID approaches that must be considered for new development and redevelopment projects. Infiltration practices implemented as part of a site-specific infiltration strategy to meet the infiltration SWM standard in Section 4.3 are considered to be GI. Refer to Chapter 6 and the BMP fact sheets for further information on which structural BMPs may be classified as GI and may be applicable toward demonstrating compliance with the GI component of the LID SWM standard.

In addition to the environmental benefits, LID practices offer the following potential benefits to the Port:

- A reduction in the development footprint may reduce the extent of clearing and grading, which may lead to savings in construction costs.
- Avoidance of sensitive areas may help to reduce permitting and regulatory approvals, resulting in reduced potential for schedule delays and permitting costs.
- A reduction in the development footprint may preserve land for future uses, maximizing the potential of the property.
- Use of GI, where applicable, may allow for stormwater treatment at a reduced cost compared to traditional structural BMPs.

4.2.2 Requirements

The Port has identified a set of LID practices that are required to be considered for potential applicability on new development and redevelopment projects. These practices may be classified under three general ***LID strategies***, which are further defined in the sub-sections below:

- Minimize disturbance of sensitive areas
- Minimize impact of development
- Manage runoff from disturbed areas

Designers are required to review the list of LID strategies and supporting practices, consider each for applicability toward the project, and where applicable, implement the practices as much as

[9] MS4 permit A.4.f.i.1., A.4f.i.3.

practicable. The consideration and implementation of LID is required to be documented within the DSM coordination checklist described in Chapter 3, which is a required component of the SWM submittal to the Port. Completion of the LID portion of the DSM coordination checklist requires that designers provide the following information:

- Assessment of applicability for each LID strategy and supporting practices.
- A description of how applicable LID practices were incorporated into the project design.
- Justification for any strategies or practices that were determined not to be applicable for the project or site, including project or site constraints, and documentation of any decisions or guidance provided by the Port.
- Identification of other LID considerations that were incorporated into the project that were not already covered by the checklist.

The Port recognizes that the applicability and feasibility of implementing each LID strategy on a given project will vary depending on a variety of project-specific and site-specific constraints, as described in Section 4.2.4, Implementation Considerations.

4.2.2.1 Minimize Disturbance of Sensitive Areas (Site Selection and Layout)

The initial strategy to be considered is to minimize the disturbance of environmentally sensitive areas that may be especially susceptible to impacts from stormwater runoff (as defined below). The intent of avoiding these areas is to protect the natural treatment, wildlife habitat, and recreational function that these areas provide, as well as minimize the potential for water quality impacts. Additionally, the disturbance of environmentally protected areas may necessitate environmental reviews, acquisition of permits, and potential mitigation requirements, which can result in impacts to project cost and schedule (see Section 4.8, Floodway and Natural Resource Protection). Minimizing the disturbance of sensitive areas requires consideration during the selection of the project site, and further consideration during the design phase as it relates to the layout of development features on the chosen site. The effectiveness of this strategy will depend on the flexibility of the potential project location and the layout of the project components. LID practices supporting this strategy that are required to be considered for project applicability include:

- Siting the development to avoid natural resource areas. (e.g., City-defined environmental overlay zones, greenway overlay zones, wetlands, buffer zones, streams, floodplains, protected wildlife habitat, and other protected zones).
- Minimizing disturbance of natural or undeveloped areas.
- Minimizing disturbance of areas that may be highly susceptible to erosion. (e.g., steeply-sloped areas or areas with erosive soil conditions).

4.2.2.2 Minimize Impact of Development (Footprint Minimization)

Once the project site has been selected, another LID strategy to consider is minimizing the potential impacts of the development by limiting the disturbance area on the site. Minimizing the impact of development is accomplished by reducing the area on-site that is cleared and graded, paved, compacted, and developed. The intent of these practices is to reduce the amount of runoff that is generated, as well as reduce the sources of potential pollutants associated with the project disturbance. These practices must be evaluated with consideration for maintaining the required development function, capacity, access, and construction. Successful application of this strategy involves minimizing the functional project footprint while still meeting project goals. LID practices supporting this strategy that are required to be considered for project applicability include:

- Minimizing the development footprint.
- Minimizing compaction of soil in pervious areas that are designed to promote infiltration.
- Minimizing clearing and grading and changes to natural drainage pattern.
- Reducing the extent of effective impervious areas.

4.2.2.3 Manage Runoff from Disturbed Areas (GI and Runoff Management)

Once the project siting and footprint have been generally established, the strategy for managing runoff from the planned development should be considered in a way that minimizes impacts to receiving waters. This strategy includes LID practices that contribute to mimicking pre-development hydrologic functions by promoting infiltration, evapotranspiration, or stormwater reuse (e.g., rainwater harvesting), where feasible, to manage the quality and quantity of off-site discharges. LID practices supporting this strategy that are required to be considered for project applicability include:

- Promoting sheet flow runoff from impervious areas, and direct runoff to pervious areas that are designed to promote infiltration (disconnecting impervious areas from piped collection systems).
- Implementing GI BMPs to collect, treat, and infiltrate runoff from developed areas.

4.2.3 Compliance Approach

Compliance with the LID SWM standard necessitates the consideration of each LID practice individually for applicability to the project, and the incorporation of applicable strategies into the project design and construction. As LID practices can involve changes to the development plan (e.g., changes to project footprint, use of pervious pavement, changes to project siting, etc.), it is recommended that LID considerations be incorporated into early project planning to minimize the potential for impacts to project cost and schedule. The Port may consider the potential applicability of various LID strategies and practices prior to the design phase, particularly those strategies that pertain to planning level decisions such as project siting, footprint, and function. Coordination with the Port on LID and other aspects of the project stormwater management design approach should begin during the project kickoff meeting, as outlined in Chapter 3.

1. At the project kickoff meeting, coordinate with the Port on LID considerations that were discussed during project planning to gain an understanding of LID practices already incorporated as well as practices that the Port does not see fit for the project.
2. During the preliminary design phase (Chapter 3), review each of the LID practices described above and consider the feasibility of incorporating each practice into the project design. Feasibility may be limited for particular practices as described under Section 4.2.4, Implementation Considerations, but these considerations are not likely to rule out all potential LID practices.
3. Discuss the feasibility of incorporating LID practices into the design with the Port at the preliminary design milestone meeting(s) (or earlier) to confirm approach and assumptions.
4. Update the project design to incorporate applicable LID practices.

5. Use the LID portion of the DSM coordination checklist to document which LID practices were determined to be applicable, and how those practices are reflected in the design.
6. Use the LID portion of the DSM coordination checklist to provide justification for LID practices that were not incorporated into the design, including site or project constraints that limited the feasibility of those practices.

4.2.4 Implementation Considerations

The MS4 permit acknowledges that a particular project or site may have conditions that may make the implementation of certain LID practices "impracticable."[10] This section provides considerations that may affect the implementation of select LID practices. In cases where applicability of a particular practice is limited by one of the considerations below, designers shall still consider the applicability of other potential LID practices that are not affected by that particular limitation. As an example, the applicability of using GI BMPs that promote infiltration (Section 4.2.2.3, Manage Runoff from Disturbed Areas (GI and Runoff Management)) may be limited at sites with limited capacity for infiltration; however, this does not rule out the ability to reduce a project footprint under the Minimize Impact of Development (Footprint Minimization) LID strategy in Section 4.2.2.2. Some examples of LID implementation considerations include, but are not limited to:

- <u>Project Function</u> – In general, LID practices can only be implemented to the extent they align with the Port's functional and capacity needs for the planned development, with consideration for operations and maintenance access. Project function often dictates the minimum sizing, layout, imperviousness, and location of the project. Port approval would be required to change the function or capacity for the purposes of LID.
- <u>Scope of Redevelopment</u> – Redevelopment projects that involve the replacement of existing pavements in kind may be limited in their ability to implement LID strategies (in particular Section 4.2.2.1, Minimize Disturbance of Sensitive Areas (Site Selection and Layout) and Section 4.2.2.2, Minimize Impact of Development (Footprint Minimization)) if there are limited opportunities to change the project footprint, siting, or drainage characteristics. These projects may have an opportunity to implement the LID strategy for Manage Runoff from Disturbed Areas (GI and Runoff Management) as part of their required water quality treatment strategy (Section 4.5, Water Quality – Capture and Treat SWM standard).
- <u>Facility Safety</u> – The implementation of LID practices should not result in the violation of any safety-focused regulatory requirements. For example, LID practices should not create hazardous wildlife attractants or violate FAA airport design standards at PDX (Section 4.7, Hazardous Wildlife Attractants SWM standard). LID practices should avoid interference with airport operations, and should not result in standing water beyond the maximum 48-hour drawdown time or vegetation that is attractive to wildlife.
- <u>Long-Term Development Plan</u> – Additionally, the implementation of LID practices should align, rather than conflict, with the facility's long-term development master plan. For example, project siting to avoid sensitive areas should not conflict with future development locations. It may not be possible to reduce the footprint or capacity of development if the project is intended to address a minimum capacity identified in a master plan. However, if long-term development needs are uncertain, it may be possible to phase the development to reduce the immediate development footprint, with approval from the Port. Because master plans are fluid, designers

[10] MS4 permit, A.4.f.iii.4

must coordinate with the Port to verify an up-to-date understanding of planned future development.

- Space Constraints – Although one component of LID is associated with minimizing the footprint of proposed development, it is possible that land availability and space constraints may limit the extent to which LID practices can be implemented on a site. Space constraints may make it difficult to avoid sensitive areas such as wetlands, or limit the footprint of GI BMPs. Potential impacts to sensitive areas must be coordinated with the Port and receive necessary regulatory permits and approvals.
- Site Drainage Characteristics – The effectiveness of LID practices that rely on infiltration can be limited by the hydrogeological characteristics of a site. Sites with poor drainage characteristics, high seasonal groundwater elevations, or low capacity for infiltration should not typically rely on infiltration-based practices. See Section 4.3, Infiltration SWM standard, for guidance on selecting a site-specific infiltration strategy and infiltration applicability considerations. GI selected as part of an LID strategy should align with the site-specific infiltration strategy.
- Cost and O&M Requirements – Depending on the LID practices being considered, the Port may require designers to provide an analysis of costs, benefits, and risks associated with selected LID practices to achieve the appropriate balance among LID benefits, costs, and Port operational needs on a project-specific basis. These analyses should incorporate costs potentially associated with O&M requirements for LID practices, such as those involving GI.

4.3 Infiltration

4.3.1 Introduction

As described under the LID SWM standard (Section 4.2), uncontrolled discharges from developed areas tend to have an increased peak flow rate and flow volume, and a reduced time of concentration (T_c), compared to predevelopment conditions. The MS4 permit requires a reduction in the post-development stormwater runoff volume, duration, and rate of stormwater discharges "to minimize hydrological and water quality impacts from impervious surfaces."[11] Strategies that promote infiltration (where practicable) help to reduce runoff volumes, peak flow rates, and the duration of discharges by retaining more stormwater on-site. Infiltration also provides for the natural treatment of stormwater as it percolates through the soil.

In addition to these environmental benefits, infiltration offers the following potential benefits to the Port:

- Reduces the potential for flooding during storm events through reduced runoff volume, which can reduce the risk of operational interruptions during a storm event.
- Reserves the existing capacity of the drainage system downstream, which provides a potential for savings in infrastructure and construction costs.
- Reduces the size of new designated stormwater conveyance system and downstream water quantity and quality control BMPs, providing a potential for savings in infrastructure and construction costs.

[11] MS4 permit A.4.f.i.2.

BMPs that promote infiltration are considered to be GI BMPs, which are one of the LID practices under the Manage Runoff from Disturbed Areas (GI and Runoff Management) LID strategy (Section 4.2.2.3). As such, a site-appropriate infiltration strategy may be applicable toward the SWM standard for Low-Impact Development (Section 4.2). Additionally, infiltration-based BMPs may be applicable toward meeting the SWM standards for Water Quantity Control (Section 4.4) and Water Quality – Capture and Treat (Section 4.5) depending on site feasibility.

4.3.2 Requirements

On-site infiltration must be implemented to the maximum extent practicable, in accordance with the MS4 permit. For the purposes of the DSM, implementing infiltration to the maximum extent practicable is defined as selecting a site-appropriate infiltration strategy. Designers must select one of three infiltration strategies, as defined below, based on the applicability requirements defined in Table 4-1:

- Full Infiltration of the Water Quality Design Storm – Complete on-site infiltration of the water quality design storm (80 percent of the annual average runoff volume) for runoff from the entire project drainage area. Designers selecting this strategy are required to comply with the sizing requirements described in the Water Quality – Capture and Treat (Section 4.5) WQ_V and WQ_F calculations.
- Partial Infiltration of the Water Quality Design Storm – On-site infiltration of a portion of the water quality design storm, depending on the ability to drawdown within 48 hours. This strategy may allow for designers to make progress toward the Water Quality – Capture and Treat SWM standard.
- No Reliance on Infiltration – On-site infiltration is demonstrated to be infeasible or impracticable based on applicability requirements and implementation considerations. Under this strategy, BMPs selected by designers to meet other SWM standards are required to drain fully without reliance on infiltration.

Table 4-1: Infiltration Strategy Applicability

Infiltration Strategy	Strategy Applicability Requirements
1. Full Infiltration of the Water Quality Design Storm (Design infiltration capacity = WQ_V or WQ_F)	Selection of this strategy requires that all of the following conditions are met: • Design infiltration rate between 0.5 and 2.4 in/hr as calculated based on field data and conversion to design infiltration rate as described in Appendix **D**. • Complete drawdown of the design surface ponding within 48 hours (subsurface ponding may remain after 48 hours). • Minimum 5-foot ***separation*** from the bottom of the BMP to the seasonal high groundwater elevation. • No known constraints that limit the ability to effectively use infiltration, such as those listed under "No Reliance on Infiltration" and "Implementation Considerations."
2. Partial Infiltration of the Water Quality Design Storm (Design infiltration capacity < WQ_V or WQ_F)	Selection of this strategy requires that all of the following conditions are met: • Design infiltration rate between 0.1 and 0.5 in/hr as calculated based on field data and conversion to design infiltration rate as described in Appendix **D**. • Complete drawdown of the design surface ponding within 48 hours (subsurface ponding may remain after 48 hours). • Minimum 3-foot separation from the bottom of the BMP to the seasonal high groundwater elevation. • No known constraints that limit the ability to effectively use infiltration, such as those listed under "No Reliance on Infiltration" and "Implementation Considerations."
3. No Reliance on Infiltration	This strategy must be selected if above strategies are not feasible, or site exhibits at least one of the limitations below: • Known contamination of groundwater or soil column that has the potential to migrate into groundwater. • Design infiltration rate less than 0.1 in/hr as calculated based on field data and the design infiltration rate calculations in Appendix **D**. • The groundwater separation is less than 3 feet from the bottom of the BMP, based on the seasonal high groundwater elevation. • Field or historical data suggests infiltration may be impracticable.

Compliance with this SWM standard requires that designers select the infiltration strategy corresponding to site conditions and infiltration feasibility, as they relate to the above applicability requirements. Selection of infiltration strategy #1 or #2, where applicable, requires the implementation of a BMP (or BMPs) that is capable of infiltrating the required infiltration volume. These BMPs may be used to meet or partially meet the Water Quality – Capture and Treat SWM standard. Additionally, compliance with the Infiltration SWM standard requires that infiltration BMPs are designed in accordance with the design criteria in Chapter 6 and the BMP fact sheets. If designers select Strategy #3, there is no minimum infiltration volume to be met, and designers must use other types of BMPs to meet water quality treatment and water quantity control requirements, as appropriate. Where the site infiltration rate exceeds 2.4 in/hr, designers may use infiltration for water quantity control but may not count infiltration toward water quality treatment (see also "Infiltration for Water Quantity Control" under the Implementation Considerations).

Infiltration BMPs shall also be designed to avoid classification as UIC systems, unless they serve only roof drainage (e.g., dry wells only receiving drainage from roof drains or downspouts). BMPs have the potential to be classified as UIC systems if they allow for direct injection of stormwater into groundwater without surface infiltration. As described in Appendix **C**, UIC systems serving non-roof areas require review and approval by DEQ. If a designer is proposing use of a UIC system serving other than roof drainage, a variance request is required to be submitted to the Port, demonstrating that a UIC system is the only option for stormwater management (see Chapter 3 for more information on variance requests). Port approval of the variance request is required before applying for DEQ approval.

4.3.3 Compliance Approach

Compliance with the Infiltration SWM standard requires selection of an infiltration strategy that maximizes infiltration based on project and site applicability considerations. A step-by-step process for selecting a site-appropriate strategy is provided below:

1. Request and review available historic data near the site, including soil analyses and groundwater elevation data, records of previous soil or groundwater contamination areas, and records or reports of previous infiltration attempts near the site. Review the applicability requirements for each infiltration strategy as well as the "Implementation Considerations" section of this SWM standard to determine if historic data presents any potential feasibility concerns for infiltration. Present findings to the Port to determine if infiltration should be ruled out (infiltration strategy #3) or if design should proceed with site-specific analyses.
2. Unless ruled out in the previous step, proceed with site-specific soil and groundwater analyses by a registered Oregon Professional Engineer (PE) or Professional Geologist to verify site conditions. Reference Appendix **D** for soil and groundwater testing guidance and design infiltration rate calculations.
3. Assess the applicability of each infiltration strategy based on comparing the applicability requirements to the results of the site-specific field analyses.
4. Select and design appropriate BMP(s) in accordance with the site-appropriate infiltration strategy and other related SWM standards as well as the design criteria within Chapter 6 and the BMP fact sheets.

4.3.4 Implementation Considerations

The following are the key considerations for incorporating infiltration into design and determining which implementation strategy is applicable to the project site.

4.3.4.1 Redevelopment Projects

Redevelopment projects that do not involve an increase in the impervious area from existing conditions are exempt from the Infiltration SWM standard. However, this does not preclude the use of infiltration facilities on these projects to meet applicable SWM standards, including Low-Impact Development (Section 4.2), Water Quantity Control (Section 4.4), and Water Quality – Capture and Treat (Section 4.5), provided that applicability requirements are met. Redevelopment projects that result in an increase in impervious area are not exempt and must select an appropriate infiltration strategy based on applicability, as is required for new development projects.

4.3.4.2 Infiltration Feasibility Screening Based on Historic Data

The Port's past experience with implementing infiltration facilities suggests that feasibility may be limited in some locations (particularly in portions of PDX) due to shallow seasonal high groundwater elevations. Before proceeding with site-specific testing, designers are encouraged to collect and review historic data associated with past soil and groundwater investigations and previously-implemented infiltration facilities in the vicinity of the project site, depending on availability. Designers should coordinate data collection with the Port, including resources such as the TRC, as well as past project and staff observations that may support a characterization of infiltration feasibility. If historic data suggest any of the following, designers are required to coordinate findings with the Port to determine if site-specific analyses are required or if the design should proceed with selecting infiltration strategy #3 (No Reliance on Infiltration):

- The seasonal high groundwater elevation in the vicinity of the project site is less than 3 feet from the surface.[12]
- Soil types are present that may not be conducive to infiltration (Natural Resources Conservation Service [NRCS][13] Hydrologic Soil Groups C or D; see Chapter 6 for a description of these soil groups).
- Historic project data indicates a poor record of performance by infiltration BMPs, or soils with poor infiltration characteristics that do not drain completely after storm events.
- Historic records suggest contamination of the soil column or groundwater in the vicinity of the site, with the potential for migration of contaminants.

4.3.4.3 Tributary Area Limitations

Based on past observations limiting applicability of infiltration, the Port does not recommend the design of infiltration facilities to act as regional BMPs serving multiple sites. See the BMP fact sheets for BMP-specific tributary area limitations.

4.3.4.4 Infiltration for Water Quantity Control

Infiltration BMPs may be designed to provide a water quantity control function, provided the proposed infiltration site is not known to exhibit any of the infiltration limitations identified under Strategy #3 in Table 4-1. Infiltration that is intended for quantity control purposes is allowed to have a design infiltration volume that exceeds the water quality design storm, provided the design surface ponding is able to drawdown within 48 hours. Infiltration for quantity control purposes is also permitted at sites where the design infiltration rate exceeds 2.4 inches per hour (in/hr). Under this scenario, BMP modifications or other forms of treatment would be necessary to meet the Water Quality – Capture and Treat SWM standard, due to a reduction in the level of treatment/removal of mobile pollutants by the soils underlying the infiltration BMP. Additionally, appropriate pretreatment or source control measures would need to be implemented upstream of the infiltration facility.

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[12] Designers may refer to the City draft "Depth to Seasonally High Water (Table)" in Appendix **J** for planning level groundwater depths, but are encouraged to seek out site-specific data where available.
[13] Formerly known as the U.S. Soil Conservation Service (SCS).

4.3.4.5 *Columbia South Shore Well Field Wellhead Protection Area*

Proposed infiltration facilities within the Columbia South Shore Well Field WHPA will require City of Portland Water Bureau review and approval. The City places restrictions on the use of infiltration BMPs within the WHPA to protect drinking water sources. In accordance with City restrictions, it is required that designers of projects within the WHPA coordinate with the City on acceptability of infiltration and on additional design requirements. If infiltration is not acceptable, designers must select infiltration strategy #3. Designers should also see the Source Controls SWM standard (Section 4.6) for additional WHPA development considerations and refer to Figure 4-1 for the location of the WHPA.

4.3.4.6 *Potential Pollutant Sources*

Runoff from areas that may have insufficient source controls to address pollutants of concern shall not be directed to infiltration facilities without first receiving treatment. Designers shall provide source controls and necessary pretreatment upstream prior to infiltration. Refer to the Source Control SWM standard for source control requirements.

4.3.4.7 *Areas Highly Susceptible to Erosion*

Erosion can cause the transport of sediments resulting in the potential to clog the infiltration BMP, which can reduce the effectiveness of the BMP and may require costly repairs to restore the BMP to function as designed. For this reason, infiltration practices shall only be used for managing runoff from stabilized sites, and should not be used for construction-phase sediment control. Additionally, developed sites with unstable soils and steep slopes may be highly susceptible to erosion and typically will require design measures to protect the intended design of the infiltration BMP, possibly including on-site erosion and sediment controls and extensive pretreatment (note that all infiltration BMPs require some form of pretreatment to preserve their long-term infiltration capacity). A geotechnical engineer should be consulted to determine if the site includes unstable or steep slopes or other conditions that are susceptible to erosion.

4.3.4.8 *Setbacks and Space Constraints*

At space-constrained sites, the extent to which infiltration facilities can be implemented on a particular site may be limited based on the required BMP footprint, design characteristics, and setbacks (see Chapter 6 and the BMP fact sheets for BMP-specific requirements). In cases where space is limited, designers are encouraged to consider implementing small-scale infiltration facilities to the maximum extent practicable and in accordance with the site-appropriate infiltration strategy.

4.4 Water Quantity Control

4.4.1 Introduction

The addition of impervious surfaces and compaction of pervious surfaces that occurs during the development process tends to increase the rate of stormwater runoff (e.g., peak flow) from a developed site, as well as create or contribute to flooding within the drainage system. The MS4 permit requires a reduction in the post-development stormwater runoff duration and rate of stormwater discharges "to minimize hydrological and water quality impacts from impervious surfaces."[14] The control of peak flow rate alone has been traditionally accomplished through the use of BMPs that retain or detain flow within a storage reservoir until it can be discharged through a flow restriction (e.g., orifice, weir, etc.) at a reduced flow rate. However, these controls may effectively prolong the duration of storm event discharges.

For the purposes of the DSM, the Port has adopted the City SWMM exemptions from peak flow control requirements for discharges to the Willamette River, Columbia River, and the Columbia Slough, based on their capacity to accept stormwater discharges without hydrological impacts. This approach is consistent with an MCDD request that the Port not restrict storm event discharges to the Columbia Slough, in the interest of reducing the duration of flow management following a storm event.

Although peak flows are not required to be restricted at outfalls, the Port has established water quantity control objectives to manage flooding issues within Port drainage systems. These objectives are intended to minimize the potential for interference with operations as well as protect Port infrastructure.

The Port has an existing hydrologic and hydraulic stormwater model at PDX that may be used to evaluate compliance with these objectives, for applicable projects at PDX. The Port does not currently have a model that establishes hydrologic and hydraulic conditions at T6.

4.4.2 Requirements

Designers of applicable projects at PDX are required to model the project design within the current PDX stormwater model and check that the minimum required water quantity control objectives are met. Designers of applicable projects at T6 are required to perform their own hydrologic and hydraulic analysis to demonstrate compliance with the below objectives.

The minimum required water quantity control objectives are as follows:

- 10-year, 24-hour storm event –Demonstrate that the maximum water surface elevations (MWSEs) do not exceed the elevation of any paved surfaces.
- 100-year, 24-hour storm event –Demonstrate that the MWSEs do not exceed the basement floor of buildings, in compliance with City freeboard requirements. See Appendix **C** for information on free board requirements within the regulations for flood hazard areas (floodplains).
- Design the drainage system (collection and conveyance) to comply with other ponding allowances identified in Chapter 5.
- Limit the duration of all surface ponding to a maximum period of 48 hours following a storm event.
- Additional project-specific flooding or flow-based water quantity control objectives, as established by the Port to minimize the potential for impacts to Port infrastructure or operations.

The Port will review the completed hydrologic and hydraulic analysis and report (Appendix **H**) to verify they adequately demonstrate compliance with water quantity control objectives.

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[14] MS4 permit A.4.f.i.2.

Additionally, the Port will also determine if additional project-specific water quantity control objectives may need to be established for the purpose of preserving drainage system capacity at critical infrastructure, minimizing ponding in critical operations areas, protecting the condition of Port infrastructure, and mitigating potential hazardous wildlife attractants. Project-specific water quantity control objectives may extend beyond flooding objectives, potentially including peak flow control requirements such as limiting post-development peak flow rates to pre-development flow rates for specified storm events. The Port also has the option to require that project designers assess potential solutions and/or incorporate measures to address existing flooding or capacity issues.

4.4.3 Compliance Approach

The following steps provide an approach for complying with the Water Quantity Control SWM standard:

1. Coordinate with the Port at the project kickoff meeting to confirm the initial set of project-specific water quantity control objectives, including the flooding objectives listed above, as well as potential additional objectives to address existing or anticipated future capacity or flooding issues.
2. For applicable projects at PDX, coordinate with the Port to obtain access to the current hydrologic and hydraulic model for the drainage basin corresponding to the project location. For applicable projects at T6, coordinate with the Port on the method to be used to perform the hydrologic and hydraulic analysis.
3. Perform hydrologic and hydraulic analysis of existing site and proposed development based on methodologies described in Chapter 5, accounting for LID and infiltration strategies.
4. Determine if MWSE flooding-based water quantity control objectives are met based on proposed design parameters. Compare pre-development flooding elevations to post-development flood elevations to assess the impact of development on flooding.
5. Develop conceptual water quantity control facilities needed to bring the design into compliance with water quantity control objectives, including detention (e.g., oversized pipes or BMPs providing storage capacity) paired with flow restrictions to reduce downstream flooding. Water quantity control facilities must be designed to minimize or mitigate for the attraction of hazardous wildlife, as described in the SWM standard for Hazardous Wildlife Attractants (Section 4.7).
6. Document the results of the analyses, including the effect of proposed development on the MWSEs, as well as potential measures to comply with water quantity control objectives, and submit to the Port to facilitate their review and discussion. Within the documentation, designers must characterize the post-development extent of flooding as well as any conveyance infrastructure capacity issues.
7. After Port review, confirm if any additional water quantity controls or objectives are required to address existing or future flooding.
8. Incorporate Port feedback into the design, and coordinate the design of water quantity or flood control BMPs with the criteria in Chapter 5, Chapter 6, BMP fact sheets, and SWM standards for Hazardous Wildlife Attractants (Section 4.7) and Water Quality – Capture and Treat (Section 4.5).

4.4.4 Implementation Considerations

Designers are required to perform the hydrologic and hydraulic analysis and develop controls to comply with this SWM standard unless otherwise exempted by the Port. This standard is driven by Port objectives to manage flooding and therefore project-specific exemptions may be granted at the Port's discretion based on knowledge of existing flooding conditions or capacity issues in the project area. Exemptions granted by the Port under this SWM standard do not imply exemption from flow controls that may be integral to compliance with other SWM standards, including Low-Impact Development (Section 4.2), Infiltration (Section 4.3), and Water Quality – Capture and Treat, (Section 4.5).

4.5 Water Quality – Capture and Treat

4.5.1 Introduction

Within developed areas, stormwater runoff has the potential to wash off and accumulate sediment, debris, or other pollutants from exposed materials, surfaces, and industrial activities. If not properly controlled or treated, these stormwater discharges have the potential to carry pollutants to downstream drainage systems and receiving waters. Stormwater runoff is most effectively managed for quality through a combination of Port operational and management strategies and procedures (e.g., spill response, pavement sweeping, etc.), structural source controls (e.g., containment berms), and structural water quality treatment BMPs (e.g., vegetated swales). The former two components are discussed in the SWM standard for Source Controls (Section 4.6). The latter component is addressed through the selection and design of site-appropriate structural water quality BMPs using the guidance and criteria in Chapter 6 and the BMP fact sheets.

The post-construction runoff control portion of the MS4 permit criteria requires that Port development and redevelopment projects incorporate measures to capture and treat 80 percent of the annual average runoff volume from new or redeveloped project sites.[15] Capture and treat strategies are traditionally aimed at routing a minimum volume or flow rate of site runoff through a water quality treatment BMP (volume or flow-based) to promote the settling of total suspended solids (TSS), debris, and pollutants that are sediment-bound (i.e., pollutants that are adsorbed to sediment). The Port performed an analysis of BMP capacity and its effect on percent capture, and used these results to establish minimum water quality BMP design capacities that would meet the 80 percent requirement, as described under "Requirements."

In addition to benefiting the environment and complying with MS4 permit requirements, the implementation of water quality capture and treat design criteria offers the following benefits to the Port:

- Prevents negative impacts that sedimentation can have on the function of existing stormwater BMPs, capacity of stormwater sewers, and capacity of natural channels.
- Reduces the frequency of sediment and debris removal and maintenance from facility pavement, sewers, ditches, sumps, drainage structures, and culverts.

[15] MS4 permit A.4.f.i.4.

In addition to MS4 permit minimum requirements for capture and treatment of sediment-bound pollutants, the Port may establish additional project-specific water quality treatment objectives to address other POCs as required for compliance with existing permits. Chapter 6 provides a recommended process for identifying POCs.

4.5.2 Requirements

To comply with the Water Quality – Capture and Treat SWM standard, applicable design projects must incorporate a water quality treatment BMP or set of BMPs that are designed to capture and treat the minimum required water quality volume or flow rate for the entire disturbance area. The minimum capacity varies between ***volume-based BMPs*** (e.g., infiltration trenches) and ***flow-based BMPs*** (e.g., vegetated filter strips). Volume-based BMPs provide treatment through extended detention times, allowing for pollutants to settle, adsorb to media, and be captured within the BMP. Flow-based BMPs provide treatment of stormwater as it flows through the BMP. For volume-based BMPs, the minimum capacity is defined as the water quality volume (WQ_v). For flow-based BMPs, the minimum capacity is defined as the water quality flow (WQ_F). Water quality BMP options are described in Chapter 6 and the BMP fact sheets, and each BMP is identified as either volume-based or flow-based, or a combination.

In the development of BMP capacity criteria, the Port separately analyzed the percentage of runoff captured by BMPs of various capacities under various conditions[16] using continuous, hydrologic simulation with historical rainfall data. Each analysis involved varying the capacity of a hypothetical BMP (based on design volume or flow rate) and allowing continuous runoff to either pass through (be captured by the BMP) or bypass the facility (when capacity is exceeded). For each BMP capacity analysis, the resulting volume of runoff being captured was compared to the total runoff volume over the rainfall period of record to estimate the long-term percentage of runoff captured and treated. The capture and treat estimates from the range of BMP analyses were compared to the MS4 permit requirement (80 percent capture and treat) to determine minimum BMP capacity criteria. Details of these water quality BMP capacity analyses and basis for the criteria selection are described in Appendix **L**. The resulting capacity criteria and methodologies for volume-based and flow-based BMPs are provided in the subsections below.

In addition to designing BMPs that meet the minimum MS4 permit capture and treat requirement, designers are responsible for designing BMPs that satisfy other Port water quality treatment objectives and POCs requiring treatment identified by the Port, as described in Chapter 6. Designers shall coordinate with the Port to determine project-specific water quality objectives.

4.5.2.1 Volume-Based BMPs

Volume-based water quality BMPs shall be sized to detain, at minimum, the WQ_V, which is the project-specific capacity required to capture and treat 80 percent of the annual average runoff volume from the project area. The WQ_V for a project shall be calculated using **Equation 4-1**, which is based on the project disturbance area, minimum water quality storm depth from the long-term rainfall analysis, and a project-specific volumetric runoff coefficient (see **Equation 4-3**).

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[16] Analyses for volume-based BMPs varied in BMP size (storage volume) and drawdown time. Analyses for flow-based BMPs varied in BMP size (flow capacity), times of concentration, and on-line vs. off-line conditions. For more information see Appendix **L**.

Equation 4-1: Water Quality Volume (WQ_V) Calculation

$$WQ_V = P_{WQV} \times R_V \times (A/12)$$

Where:
WQ_V = Water Quality Volume (in acre-feet)
P_{WQV} = Water Quality Storm Depth (in inches, from Table 4-2)
R_V = Volumetric Runoff Coefficient (dimensionless, from **Equation 4-3**)
A = Project Disturbance Area (in acres)

Table 4-2: Water Quality Storm Depth (P_{WQV})

Drawdown Time (hrs)	Water Quality Storm Depth, P_{WQV} (inches)
1	0.06
2	0.10
3	0.13
6	0.20
12	0.31
24	0.45
36	0.56
48	0.65
72[1]	0.82

[1] *In accordance with the Hazardous Wildlife Attractants SWM standard, BMP drawdown time at PDX must not exceed 48 hours for surface (aboveground) storage. Water may remain in subsurface (below the ground or media surface) storage after 48 hours*

Table 4-2 summarizes the required minimum water quality storm depths to meet the 80 percent capture and treat MS4 permit requirement, based on the Port's percent capture modeling analysis. The required minimum depths vary depending on the design drawdown time for the water quality BMP that is selected to meet this SWM standard. The drawdown time may refer to either surface or subsurface storage depending on the BMP design features. Please refer to Chapter 6 and the BMP fact sheets for BMP-specific drawdown time and storm depth selection requirements. Designers may want to consider designing water quality treatment BMPs or BMP systems with consideration for additional functions that may support compliance with other runoff control SWM standards, including Infiltration (Section 4.3) and Water Quantity Control, 4.4.

4.5.2.2 Flow-Based BMPs

Flow-based water quality BMPs shall be designed to receive and accommodate, at minimum, the WQ_F, which is the project-specific capacity required to capture and treat 80 percent of the annual average runoff volume from the disturbance area draining to the BMP. The WQ_F for a project shall be calculated using **Equation 4-2**, which is based on the rational method. The equation requires the project disturbance area, minimum water quality storm intensity from the long-term rainfall analysis (see Table 4-3), and a project-specific volumetric runoff coefficient (see **Equation 4-3**).

Equation 4-2: Water Quality Flow (WQ_F)

$$WQ_F = i_{WQF} \times A \times R_V$$

Where:
WQ_F = water quality flow (in cubic feet per second)
i_{WQF} = water quality storm Intensity (in inches/hour, from Table 4-3)
A = project disturbance area (in acres)
R_V = volumetric runoff coefficient (dimensionless, from **Equation 4-3**)

Water quality storm intensity values vary with estimated project time of concentration and also vary depending on whether the flow-based BMP is ***on-line*** or ***off-line***, as described in further detail in Chapter 6. Off-line flow-based BMPs are defined as those that are designed to receive only flows up to and including the WQ_F and the fraction of flow exceeding the WQ_F is bypassed around the BMP. All flows passing through an off-line BMP are assumed to receive 100 percent water quality treatment. On-line flow-based BMPs are defined as those designed to receive all flows from the primary conveyance serving the site, including storm events with flows exceeding the WQ_F, with no bypass or diversion of the WQ_F from larger storm flows. On-line BMPs are assumed to provide 100 percent treatment of small flows up to and including the WQ_F, but no treatment of any flows are assumed when flow rates exceed the WQ_F. For example, vegetated swales are not expected to provide any significant treatment once the flow depth exceeds the height of the vegetation or when the vegetation can no longer stand upright to provide ***filtration***. As such, on-line BMPs must be designed for a more intense storm (larger i_{WQF}), and therefore a larger design treatment rate (WQ_F), to achieve 80 percent capture and treat. Acceptable values of i_{WQF} for use in calculating WQ_F are summarized in Table 4-3.

Table 4-3 : Water Quality Storm Intensity (i_{WQF})

On-line or Off-line BMP	Time of Concentration, T_C[1] (minutes)	Water Quality Storm Intensity, i_{WQF} (in/hr)
On-line BMP	5 min. ≤ T_C < 10 min.	0.20
	10 min. ≤ T_C < 20 min.	0.17
	20 min. ≤ T_C < 30 min.	0.15
	30 min. ≤ T_C < 60 min.	0.14
	60 min. ≤ T_C	0.11
Off-line BMP	5 min. ≤ T_C < 10 min.	0.13
	10 min. ≤ T_C < 20 min.	0.10
	20 min. ≤ T_C < 30 min.	0.08
	30 min. ≤ T_C < 60 min.	0.07
	60 min. ≤ T_C	0.06

[1] *Time of concentration should be calculated in accordance with hydrologic methods selected through guidance within Chapter 5. For calculated times of concentration less than 5 minutes, apply the time of concentration for the range of 5 to 10 minutes.*

4.5.2.3 Volumetric Runoff Coefficient

The calculation of WQ_V and WQ_F, as appropriate, requires a project-specific volumetric runoff coefficient, R_V. The methodology for calculating this runoff coefficient is implicit to the long-term rainfall analysis performed by the Port for development of this DSM and the selection of the water quality design storm depth and intensity. Therefore, it is required that **Equation 4-3** alone be used to estimate a runoff coefficient, as opposed to selecting a runoff coefficient from an outside source or alternate method. The calculation of a project-specific R_V is a function of the imperviousness of the proposed project.

Equation 4-3: Volumetric Runoff Coefficient (R_V)

$$R_V = 0.82 \times IMP + 0.02$$

Where:
R_V = volumetric runoff coefficient (dimensionless)
IMP = imperviousness area fraction (impervious area/total area)

Pervious pavement that is designed to allow infiltration into the subsurface may be considered to be pervious area, and excluded from the imperviousness area fraction.

4.5.3 Compliance Approach

The following steps provide an approach for complying with the Water Quality Capture and Treat SWM standard:

1. Coordinate with the Port on site activities and POCs; determine appropriate treatment methods, as described in Chapter 6.
2. Calculate the project R_V, based on project impervious area.
3. For volume-based BMPs, calculate the WQ_V, as defined under “Requirements.”

4. For flow-based BMPs, calculate the WQ_F, as defined under “Requirements.”
5. Coordinate the BMP design with other treatment goals as determined by the Port in accordance with the BMP guidance and requirements in Chapter 6.
6. Coordinate with the Port on the potential use of existing or planned regional water quality treatment facilities to provide the required treatment capacity for the project’s pollutants of concern requiring water quality treatment.
7. If evaluation of new onsite treatment facilities is determined appropriate, use guidance from Chapter 6 and the BMP fact sheets and knowledge of the site to consider BMP layout and whether it is feasible to construct required controls on-site.
8. If space constraints do not allow an adequately-sized BMP to be constructed on the project site, coordinate with the Port to assess off-site mitigation options and requirements and whether they will need to be part of the project design.

Consider the implementation considerations below when implementing this procedure.

4.5.4 Implementation Considerations

The requirements of this SWM standard are applicable to all projects that are not currently served by a BMP meeting the requirements of this standard and meet the DSM applicability criteria defined in Chapter 1. As described in Chapter 1, maintenance and repair activities that do not result in additional hydrologic impacts and do not increase site impervious areas are exempt from DSM requirements.

The subsections below provide considerations for implementation of water quality treatment in the form of a regional control or off-site mitigation, as appropriate.

4.5.4.1 Use of Regional Controls

The Port’s overall stormwater management strategy includes the implementation of regional controls, where appropriate, to satisfy water quality treatment and water quantity control requirements for a variety of projects and Port initiatives. The Port may decide to design and construct regional controls to be managed as mitigation “banks” for development projects. Planning for regional controls allows the Port to consider facility-wide stormwater management needs in a comprehensive manner, as opposed to piecemeal project-specific solutions. Other benefits include the ability to take advantage of economies of scale as well as reserve available land and maximize its effective use for stormwater management. The PDX Stormwater Master Plan (2015) included the identification of specific regional solutions for a range of planned near-term and long-term development projects at the airport.

During the project planning phase, the Port will evaluate if a regional facility may be appropriate to meet or partially meet project-specific water quality treatment needs. This assessment may depend on the pollutants of concern requiring treatment, as identified by the Port (Chapter 6), as well as the type and available capacity of the regional BMP facility. The Port will notify designers in the project scope or at the project kickoff meeting if a regional BMP is planned to be used to serve the project. The Port will maintain a log documenting the portion of the regional facility that is dedicated to particular projects, and track the capacity remaining for future treatment needs.

In some cases, the Port may determine that treatment requirements for a particular project shall be addressed at a regional facility that has not yet been constructed. This circumstance may occur while the Port is in the process of implementing recommendations of the PDX Stormwater Master Plan. It may also occur in response to an unforeseen treatment requirement, or one that is unable to be implemented on the project site (through the off-site mitigation process, as discussed in the next section). In these cases, the Port will develop a schedule to meet the stormwater treatment requirements of the DSM on a project-by-project basis based on the Port's ability to design and fund regional infrastructure.

4.5.4.2 Off-Site Mitigation

The MS4 permit requires the implementation of "equivalent pollutant reduction measures" to meet, capture, and treat requirements when a project site has insufficient space or other constraints limiting on-site treatment. To address this requirement, the DSM allows for off-site mitigation, where treatment capacity that is not able to be provided on the project site is implemented at a location outside the project site. The off-site mitigation implementation process is described below:

1. Initiate Off-Site Mitigation (Designers) – When designers first identify site conditions that may make it impracticable to implement the required water quality treatment capacity on the project site, they shall notify the Port as soon as possible through the variance request process (Chapter 3). The variance request must document the site constraints limiting on-site treatment, demonstrate what treatment capacity can be provided on-site, and identify the remaining capacity that will need to be provided at a location outside the project site. The designer should also indicate what changes to the design may be required to allow the required treatment capacity to be met on the project site. The Port may approve the request, allowing off-site mitigation to proceed, or deny the request, directing the designer to implement an alternative design approach.
2. Select Off-Site Mitigation Location (Port) – Once the off-site mitigation process is initiated, the Port will select an appropriate off-site mitigation location. Off-site mitigation is required to occur within the same watershed (draining to the same receiving stream) as the original project. Off-site mitigation facilities shall be located in an area that receives drainage from a similar land use as the design project, and are required to comply with any applicable NPDES requirements for outfall discharges. The Port will consider project schedule and potential BMP locations, and will use this information to determine if there is an opportunity to address off-site mitigation needs within an existing or planned regional treatment facility (as described in the section above) or if a standalone off-site facility will need to be implemented to serve only the project.
3. Implement Off-Site Mitigation (Port or Designers) – Implementation of the off-site mitigation alternative may be performed by the Port or designers, depending on the option selected. Regional facilities will be implemented by the Port as described in the section above. If the need for a standalone off-site BMP is identified, the Port will determine if the project designers shall develop the off-site mitigation facility or if it shall be developed as a separate Port project.

4.6 Source Controls

4.6.1 Introduction

As stated within the Water Quality – Capture and Treat discussion (Section 4.5), procedures to manage the quality of stormwater include a combination of source controls and structural water quality treatment BMPs. Once pollutants from industrial activities have been exposed to stormwater, the effects of dilution can require the treatment of large volumes of water within structural water quality treatment BMPs. Source controls provide a first line of defense by managing the pollutant at the source before it has the opportunity to mix with stormwater. Depending on the project design and planned activities, source controls may be needed to supplement structural water quality treatment BMPs to facilitate compliance with a variety of water quality-related regulatory requirements.[17] Additionally, the implementation of source controls offers the following benefits to the Port:

- Reduces the risk of an accidental spill or release, which may entail costly spill response or cleanup activities, operational interruptions, and regulatory consequences.
- Protects downstream BMPs and treatment facilities from spills and releases that could compromise their operation and require maintenance or repairs.
- Enhances employee safety at the facility through plans that educate and prepare workers on standard procedures for hazardous material management.
- Reduces material costs.

Potential source controls may be classified under the following categories, each of which is described in further detail in the subsections below.

4.6.1.1 Operational Source Controls

Operational source controls include Port and tenant operational activities to minimize stormwater pollution that are integrated into daily facility operations. Operational source control activities are regularly performed by the Port and tenants in accordance with regulations, permits, and good housekeeping practices based on the industrial activity.

There are a variety of operational source control activities for industrial activities, including but not limited to the following:

- Operational procedures to limit excess use or exposure of materials that can become pollutants and reduce the potential for runoff.
- Inspection and maintenance of equipment, vehicles, and facilities to prevent potential leaks.
- Inventory tracking of stored materials and observation of loading/unloading activities to identify sources of leaks or spills.
- Spill response procedures, including the use of absorbent materials, barriers, or other spill response materials and contacting emergency spill responders to clean up spills before they reach stormwater.
- Employee training on pollution prevention and spill response.
- Placement of covers or tarps over temporary external material storage areas.
- Reduction in the application volume or timing of externally applied chemicals.
- Reduction in the amount of industrial materials that are stored on-site.

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[17] Where applicable, these may include but are not necessarily limited to the MS4 permit, industrial NPDES permits (1200-COLS, 1200-Z, and industrial deicing permit) and associated SWPCPs, SPCC regulations (40 CFR 112 EPA). Oregon Administrative Rule 340 Division 41 “Water Pollution State-Wide Water Quality Maintenance Plan; Beneficial Uses, Policies, Standards, and Treatment Criteria For Oregon”, City Code Chapter 17.39 “Storm System Discharges” and the WHPA.

- Use of industrial materials with lower toxicity or less potential to release pollutants.

4.6.1.2 Structural Source Controls

Structural source controls are permanent features that are designed to physically block pollutants from exposure to precipitation, or reduce the potential for runoff that has been exposed to pollutants to reach the drainage system and mix with stormwater. These features are typically incorporated into a project design, serving areas where there is potential for a spill, leak, or runoff of potential pollutants associated with industrial activities. Some structural source controls need to be implemented in conjunction with collection equipment or operations to collect industrial runoff that has been prevented from entering the storm sewer system (such as use of a vacuum truck, with subsequent appropriate disposal of collected material). Examples of structural source controls include:

- Drain covers or operable catch basin valves (to be closed during activities with the potential to produce runoff or spills).
- Secondary containment sumps, berms, containers, or double-walled tanks for material storage areas.
- Design of material storage or industrial activity areas to drain to sanitary sewer (if acceptable) or coordinate with other collection strategies that prevent drainage to stormwater collection systems.
- Construction of permanent roofs over material storage areas or indoor facilities for storage of materials.
- Emergency shut-offs, level alarms, monitors, leak detection systems, and other instrumentation and controls features to identify and minimize leaks and spills.

4.6.2 Requirements

Designers are required to implement structural source control measures into their project design in accordance with the requirements below, as well as any additional source controls identified by the Port or tenant as required to comply with permits and regulatory requirements. Designers are also required to design their project to facilitate Port or tenant operational source control activities identified by the Port or tenant. To comply with this SWM standard, designers must meet the source control requirements that are summarized in the sections below.

4.6.2.1 Activity-Specific Source Control Requirements

The City Source Control Manual (SCM) identifies specific source control measures for select industrial activities and potential pollutant sources. The Port requires that projects that include the following activities or pollutant sources implement source control measures in accordance with the requirements of the SCM:

- Solid waste storage areas, containers, and trash compactors
- Material transfer areas/loading docks
- Fuel dispensing facilities and surrounding traffic areas
- Aboveground storage of liquid materials, including tank farms
- Equipment and vehicle washing facilities
- Exterior storage and/or processing of bulk materials
- Covered and uncovered vehicle parking area
- Water reclaim and reuse systems

Project areas that include one or more of the above industrial activities and that discharge to the public sanitary sewers are required to submit planned source control measures to the City for review and formal approval. Initial coordination with the Port must occur prior to submitting to the City.

The following activities are also identified within the SCM but are excluded from the DSM as these activities are covered by Port processes or DSM requirements. If the project is planning on having the following activities or pollutants sources, designers are required to coordinate with the Port on required source controls.

- Site dewatering and discharges
- Motorized vehicle and equipment areas
- Soil, stormwater, and groundwater management for development on land with suspected or known contamination or adjacent to contaminated sites

4.6.2.2 Restrictions on Exposure of Select Building Materials

In addition to the activity-specific source control requirements, the Port prohibits the use of exposed galvanized materials in locations that may make contact with precipitation or stormwater and have the potential to contribute pollutants to stormwater runoff. These locations include stormwater conveyance infrastructure and BMPs, as well as external portions of structures or facilities that are exposed to precipitation or runoff. Galvanized materials that are painted and do not expose the galvanized surface to stormwater may be allowed. Designers shall coordinate with the Port early in the design process to determine if any of the proposed building materials have restrictions on installation locations or exposure.

4.6.2.3 Columbia South Shore Well Field WHPA Requirements

When developing within the WHPA, the designer must also comply with the standards for structural source controls within the *Columbia South Shore Well Field Wellhead Protection Manual* (Portland Water Bureau 2010). Figure 4-1 displays the WHPA as it is defined by the City. The designer is responsible for confirming applicability of WHPA requirements.

4.6.2.4 Additional Project-Specific Source Control Requirements

In addition to the requirements above, the Port has the option to require designers to incorporate additional source controls if necessary to address POCs and comply with applicable permits and regulatory requirements.

4.6.3 Compliance Approach

The following steps provide an approach to comply with the source control SWM standard.

1. Coordinate with the Port to assess the potential industrial activities for the project site and associated POCs. Also determine what operational source control activities are planned by the Port and if they will require special infrastructure or access provisions. The following must be determined:
    a. Location and nature of industrial activities planned for the site with the potential to create pollutant sources, including materials to be stored on-site as well as operations with the potential to result in leaks, spills, applied materials, or other industrial runoff.
    b. Applicability of City SCM based on the planned industrial activities.

   c. POCs that are potentially associated with planned activities as well as regulatory requirements that are applicable to the project site (as described in Chapter 6).
   d. Existing or potential new operational source control activities that may be appropriate for implementation at the project site by the Port or tenant, as applicable. These activities must be considered in the project design with consideration for supporting infrastructure that may be required and operational access to potential pollutant sources.
2. Determine if the activity requires one or more of the following:
   a. An activity-specific source control based on applicable SCM or Port source control requirements.
   b. Measures to reduce or eliminate exposure of restricted materials to stormwater.
   c. Specific source controls pertaining to the WHPA.
3. Determine the necessary source controls that will comply with requirements. If constructing within the WHPA, comply with requirements of the *Columbia South Shore Well Field Wellhead Protection Manual* (Portland Water Bureau 2010) in addition to the requirements of this SWM standard.
4. Discuss and coordinate with the Port to determine if any remaining POCs should be addressed through additional source controls or treatment.
5. Coordinate with the Port on planned source control measures prior to making formal submittals to the City for compliance with the SCM, where applicable.

4.6.4 Implementation Considerations

This SWM standard is applicable to all projects, but the detailed source control requirements will vary between projects depending on planned activities, POCs, regulatory requirements, and site location, as described under "Requirements." WHPA requirements are applicable for any proposed development located within the WHPA, as identified using the *Columbia South Shore Well Field Wellhead Protection Manual* (Portland Water Bureau 2010).

4.7 Hazardous Wildlife Attractants

4.7.1 Introduction

Compliance with DSM SWM standards may require the implementation of structural stormwater BMPs, conveyance, and other design features that manage stormwater runoff on-site, further referred to as stormwater management facilities. Stormwater management facilities with an exposed water surface are recognized by the FAA as one potential type of hazardous wildlife attractant, due to their tendency to attract wildlife, particularly birds that pose a high strike risk to aircraft (FAA 2013b).[18]

[18] According to the FAA, 97 percent of wildlife strikes are caused by birds.

Wildlife management requirements are defined by the PDX WHMP, ORS 836.623,[19] and within FAA AC 150/5200-33 (FAA 2007).[20] FAA wildlife management objectives are also reflected in FAA ACs covering airport design, operations, safety, and other requirements. These documents discourage the creation of new hazardous wildlife attractants within defined separation criteria from an airport. Additionally, these documents define mitigating design characteristics and features that make a new stormwater management facility or impoundment less attractive to wildlife. See Appendix **C** for more information on FAA ACs.

4.7.2 Requirements

The Hazardous Wildlife Attractants SWM standard requires that applicable project designs at DSM-applicable Port facilities comply with the requirements of the PDX WHMP, ORS 836.623,[21] and within FAA AC 150/5200-33. These documents establish key requirements that vary based on separation distances and defined zones around the airport, as described in Appendix **C** and summarized below.

The FAA defines a 10,000-foot separation distance[22] between an airport's air operations area and the nearest hazardous wildlife attractant, within which the creation of new hazardous wildlife attractants is discouraged and management of existing and potential hazards is required. The FAA also defines a 5-mile separation distance from the air operations area associated with protection of the airspace surrounding the airport. The PDX WHMP further divides up the 10,000-foot separation distance into three zones:

- Primary Zone – This zone is defined in the WHMP as a 300-foot buffer around the airfield perimeter fence and the runway protection zones at the end of each runway.
- Intermediate Zone – This zone is defined in the WHMP as all Port-owned airport land outside of the primary zone and within the FAA's 10,000-foot separation distance.
- Secondary Zone – This zone is defined by the remaining land within the 10,000-foot separation distance that is not included in the primary or intermediate zones. While the secondary zone is not under direct Port management, the Port has worked with the City to establish an airport planning district that allows the Port to complete screening of land use proposals for compatibility with aviation safety on non-Port properties within this zone.

For purposes of this SWM standard and to promote consistency with the WHMP, key wildlife requirements have been summarized based on applicability within each of the five wildlife zones defined above. The boundaries of these zones are illustrated for reference purposes on Figure 4-2**,** and the key requirements corresponding to wildlife management in each zone are summarized

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[19] ORS 836.623 "Local compatibility and safety requirements more stringent than state requirements; criteria; water impoundments; report to federal agency; application to certain activities," https://www.oregonlegislature.gov/bills_laws/lawsstatutes/2011ors836.html.
[20] Advisory Circular 150/5200-33B was in effect and 150/5200-33C was in draft form at the time of DSM release.
[21] ORS 836.623 "Local compatibility and safety requirements more stringent than state requirements; criteria; water impoundments; report to federal agency; application to certain activities," https://www.oregonlegislature.gov/bills_laws/lawsstatutes/2011ors836.html.
[22] For airports serving turbine-powered aircraft, such as PDX.

in Table 4-4. Designers are required to coordinate these requirements with the DSM design criteria for drainage systems (Chapter 5) and BMPs (Chapter 6 and the BMP fact sheets).

Designers are also required to discuss design characteristics for planned stormwater management facilities at the preliminary design milestone meeting, including proposed mitigating features. This will allow the Port to consider the potential wildlife strike risk associated with proposed facilities, through use of Port wildlife risk analysis tools as well as the *Bird Strike Risk Analysis and Stormwater Management Decision Tool* developed in 2014 for the Airport Cooperative Research Program (ACRP) Project 09-08. Based on their review, the Port may identify additional airport mitigation practices or BMP-specific design changes to be incorporated into the design before the final design milestone.

Table 4-4: Summary of Key Hazardous Wildlife Attractants Zone Requirements

Wildlife Zone	Design Requirements
Primary	• Meet requirements for the intermediate zone, in addition to those below • Vegetation selected for the design of BMPs must be standard airfield turf mix • Designers shall not use soils attractive to earth worms • City landscaping requirements are waived within the airfield; designers are required to follow applicable PDX landscape requirements[1]
Intermediate	• BMPs with an exposed water surface must be completely covered by a solid cover or bird balls to block visibility of the water surface (netting not permitted) • Stormwater collection systems must be designed to provide adequate surface drainage (FAA AC 150/5320-5D)[2] • Line areas where constant flow/wetness is expected with concrete/pavement (FAA AC 150/5200-33)[3] • BMPs with an exposed water surface must be designed such that they are steep-sided, riprap lined, narrow, and linearly shaped (FAA AC 150/5200-33) • BMPs with an exposed water surface must be designed, engineered, constructed, and maintained for a maximum 48–hour detention period after the design storm and remain completely dry between storms (FAA AC 150/5200-33)[4] • Must follow landscaping standards within the PDX WHMP, including the approved plant list and identification of plant variances for projects at PDX (PDX WHMP)[5] • Unless mitigated in accordance with above requirements, “No new water impoundments of one-quarter acre or larger are allowed within the approach corridor and within 5,000 feet from end of runway; or on land owned by the… airport sponsor (that) is necessary for airport operations.” (ORS 836.623)[6]
Secondary	Should not create any new attractants for wildlife species of concern or enhance any existing attractants (PDX WHMP)
Five-Mile	Designers may be required by the Port to incorporate mitigating features into the BMP design if the attractant could cause hazardous wildlife movement into or across the approach or departure airspace (FAA AC 150/5200-33)

1 *Intergovernmental Agreement for Natural Resources Related to the Airport Futures Project (2011). Available online at http://www.pdxairportfutures.com/Documents.aspx.*
2 *FAA AC 150/5320-5D, “Airport Drainage Design” (August 15, 2013).*
3 *FAA AC 150/5200-33, “Hazardous Wildlife Attractants On or Near Airports”. Advisory Circular 150/5200-33B was in effect and 150/5200-33C was in draft form at the time of Manual release*
4 *The 48-hour requirement is applicable for all BMPs and refers to ponding above the ground or media surface.*
5 *Portland International Airport Wildlife Hazard Management Plan (2009).*
6 *ORS 2011 Edition, Volume 17, Chapter 836, “836.623 Local compatibility and safety requirements more stringent than state requirements; criteria; water impoundments; report to federal agency; application to certain activities*

4.7.3 Compliance Approach

The following steps provide an approach for complying with the Hazardous Wildlife Attractants SWM standard:

1. Review Figure 4-2 and zone definitions to determine how the project site location relates to the defined hazardous wildlife attractant zones.
2. Review Table 4-4 to identify stormwater management requirements that should be incorporated within the identified zone.
3. Coordinate with the Port on proposed stormwater management facility design characteristics at the preliminary design milestone.
4. Incorporate all requirements and Port feedback into the project design.

4.7.4 Implementation Considerations

Applicability of hazardous wildlife attractant management requirements is dependent on the location of the project site relative to the zones defined under “Requirements.” Requirements pertaining to each of these zones are summarized in Table 4-4. The zones of interest are illustrated on Figure 4-2 and described further within Appendix **C**.

It is important to note that select portions of Port facilities other than PDX also fall within defined hazardous wildlife attractant zones. The above compliance approach must be followed for DSM-applicable projects at any applicable Port facility, to determine if any requirements of this SWM standard apply.

If the project site does not fall within any of the defined zones, then wildlife considerations do not need to be incorporated into the design of stormwater management facilities, unless otherwise specified by the Port.

4.8 Floodway and Natural Resource Protection

4.8.1 Requirements

The DSM requires that designers develop project concepts and design with a full understanding of the criteria, requirements, and limitations of regulations for floodway and natural resources protection. As part of this requirement, designers must site new and redevelopment projects to avoid applicable regulated and protected natural resources and observe applicable regulatory buffers to the extent possible. If designers determine that project objectives cannot be met without impacts to regulated areas, they shall coordinate with the Port as early as possible in the project to characterize the issue (at minimum, conflicts with these regulations must be identified by the preliminary design milestone meeting), and determine if an alternative design may facilitate avoidance of these areas. The Port will determine if permits and approvals for potential impacts will be sought and will provide direction to the designer regarding support needed for that process. Designers shall not proceed with design activities that include assumed impacts to regulated areas without Port approval. Should the Port decide to proceed with the permitting process, designers are required to proceed with the design in accordance with conditions of the permit or regulatory approval, including setbacks, design standards, and other applicable criteria.

For reference purposes, the list below identifies some of the local, regional, state, and federal regulations that are potentially applicable to floodway and natural resource protection at Port facilities:

- Floodway Protection Regulations:
  - Federal
    - Title 44 of the Code of Federal Regulations (CFR), "Emergency Management and Assistance" (e.g., Federal Emergency Management Agency [FEMA] requirements)
  - Regional
    - Metro Title 3, "Water Quality and Flood Management"
  - Local
    - City Code Chapter 24.50, "Flood Hazard Areas"
    - City Code Chapter 33.631, "Sites in Special Flood Hazard Areas"
- Natural Resource Protection Regulations:
  - Federal
    - Section 401 of the Clean Water Act (CWA)
    - Section 404 of the CWA
    - Section 10 of the Rivers and Harbors Act
    - Endangered Species Act
    - Magnuson-Stevens Fishery Conservation and Management Act
    - Migratory Bird Treaty Act
  - State
    - ORS 196.795-990, "Removal of Material; Filling" (Oregon's Removal-Fill Law)
  - Regional
    - Metro Title 3, "Water Quality and Flood Management"
  - Local
    - City Code Chapter 33.430, "Environmental Zones"
    - City Code Chapter 33.440, "Greenway Overlay Zones"

Please refer to Appendix **C** for more information on the above listed regulations. In addition, the following figures illustrate locations of some of the zones defined and protected by the above regulations:

- Figure 4-3: FEMA 100-Year Floodplain
- Figure 4-4: February 1996 Flood Inundation Areas
- Figure 4-5: Greenway Overlay Zones
- Figure 4-6: Environmental Overlay Zones

4.9 Erosion and Sediment Control

4.9.1 Requirements

The DSM requires that designers incorporate measures into their design to minimize the potential for sedimentation and erosion during the construction phase. Designers must comply fully with the City's erosion and sediment control requirements in City Code Title 10 (City of Portland 2009a) and their *Erosion and Sediment Control Manual* (City of Portland 2008a). On applicable projects, designers are also required to initiate the process for applying for a construction permit through DEQ.

All projects are required to have erosion and sediment control measures in place at the site prior to beginning any ground-disturbing activities, in accordance with City requirements and DEQ construction permit, if applicable. Proper maintenance of control measures, monitoring and recordkeeping must occur in compliance with City Code Title 10, Port construction specifications, and any applicable permit requirements. Designers are responsible for developing design documents that are consistent with these requirements, as well as incorporating the Port's technical specification "01 57 13 – Temporary Erosion, Sediment, and Pollution Control" (Port of Portland 2013c) into project design documents.

Designers of projects that meet applicable DEQ and/or City regulatory thresholds (Appendix **C**) are required to develop an ***Erosion, Sediment, and Pollutant Control Plan*** (ESPCP) that details erosion and sediment control practices and implementation of selected practices.[23] Sites that meet both applicability thresholds for the City and DEQ construction permit are encouraged to develop a single plan that meets requirements of both agencies. In general, the ESPCP should consist of narratives detailing the nature of the activity, activity schedule, site map, and drawings. The ESPCP, where applicable, is a required component of the SWM submittal for review by the Port, as described in Chapter 3. Once approved, the designer should coordinate with the Port on submittal of the ESPCP to the City and DEQ, as applicable. Additionally, designers must determine construction permit applicability based on the permit threshold, and coordinate with the Port to initiate the permit application process. For more information on construction permit applicability see Appendix **C**.

[23] The City calls this plan the "Erosion, Sediment, and Pollutant Control Plan" (ESPCP) where DEQ calls this plan "Erosion and Sediment Control Plan" (ESCP).

5 DRAINAGE SYSTEM DESIGN

5.1 Introduction

5.1.1 Objective

The objective of this chapter is to describe the primary design criteria for stormwater collection and conveyance facilities for new development and redevelopment sites at applicable Port facilities.

5.1.1 Chapter Contents

This chapter provides required design criteria and hydrologic and hydraulic methodologies for the design of drainage systems at applicable Port projects and facilities, including collection, conveyance, and flow control infrastructure. This chapter does not present design criteria or requirements related to water quality or quantity control BMPs or combined sewer overflow systems. Please refer to Chapter 4 for SWM standards, including BMP sizing requirements, and refer to Chapter 6 and the BMP fact sheets for specific selection and design criteria.

The drainage system design criteria included in this chapter are the minimum required for new and redevelopment sites at applicable Port facilities. The Port reserves the right to impose more restrictive criteria than those included in this DSM for selected areas based on the specific project, existing drainage system, and operational needs. Use of these design criteria does not relieve a designer from the responsibility to apply conservative and sound professional judgment when designing stormwater collection and conveyance facilities for Port projects.

Designers should consult the Port standard details when selecting stormwater collection and conveyance facilities.

5.1.2 Coordination with Other DSM Chapters and Appendices

Designers should be become familiar with the following DSM chapters and appendices, which may be applicable to specific projects:

- Chapter 1 – Facility and project applicability of DSM requirements.
- Chapter 3 – SWM submittal requirements, including the review and variance request process.
- Chapter 4 – SWM standards for quantity and quality control of stormwater runoff, including LID, Infiltration, peak flow control, and Water Quality – Capture and Treat SWM standards
- Chapter 6 and BMP Fact Sheets – Guidance on selecting, siting, and designing appropriate BMPs, which need to be coordinated with drainage system design
- Appendix **K**_– Drainage system design references are located in this appendix, including necessary equations, tables, exhibits, and procedures for design.

5.1.3 Regulatory Considerations

Depending on a project's location within the Port, various permits may be required. Regulatory context for stormwater management at Port facilities are described in Chapter 2. Designers are responsible for meeting Port design criteria provided within this chapter, as well as all applicable laws and regulations. In cases where there is a discrepancy between Port criteria and regulatory requirements, designers shall comply with the most stringent criteria and shall coordinate with the Port on any conflicts.

5.2 General Conveyance Requirements

This section provides general criteria for conveyance design for applicable projects and Port facilities.

5.2.1 Conveyance Capacity and Design Storms

Table 5-1 provides a summary of minimum design storm recurrence intervals for design of various conveyance facilities. In addition to the design storms listed, designers should design the conveyance such that the 25-year storm hydraulic grade line remains at least 6 inches below the lowest critical elevation identified within the system (e.g., ground surface or property where potential flooding could occur). Coordinate with the Port to determine critical elevations applicable to the design project.

The 100-year storm shall be used as the ponding check storm for surface flooding. See Section 5.2.4 for ponding allowance considerations.

Table 5-1: Summary of Design Storm Recurrence Intervals

Facility Type	Design Storm Recurrence Interval, years				
	PDX	Columbia South Shore Planning District	Marine Terminals and Industrial	Railroads	Floodplains
Airfields, runways, taxiways and aprons[1]	10	—	—	—	—
Street Gutter and Inlets[2]	10	10	10	10	100
Piped Flow with no surcharge[3]	10	25	10	10	100
Surface flows - open channels including swales, channel or ditch[4]	25	25	25	25	100
Culverts	25	25	25	25	100
Sags[5]	50	25/50	25/50	50	100
Gravity outfalls	25	25	25	25	100
Depressed areas which can only drain via conveyance such as underpasses	50[8]	25	10	10	100
Ponding Check Storm[6]	100	100	100	100	100

[1] The FAA AC 150/5320-5D Surface Drainage Design 150/5320-5D (FAA 2013b) requires a 5-year design storm event with no encroachment of runoff onto taxiway and runway pavements, including paved shoulders, which is less restrictive than the DSM. For compliance with the DSM, designers must comply with a minimum 10-year design storm for airports. Review the circular for additional ponding requirements on each type of airfield, runways, taxiways, and aprons for larger storm events.

[2] In areas where overflow of gutters and inlets could result in significant damage or pose a safety hazard, design inlets to capture stormwater flow resulting from the 100-year storm event.

[3] New storm sewer systems should be designed so that they have the capacity to convey the design storm without surcharging the pipe. The existing system they connect to may result in surcharge, which may be acceptable if the Port does not want to improve the entire system.

[4] *This is consistent with the City of Portland open channel design storm.*

[5] *A sag (or sump) is a low spot in the roadway profile, usually located in a transition point between two descending grades. Use 25-year if the sag is a localized low spot or sag within a project or 50-year if located on a main roadway. Coordinate with the Port to determine roadway classification.*

[6] *Downstream constraints and backwater conditions are to be considered when performing ponding checks. Ponding criteria for the ponding check storm are defined in Section 5.2.4.*

5.2.2 Design Storm Rainfall Distribution

For hydrologic analyses, use the NRCS Type 1A 24-hour storm distribution included in Exhibit 5-1. These distributions should be applied to the 24-hour rainfall depths for recurrence intervals corresponding to the design storms, as summarized in Table 5-2.

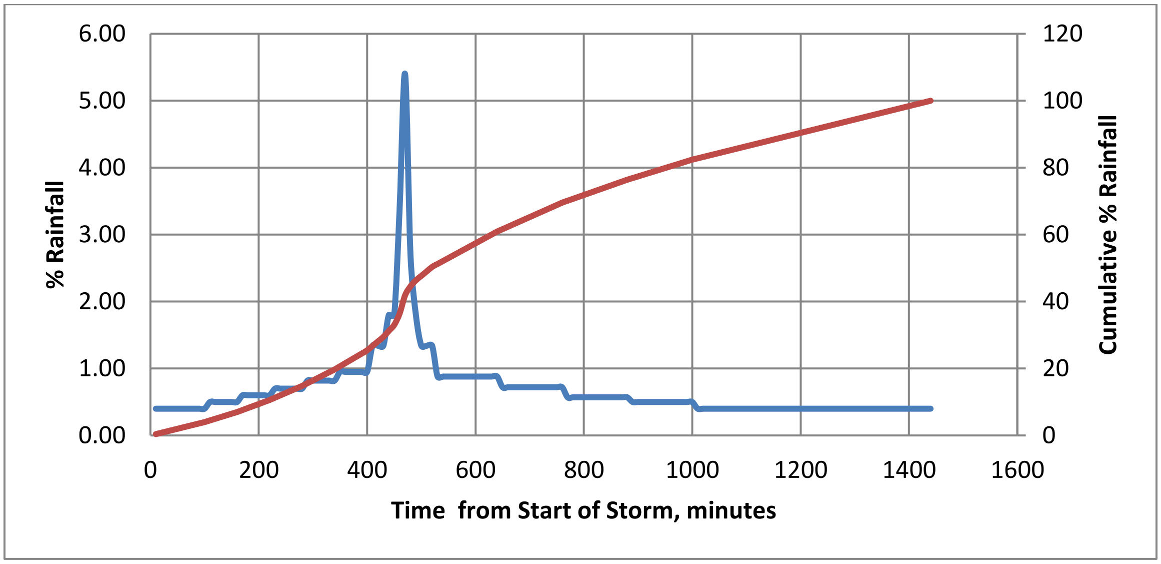

Exhibit 5-1: NRCS 24-Hours Type 1A Hyetograph

Table 5-2: 24-Hour Rainfall Depths at Portland International Airport (City of Portland 2008)

Recurrence Interval, Years	2	5	10	25	100
24-Hour Depth, Inches	2.4	2.9	3.4	3.9	4.4

5.2.3 Velocity and Slope Requirements

Storm drainage facilities shall be designed using Manning's equation to provide a minimum full flow velocity of 3 feet per second (ft/sec) to prevent sediment accumulation (e.g., promote self-cleaning). The minimum allowed Manning's roughness coefficient ("n") for conveyance pipe is 0.013, in accordance with the City's *Sewer and Drainage Facilities Design Manual* (City of Portland 2011).

Pipes not meeting the minimum velocity criteria are only allowed upon Port approval through a variance request (refer to Chapter 3 for a description of the variance process).

5.2.4 Ponding Allowance

Designers shall evaluate flooding during both the 10-year and ponding check (100-year) storms, as identified in Table 5-1. For these storm events, the designers must meet the following criteria:

- Conduct ponding check analyses accounting for downstream constraints (e.g., existing capacity issues, etc.) and boundary conditions, unless otherwise exempted by the Port. Coordinate with the Water Quantity Control SWM standard (Section 4.4).
- Freeboard between the storm flood elevation and the lowest floor (including basement) of structures shall meet the minimum criteria identified in Floodway and Natural Resource Protection SWM standard (Section 4.8).
- Limit ponding of stormwater to no more than 4 inches deep around the inlets on airport aprons.
- Temporary ponding (less than 48 hours) during the 10-year design storm is acceptable as long as the flood elevation remains below adjacent pavement. This is more restrictive than AC 150/5320-5D, which only requires that the center 50 percent of runways, taxiways, and helipad surfaces along the centerline remain free of standing water during the 10-year event.
- At PDX, all surface ponding must drain within 48 hours after the design storm, in accordance with AC 150/5200-33 (FAA 2007). Designers shall coordinate with the Port if it is not feasible to drawdown ponding in accordance with this requirement.
- Additional project-specific ponding criteria and objectives, as identified by the Port.
- New water impoundments of 1/4 acre or larger are not allowed within 5,000 feet of the end of an airport runway or on airport land that is necessary for airport operations, per ORS 836.623, unless the impoundment is mitigated for hazardous wildlife attractants as described in Section 4.7, Hazardous Wildlife Attractants SWM standard.

5.3 Hydrologic Analysis

This section provides required hydrologic methods and procedures to be used in support of designing drainage systems at applicable Port facilities. This section specifically provides acceptable analytical methods to estimate peak flows, volumes and time distributions of stormwater runoff. These parameters and their analysis are fundamental to the design of stormwater collection and conveyance facilities.

5.3.1 Acceptable Hydrologic Methods

Acceptable hydrologic methods are limited to:

- Santa Barbara Urban Hydrograph (SBUH)
- Soil Conservation Service (SCS)[24] Technical Release 55: Urban Hydrology for Small Watersheds
- SWMM-Based Stormwater Model (EPA SWMM-Runoff)
- Hydrologic Engineering Center- Hydrologic Modeling System (HEC-HMS)
- Rational Method (peak runoff flows only)

[24] The Soil Conservation Service (SCS) is the former name for the National Resource Conservation Service (NRCS), a federal agency within the United States Department of Agriculture.

Use of other hydrologic methods may be allowed upon Port approval through a variance request (see Chapter 3 for a description of the variance request process).

5.3.2 Methodology Limitations

Hydrologic models are only as good as the selection of the input parameters (e.g., drainage area, shape and orientation, ground cover, soil types, and slope) and limitations of the methodology assumptions. Designers should be aware of each method's limitations when considering applicability to a specific project. Table 5-3 provides a summary of each method's limitations and recommended applications. Designers must coordinate with the Port at the pre-design orientation meeting and subsequent design review meetings (as described in Chapter 3) to confirm that methods being considered are appropriate for the current project. The Port may also require designers of particular projects at PDX to use EPA SWMM runoff (hydrologic) methodology for consistency with the existing airport-wide stormwater model.

Table 5-3: Limitations and Recommended Application of Selected Hydrologic Methods (City of Portland 2011)

Method	Area Limitations	Application	Overbank Flood Protection	Extreme Flood Protection	Flow Control Storage Facilities	Outlet Structures	Diversion Structures	Gutter Flow and Inlets	Storm Sewers	Culverts < 50 acres	Culverts > 50 acres	Small Roadside Ditches	Open Channels	Energy Dissipation
SBUH	Less than 50 acres	SBUH generates a hydrograph that can be used to size flow control storage facilities. SBUH should not be used for conveyance design.			X	X	X							
SCS	Greater than 50 up to 1,000 acres	SCS can be used to estimate peak flows and hydrographs for all applications.	X		X	X	X		X[1]					X[1]
EPA SWMM-Runoff	Greater than 50 up to 1,000 acres	EPA SWMM-Runoff can be used to estimate peak flows and hydrographs for all applications.	X	X	X	X	X	X	X[1]	X	X[1]	X	X[1]	X
HEC-HMS	Greater than 50 up to 1,000 acres	HEC-HMS can be used to estimate peak flows and hydrographs for all applications.	X	X	X	X	X	X	X	X	X[1]	X	X[1]	X
Rational Method	Less than 50 acres	Calculates peak discharge but does not allow for development of hydrographs or estimates of runoff volume. Do not use for design of detention, retention, or other volume-based facilities. Time of concentration should be limited to no more than 30 minutes.						X	X	X		X	X	

[1] *Requires Port approval.*

5.3.4 Rational Method Parameters

Refer to Appendix **K** (Page K-1) for required parameters and Equation K-1 for the use of the Rational Method. Table K-1 and Table K-2 provide runoff coefficients, and Exhibit K-1 and Table K-3 provide intensity duration frequency (IDF) curve data. Refer to Chapter 6 for NRCS hydrologic soil group descriptions. Consult the project-specific geotechnical investigation report to determine site specific hydrologic soil group before selecting a runoff coefficient. Each drainage basin has its own Time of concentration (T_c). Use each drainage basin T_c to establish the duration of rainfall for that basin to estimate the average rainfall intensity (I) using the appropriate IDF curve (Table K-3 and Exhibit K-1).

5.3.5 Curve Numbers

For applicable hydrologic methods (e.g., SBUH, SCS, EPA-SWMM, and HEC-HMS), use the SCS curve numbers listed in Table K-4. When analyzing a drainage area with varying land uses, designers shall separately assess the curve numbers for each cover type and soil group and then calculate a composite curve number based on a weighted average of the curve numbers and their applicable areas.

5.3.6 Time of Concentration and Travel Time

Time of concentration (T_c) is the theoretical time for a drop of water to travel from the hydrologically most distant point in a drainage basin to the point of interest. In the Rational Method, T_c is used to determine the rainfall intensity using an IDF curve. In the other hydrological methods, T_c is used to develop either a unit or project specific hydrograph which can then be used to determine runoff.

Calculate T_c for the various flow regimes using the travel time equations in Appendix **K**, which are based on the methodology from NRCS.

Use Equation K-5 or Equation K-6 to determine the velocity of shallow concentrated flow (to be used in Equation K-3). Use Equation K-4 to calculate travel time in channels.

The minimum T_c allowed is 5.0 minutes (as specified in the SDFDM), with the following limitations:

- Overland sheet flow shall be limited to no more than 100 feet.
- Overland sheet flow transitions into shallow concentrated flow or open channel.
- Assumed T_c through lakes or wetlands is zero.

5.4 Hydraulic Analysis and Design

The sections below provide design criteria, tools, and methods for the hydraulic design of stormwater collection and conveyance infrastructure. Depending on the project, the Port may allow or require the use of hydraulic modeling software to perform hydraulic analyses and design calculations, as needed to account for drainage system flow conditions and constraints. Designers shall coordinate with the Port at the pre-design orientation meeting (as described in Chapter 3) to confirm that methods being considered are appropriate for the current site and project, as well as to understand potential drainage system boundary conditions to be considered in the design. The Port may also require that particular projects at PDX use stormwater modeling software that is consistent with the existing airport-wide stormwater model.

5.5 Pavement Drainage

Pavement drainage is affected by numerous characteristics, including roadway geometry and materials. Stormwater conveyance facilities should be designed to meet the requirements of Section 5.5.2.

The City of Portland's Bureau of Transportation must approve all pavement drainage designs for roads within City of Portland right-of-way.

For non-airfield pavement, the minimum roadway pavement cross slope (S_x) allowed is 2 percent (ODOT 2011a). Minimum and maximum transverse and longitudinal slopes for military airfields can be found in UFC 3-260-01 and for FAA facilities (including airfields) in AC 150/5300-13.

5.5.1 Curb and Gutter

Designers shall design curb and gutters using the rational method and the modified forms of Manning's equations in Appendix **K** (Page K-11), Equation K-9.

5.5.2 Inlet Design Parameters

Place inlets to limit spread to the maximum distance discussed below. Spread of stormwater onto Department of Defense or FAA airfields is not allowed. Space inlets on grade as required to collect stormwater runoff from the rainfall intensities listed in Table 5-1. At a minimum, inlets should be placed in the following locations, regardless of contributing drainage areas:

- At all low points in gutter grade;
- At all sag points in roadway profile;
- Immediately upstream of intersections, cross-walks, entrance and exit ramps, and breaks in medians;
- Immediately upstream and downstream of bridges;
- Immediately upstream of roadway super-elevation transitions (e.g., cross slope reversals); and
- Less than 400 feet from upstream and downstream inlets.

On roadways, place inlets to limit spread to 2 feet plus shoulder using the design storm listed in Table 5-1. Refer to AC 150/5320-5D for allowable spread on DOD and FAA airfields, runways, taxiways, and aprons. Bicycle lanes can be included in the spread calculation. Inlet design flow must meet or exceed gutter design flow. Limit bypass flow to less than 0.10 cubic feet per second (cfs) or space inlets so that spread is maximized to the limits discussed above.

Place one inlet at the lowest point in roadway profile sag, with flanking inlets on either side to capture stormwater if the main inlet becomes clogged. Do not include flanking inlets in design calculations.

Assume that the capacity of grate inlets and inlets in sags are decreased by 50 percent (e.g., a clogging factor of 50 percent) and curb/gutter grate inlets by 35 percent; for at grade inlets, assume 30 percent. Use the equations shown in Equation K-9 and procedures in Exhibit K-2 to design inlets.

5.6 Open Channel Design

The following provides general design criteria for conveyance in open channels and is based on the Oregon Department of Transportation's Hydraulics Manual, Chapter 8 (ODOT 2011a). This section does not provide water quality design criteria for vegetated swales, which will be wider to promote shallow flow and more densely vegetated to promote filtration and sedimentation. Please refer to Chapter 4, Chapter 6, and the BMP fact sheets for SWM standards and BMP design criteria pertinent to water quality. Designers should coordinate with Port wildlife management staff to confirm acceptability of open channels as it relates to potential hazardous wildlife attractants, including siting and design characteristics (please refer also to Chapter 4 SWM standard for Hazardous Wildlife Attractants and the Port's WHMP).

5.6.1 Design Parameters

Configurations of open channels are limited to trapezoidal, triangular, or rectangular shapes, unless otherwise directed by the Port. Design open channels to convey the 25-year storm and use the design procedures outlined in Chapter 8 of the Hydraulics Manual (ODOT 2011a). Refer to AC 5300/13A (FAA 2013c) for minimum grading requirements within safety areas on PDX and coordinate with the Port for maximum grading requirements to allow for mowing and other maintenance activities.

The minimum channel slope allowed is 0.003 feet/foot (0.3 percent) in order to minimize surface ponding and sediment accumulation. Provide a minimum freeboard of 12 inches above the design water surface elevation.

Shear stress on channel linings (e.g., grasses, riprap) can cause erosion. Use the procedures in Appendix **K** (Page K-18 and Page K-22 for vegetative and flexible linings) to design channel linings.

5.7 Culvert Design

The following section provides design criteria for culvert design and is based on Chapter 6 and Appendix **J** of the SDFDM and Appendix B of the City SWMM.

Coordinate with the Port, the Oregon Department of Fish and Wildlife and the National Oceanic and Atmospheric Administration - National Marine Fisheries Service to determine if fish passage must be provided for a specific project.

For culverts crossing railroads, use the equations and design criteria included in the American Railway Engineering and Maintenance-of-Way Association (AREMA) *Manual for Railway Engineering* (AREMA 2012). Unless otherwise directed by the Port, designers should use the most restrictive guidelines when designing culverts.

At a minimum, design culverts within safety areas on PDX to withstand a minimum load of 100-kips. Verify this is the correct loading for each airfield through consultation with AC 5300/13A and a project's location with the most recent version of the PDX airport layout plan. Further coordination with Port staff to determine future loading scenarios is recommended.

5.8 Culvert Design Procedures

Design culverts to convey the design storms listed in Table 5-1 with no surcharge (e.g., water surface elevation must be below the culvert crown) using Manning's Equation (Equation K-20). Overtopping of culverts during the 100-year storm is not allowed.

5.8.1 Culvert Design Parameters

Refer to the City's SDFDM and SWMM for specific design parameters such as minimum slope, geometry, minimum span, and end treatments.

The maximum velocity is 10 ft/sec to avoid abrasion of the inlet, streambed scour, and bank erosion. The minimum allowed culvert pipe size is 12 inches, but should not be less than the active channel width when placed in stream channels. Coordinate with the Port, Oregon Department of Fish and Wildlife, and NMFS to verify minimum culvert design parameters (e.g., width, minimum embedment depth, etc.). Use a Manning's "n" value of 0.013 for all culvert designs, regardless of material type.

Refer to Section 5.10.2 for approved culvert materials. Note cast-in-place concrete culverts are also allowed.

5.9 Outfall Design

The following section provides design criteria for outfall design and is based on Chapter 8 and Appendix J of the SDFDM and Appendix B of the City SWMM. Additionally, changes to existing outfalls or addition of new outfalls at receiving streams may require coordination with or modifications to existing industrial stormwater National Pollutant Discharge Elimination System permits. Coordinate outfall designs in advance with the Port.

This section does not address water quality design criteria. Refer to Chapter 4 for SWM standards requiring management of the quality and quantity of stormwater upstream of discharge points at outfalls.

5.9.1 Outfall Design Parameters

Design all outfalls to accommodate the peak flow for the design storm event listed in Table 5-1. Refer to Appendix **K** (Page K-18 and Page K-22) for limitations for specific channel lining materials. Design outfalls to minimize the distance from the bottom of the open channel to the bottom of the receiving waterway. Provide end treatment for all outfalls according to Chapter 8 of the SDFDM.

5.10 Storm Sewer Design

The following section provides design criteria for storm sewer design. Except as noted, this section is based on Chapter 6 of the SDFDM.

5.10.1 Storm Sewer Design Procedures

Refer to Table 5-1 for general conveyance design parameters including design storm events. Design all storm sewers such that all pipes are flowing full with open channel conditions. Use Manning's equation to determine the size, shape, and slope required to convey the peak design flow.

5.10.2 Design Parameters

Materials approved for storm sewer pipe are:

- Reinforced concrete (see Exhibit K-4 for fill height requirements).
- Non-reinforced concrete (see Exhibit K-4 for fill height requirements).
- Corrugated smooth wall polyethylene (see Exhibit K-5 for fill height requirements).
- Corrugated smooth wall polypropylene (see Exhibit K-7 and Exhibit K-8 for fill height requirements).
- Spiral wound steel reinforced polyethylene (see Exhibit K-6 for fill height requirements).
- Ductile iron.
- Smooth wall polyvinyl chloride (PVC) (see Exhibit K-10 for fill height requirements).

Maximum height of cover is greatest distance from top of pipe to finished grade. Minimum cover is defined as the least vertical distance between finished grade and the top of a pipe or subgrade and the top of pipe (if storm sewer is located within a paved area). Less cover is allowed if supported by design calculations demonstrating the pipe material can withstand the anticipated live and dead loading.

At PDX, follow the requirements and design procedures included in the FAA AC 150/5320-5D. Consult with the Port for loading scenarios for a specific project. At a minimum, storm sewers within safety areas on PDX must be able to withstand a minimum load of 100 kips. Verify this loading through consultation with AC 5300/13A and the project's location with the most recent version of the PDX airport layout plan. Confirm future loading scenarios with Port staff. For other areas within the Port, assume American Association of State Highway and Transportation Officials (AASHTO) H-20 loading as the design load.

5.10.3 At Railroads

Unless otherwise directed, design all storm drainage pipe crossings of railroads for a minimum of Cooper E-80 loading in accordance with the AREMA Manual (AREMA 2012). Place all storm sewer pipe under railway tracks or crossing railway rights-of-way within a leak-proof protective casing (carrier pipe), also designed for Cooper E-80 loading whose annular space is filled with sand. Protective casings may be omitted, upon the approval of the railroad, from secondary or industrial line tracks or for non-pressure sewer crossings where the selected pipe material can withstand the railway loading. Protective casings shall be a minimum of 1.8 times the size of the drain pipe (AREMA 2012). The allowable minimum cover, measured from the base of rail to the top of pipe, is 4.5 feet (AREMA 2012). For railroad underdrains and other high-load areas, pipes smaller than 12 inches are allowed. For specific pipe material characteristics for use in railroads, including on-grade crossings and yards, refer to the AREMA Manual (AREMA 2012).

5.11 Manhole and Structure Design

The following section provides design criteria for storm sewer and is based upon Chapter 4 of the SDFDM. Manholes are required in the following circumstances:

- At every grade break.
- At every change in alignment.
- At every change in pipe size.
- At every present or future junction with another sewer.

- At every abrupt elevation change.
- At a storm inlet where it connects to a sewer that is less than 24 inches.
- At a storm inlet where it connects to a combined sewer, and where escape of sewer gas and odor is possible.
- At all private connections where the diameter of the private line exceeds one half the diameter of the public sewer.
- At any location determined by the Port.
- At maximum distances from upstream and downstream manholes as specified below.

The minimum pipe size allowed is 12 inches, but 8 inches may be used for laterals and roof drains.

For specific pipe material characteristics, refer to the SDFDM.

5.11.1 At Marine Terminals

Consult with the Port for structure loading scenarios (based on wheel configuration and equipment weight). For high-load areas, pipes smaller than 12 inches are allowed.

5.11.2 Structure Spacing

Maximum manhole and structure spacing is dependent on pipe sizes.

- For 12- to 24-inch-diameter, maximum spacing is 300 feet.
- For 27- to 36-inch-diameter, maximum spacing is 400 feet.
- For 42-inch-diameter and larger, maximum spacing is 500 feet.

Refer to Chapter 4 of the SDFDM for additional manhole spacing requirements.

5.11.3 Structure Design Loads

Provide manholes in accordance the Port Standard Details and the Manufacturing Standards for Precast Concrete Products (City of Portland 2009b). Consult with the Port for structure loading scenarios (based on wheel configuration and aircraft weight).

At a minimum, manholes within safety areas on PDX must be able to withstand a minimum load of 100 kips. Verify this loading through consultation with AC 5300/13A and verification of a project's location with the most recent version of the PDX airport layout plan. Manholes subject to airport loading shall be designed using guidance in AC 150/5320-5C, Chapter 7 (FAA 2006).

At a minimum, design manholes and other structures located within 30 feet of railroad track center lines to meet Cooper E-80 loading or use AASHTO H-20 loading in all other areas. Refer to the AREMA Manual (AREMA 2012) for specific design criteria.

5.11.4 Structure Sizing

The minimum allowed manhole diameter is 48 inches and the maximum allowed is 96 inches. The minimum diameter for precast manholes, based on maximum pipe sizes and deflection angles between incoming and outgoing pipe, is provided in Table K-12, assuming no other pipe connection to the manhole. Maintain a minimum 1-foot vertical and horizontal separation between the outside edges of each core hole in the manhole wall that receives a pipe. Refer to Exhibit K-12 for new construction pipe geometry. This does not apply to setting a new manhole over an existing storm sewer (refer to Exhibit K-13). When the minimum clearance between new and existing storm sewer pipe cannot be maintained, provide an off-set detail similar to Exhibit K-14, including the dimensions (e.g., deflection angle and offset distance).

The maximum allowable manhole depth is 30 feet and the minimum is 4 feet from the top of channel bench to the top of manhole sections. When this depth is less than 4 feet, but no less than 3 feet, provide a flat top shallow-type manhole. The maximum pipe size for shallow manholes is 12 inches.

5.12 Pump Stations

Pump station design shall comply with applicable criteria in Section 5.11, including minimum pipe size, structure sizing criteria, and structural design load requirements. Designers of projects involving pump stations shall coordinate with the Port to determine additional design criteria that may be specifically applicable to pump stations.

6 BMP SELECTION, DESIGN, AND IMPLEMENTATION

6.1 Introduction

6.1.1 Objectives

The primary objectives of this chapter are as follows:

- Provide an overview of the function and application of Port-approved BMPs for treatment and runoff control of post-construction runoff.
- Provide BMP design criteria that are generally applicable to BMPs.
- Provide guidance on the selection, design and implementation of stormwater quality and flow control BMPs.
- Provide an overview of the structure for 14 BMP fact sheets that describes design criteria specifically applicable to the individual BMP types. The BMP fact sheets also provide non-mandatory guidance on the siting, design and operation and maintenance of 14 types of BMPs.

6.1.2 Chapter Contents

This chapter provides information related to the selection, design, and implementation of stormwater management water quality and flow control BMPs. The following topics are addressed in this chapter:

- Introduction to DSM BMPs: Describes the types of BMPs included in the DSM, such as functions, mechanisms, typical applications, and means of BMP acquisition and design.
- BMP Selection Process: Presents a step-wise process for selecting site-appropriate and project-specific BMPs based on compliance with the DSM Stormwater Management Standards and the pollutants of concern. The BMP selection process is coordinated with the DSM compliance process described in Chapter 3.
- BMP Design Requirements and Considerations: Describes requirements for BMP features, siting, O&M, and other aspects to be incorporated into the design.
- Additional BMP Resources: Describes the format of the BMP fact sheets provided in the DSM and provides other industry BMP resources that may be useful to designers.

For Port development and redevelopment projects where the DSM is applicable (as defined in Chapter 1 under Project Applicability, the Port may ask the designer to select and design structural stormwater BMPs to meet the requirements of this DSM. Implementation of the BMPs supports the Port's overall project strategy for complying with the Port's MS4 permit and with applicable Port and tenant-held Industrial NPDES permits. BMPs that provide treatment of pollutants will often be needed to meet the SWM standards for Water Quality – Capture and Treat and Source Control, described in Chapter 4. BMPs that manage volume, flow rates, and flow duration in runoff from a project site may be needed to meet SWM standards for Water Quantity Control and Infiltration as described in Chapter 4. BMPs should be selected to meet the specific stormwater management requirements applicable to the project, including those from the DSM and applicable water resource regulations, while considering identified constraints and conditions of the site. This chapter provides guidance for the selection and design of BMPs implemented on Port properties.

For projects on properties owned and operated by the Port, the Port will lead evaluation of overall permit compliance needs and runoff management needs in the project planning phase, prior to design. That evaluation will result in the definition of the pollutants of concern requiring water quality treatment and any project-specific runoff management criteria, such as maximum flood elevations. That information will be communicated from the Port to the project designer through a scope-of-work and/or planning level documentation associated with the stormwater management approach (refer to Section 6.3.1.1 for a summary of potential Port POCs as well as the process for identifying pollutants of concern requiring water quality treatment). Designers will be required to apply the SWM standards and design criteria in this DSM to the project specific information to select, size, and design the BMP system.

For projects on Port properties leased to tenants where tenants are implementing development projects, the tenants will be responsible for providing their BMP designers with sufficient information to allow for the selection and design of BMPs that comply with the Port's MS4 permit requirements. The Port has the authority to review, approve, or reject the proposed BMPs to ensure compliance with the Port's MS4 permit requirements.

The BMPs included in this chapter and in the 14 BMP fact sheets were selected based on their relevance to the pollutants and flow control measures most applicable to the Port. The Port encourages use of these BMPs to meet the DSM requirements, but also allows flexibility for the proposal of alternative measures. The Port has reviewed and approved use of the BMP types listed in the DSM for the purposes of achieving compliance with MS4 permit requirements. Designers who follow the design criteria for the BMPs presented in this chapter and in the BMP fact sheets will need to submit basic documentation on the applicability of the BMPs toward the project to the Port, as part of the SWM submittal and review process described in Chapter 3. Designers who propose to use criteria that vary from the DSM design criteria or designers who propose to use BMPs not included in the BMP fact sheets will be required to submit a variance request that provides more detailed documentation on the proposed deviations from the DSM, as described in Chapter 3. Proposed BMPs that are not within the DSM must be certified under the Washington State Department of Ecology Technology Assessment Protocol program or an equivalent review system approved by the Port. The variance request is subject to Port approval.

Occasionally, particularly where compliance with industrial NPDES permit requirements is concerned, treatment processes that are more advanced than the BMPs described in this chapter and in the BMP fact sheets may be required to obtain effective treatment and produce the needed effluent quality to meet Industrial NPDES permit parameter benchmarks. Circumstances that may affect the applicability of the BMPs presented in the DSM to meet Industrial NPDES permit requirements include, but are not limited to:

- High influent pollutant concentrations
  - Stormwater with high potential to be contaminated from large chemical spills where potential application of source controls (Section 4.6, Source Controls) still results in pollutant types and concentrations that differ from typical urban stormwater runoff
  - Stormwater containing quantities of pavement deicers and/or aircraft deicers[25]

[25] The Port operates a deicer management system to meet the requirements of its individual deicing NPDES Permit (Permit No. 101647, expires May 31, 2014) which regulates anti-icing and deicing

  - Runoff from areas where exposure of operations or structures to precipitation and runoff has the potential to release unusually high concentrations of pollutants
- Stringent effluent limitations or Industrial NPDES permit benchmarks
  - Stormwater subject to effluent limits or benchmarks that are lower than is technically feasible to achieve using standard passive stormwater BMPs.

Guidance for selection of more advanced treatment processes involving these conditions is beyond the scope of this DSM. Designers should coordinate with the Port if it is anticipated that these conditions exist.

The water quality BMPs presented in this chapter are primarily applicable to the treatment of runoff from development or redevelopment project sites subject to MS4 permit post-construction requirements, as described in Chapter 1. For purposes of compliance with MS4 permit requirements, the BMPs are to be sized based on the land area disturbed by the project after accounting for utilization of LID strategies that can reduce the disturbed area footprint, as described in the Chapter 4 SWM standard for Water Quality – Capture and Treat. The Port may incorporate LID measures at the planning level, as well as source controls, into the overall compliance strategy. Source controls, as introduced in the Chapter 4 Source Controls SWM standard, are permanent structures, operational activities, or source reduction approaches that aim to prevent runoff pollution by reducing the potential for contact between the pollutant source and stormwater runoff.

6.1.3 Coordination with Other DSM Chapters and Appendices

- Chapter 3 – Guidance for the executing the overall DSM compliance process, including preparation of a development project-specific stormwater management approach that complies with the requirements of the DSM, as well as guidance for coordinating with the Port and meeting the requirements of the SWM submittal.
- Chapter 4 – SWM standards describing the minimum requirement for siting and sizing of BMPs, including LID, infiltration, water quantity control, water quality treatment, source control, hazardous wildlife management, natural resource protection, and erosion and sediment control. Chapter 4 also includes applicability considerations for each SWM standard. Application of the SWM standards to the project provides the basis for determining the minimum size criteria for the BMPs.
- Chapter 5 – Criteria, guidance, and methodologies for the design of drainage systems, including collection systems, conveyance, and outfalls, which should be coordinated with the design of BMPs.
- BMP Fact Sheets – BMP-specific planning-level applicability considerations and detailed design criteria for the 14 types of BMPs introduced in this chapter.
- BMP Capital Cost Estimation Methods (Appendix **N**) – Planning level comparison of BMP capital construction costs.
- BMP Operations and Maintenance Level of Effort (Appendix **O**) – Planning level comparison of the estimated number of hours required for annual O&M for each BMP type.

activities. If projects result in new deicing areas, additional deicing activities or changes to deicing locations, potential BMPs or controls should be coordinated through the Port with consideration of the existing deicer management system.

- Sustainability Considerations for BMPs (Appendix **P**) – Considerations for sustainability in the selection, design, and implementation of stormwater management BMPs.

6.2 Introduction to DSM BMPs

As previously described, the DSM includes a series of 14 BMP fact sheets describing various BMPs that may be used to meet the water quality treatment and flow control requirements of the DSM. Most of the fact sheets focus on a particular type of BMP and potential variations in the design of that BMP, although several fact sheets include a group of BMP types that may share a particular characteristic. Each fact sheet provides specific design criteria, information to support BMP selection, and guidance for BMP design, construction, operation, and maintenance.

The BMPs included in the DSM differ in a variety of ways, including applications, functions provided, and design approaches. The specific characteristics of individual BMPs are important to consider in the BMP selection process, as described in Section 6.3. This section provides an overview of the range of BMP types included in the DSM. Major variations are introduced in the sections below and further details are provided in individual BMP fact sheets. Table 6-1 provides a summary of the BMPs included in the DSM, including the fact sheets where they are defined, and how the BMP may be categorized based on various topics detailed in the sections below. Additionally, each of these BMPs has varying design considerations and requirements, which are summarized in Section 6.4 and the BMP fact sheets.

Table 6-1: Summary of BMPs Included in the DSM

BMP Type	BMP Fact Sheet	Primary BMP Function[1]	Green Infrastructure Classification	Capture and Treat[2] Design Capacity Basis	Primary Mechanism	Physical Mechanisms	Target Pollutants	Biological Mechanisms	Target Pollutants	Chemical Mechanisms	Target Pollutants
Dry Extended Detention Basin	FS1: Dry Extended Detention Basin	Water quality & flow control	N	Volume-based	Detention/Retention	Settling	Fine sediment, oil and grease	N/A[3]	N/A	N/A	Fine sediment, nutrients
Retention Basin Wetland Basin Pocket Wetland	FS2: Wet Basin	Water quality & flow control	N	Volume-based	Detention/Retention	Settling	Fine sediment, oil and grease, pathogens	Microbial Activity, Plant Uptake and Storage	Metals, nutrients, organics, bacteria	Coagulation, Flocculation	Fine sediment, metals associated with fine sediment, nutrients
Subsurface Flow Wetland	FS3: Subsurface Flow Wetland	Water quality	Y	Volume-based, flow based, or a combination	Detention/Retention	Settling, Size Separation and Exclusion	Fine sediment, pathogens	Microbial Activity, Plant Uptake and Storage	Metals, nutrients, organics	Chemical Sorption, Ion Exchange	Metals, nutrients, organics
Bioretention area with and without underdrain	FS4: Bioretention	Water quality & flow control	Y	Volume-based	Filtration/Biofiltration	Physical Sorption, Settling, Size Separation and Exclusion	Nutrients, metals, petroleum hydrocarbons, coarse and fine sediment, oil and grease, pathogens	Microbial Activity, Plant Uptake and Storage	Metals, nutrients, organics	N/A	N/A
Infiltration Trench	FS5: Infiltration Trench	Flow control	Y	Volume-based	Infiltration	Size Separation and Exclusion	Coarse sediment	Microbial Activity	N/A	Chemical Sorption	Metals, nutrients, organics
Vegetated Swale with and without underdrain	FS6: Vegetated Swale	Water quality treatment	Y	Flow-based	Filtration/Biofiltration	Settling, Size Separation and Exclusion	Coarse sediment, fine sediment, oil and grease	Microbial Activity, Plant Uptake and Storage	Metals, nutrients, organics	N/A	N/A
Vegetated Filter Strip	FS7: Vegetated Filter Strip	Water quality & flow control	Y	Flow-based	Filtration/ Biofiltration	Settling, Size Separation and Exclusion	Coarse sediment, fine sediment, oil and grease	Microbial Activity, Plant Uptake and Storage	Metals, nutrients, organics	Chemical Sorption	Metals, nutrients, organics
Surface, perimeter and underground media filters, with various media including sand and granulated activated carbon, with and without underdrain	FS8: Media Filter	Water quality treatment	Y or N	Volume-based	Filtration/Biofiltration	Size Separation and Exclusion, Physical Sorption	Coarse sediment, pathogens	N/A	N/A	Ion Exchange, Chemical Sorption	Metals, nutrients
Infiltration Vault, Tank, Chamber	FS9: Underground Stormwater Control Facilities (USCF)	Flow control	Y	Volume-based	Infiltration	Size Separation and Exclusion	Nutrients, metals, petroleum hydrocarbons, coarse sediment	Microbial Activity	N/A	Chemical Sorption	Metals, nutrients, organics

BMP Type	BMP Fact Sheet	Primary BMP Function[1]	Green Infrastructure Classification	Capture and Treat[2] Design Capacity Basis	Primary Mechanism	Physical Mechanisms	Target Pollutants	Biological Mechanisms	Target Pollutants	Chemical Mechanisms	Target Pollutants
Detention Vault, Tank, Structural Detention	FS9: USCF	Flow control	N	Volume-based	Detention/Retention	Settling	Fine sediment, oil and grease	N/A	N/A	N/A	N/A
Wet Vault, Tank	FS9: USCF	Water quality treatment	N	Volume-based	Detention/Retention	Settling	Fine sediment, oil and grease	N/A	N/A	Coagulation, Flocculation	Fine sediment, nutrients
Pervious Pavement with and without underdrain	FS10: Pervious Pavement	Flow control	Y	Volume-based	Infiltration	Size Separation and Exclusion, Physical Sorption	Coarse sediment, oil and grease, pathogens	N/A	N/A	Chemical Sorption	Metals, organics
Planter Box Filters	FS11: Building BMPs[4]	Water quality treatment	Y	Volume-based, flow based, or a combination	Filtration/ Biofiltration	Size Separation and Exclusion	Coarse sediment	Microbial Activity, Plant Uptake and Storage	Metals, nutrients, organic pollutants	Chemical Sorption	Metals, nutrients, organics
Green Roofs	FS11: Building BMPs	Flow control	Y	Volume-based	Filtration/ Biofiltration	Physical Sorption	Nutrients, metals	Plant Uptake and Storage	Metals, nutrients, organics	Chemical Sorption	Metals, nutrients, organics
Cisterns	FS11: Building BMPs	Flow control	Y	Volume-based	Storage	N/A	N/A	N/A	N/A	N/A	N/A
Dry Well	FS11: Building BMPs	Flow control	Y	Volume-based	Infiltration	Size Separation and Exclusion	Coarse sediment	N/A	N/A	Chemical Sorption	Metals, nutrients, organics
Cartridge Filter Vaults	FS12: Cartridge Filter[5]	Water quality treatment	N	Flow-based	Filtration/ Biofiltration	Physical Sorption, Size Separation and Exclusion	Coarse sediment	N/A	N/A	Ion Exchange, Chemical Sorption	Metals, nutrients, organics
Oil/Water Separators	FS13: Oil/Water Separator[5]	Pretreatment	N	Flow-based	Gravity Separation	Density Separation	Coarse sediment, oil and grease, petroleum hydrocarbons	N/A	N/A	N/A	N/A
Hydrodynamic Separators	FS14: Hydrodynamic Separator[5]	Pretreatment	N	Flow-based	Hydrodynamic Separation	Settling, Size Separation and Exclusion	Coarse sediment, fine sediment, oil and grease	N/A	N/A	N/A	N/A

Notes:
[1] *Identifies the primary function of the BMP. Secondary functions are provided in the BMP fact sheets.*
[2] *Refers to the basis of design capacity according to Section 4.5, Water Quality – Capture and Treat.*
[3] *N/A, where it appears, means that the treatment mechanism is Not Applicable. The treatment mechanism may occur in the BMP, but to an incidental degree.*
[4] *BMPs in the Building BMPs fact sheet are typically applicable to building roofs rather than land surface developments. Treatment processes for these BMPs are not comparable to other BMPs that treat runoff from a wide range of impervious surfaces, which generally have higher pollutant concentrations than roofs.*
[5] *The treatment processes employed by proprietary BMPs should be confirmed by the manufacturer.*

6.2.1 Basic BMP Functions

The structural BMPs described in this chapter are water quality treatment and flow control facilities that require engineering analysis as part of the BMP design process. Structural BMPs employ various water quality treatment and flow control mechanisms and should be selected and designed based on the specific functions they provide relative to a project's stormwater management requirements. Many of the individual BMPs described in the BMP fact sheets provide some level of both water quality treatment and flow control, although some BMPs are focused more on one function than the other. This is evident on the BMP fact sheets through the identification of primary and secondary functions.

6.2.1.1 Water Quality Treatment

BMPs that provide water quality treatment are intended to reduce the influent pollutant concentration and mass loading prior to discharge to surface waters or infiltration to groundwater. These BMPs employ various treatment mechanisms to reduce the concentration and mass loading of pollutants in stormwater runoff, including the following:

- Physical Mechanisms – Physical mechanisms include gravity separation (i.e., settling), exclusion and filtration/physical adsorption. These mechanisms typically target larger particles (such as TSS) and those pollutants which sorb to such particles (such as sediment-bound nutrients, metals, and organic compounds);
- Biological Mechanisms – Biological mechanisms are those caused by the presence or functions of biota in the BMP. These mechanisms may include protozoal predation (i.e., in biofilms that may be formed in filter-based BMPs), bacterial degradation or transformation of target pollutants, such as nutrients, or certain metals and organics, to render them less mobile and/or harmful, and plant uptake (phytoaccumulation); and
- Chemical Mechanisms – Chemical mechanisms involve transformations at the molecular level. Such mechanisms may include ion exchange, chemical sorption and natural coagulation/flocculation, resulting in chemical transformation of pollutants (e.g., such as changes in pollutant speciation that render the pollutant more amenable to treatment) and/or subsequent physical treatment mechanisms (i.e., settling of target pollutants due to flocculation).

BMPs typically employ mechanisms that provide treatment as stormwater flows through the unit. BMPs (and BMP components) may be selected based on associated unit processes which have been identified as effective at removing or aiding in the removal of targeted pollutants. For an individual development project, the required stormwater management system could consist of a single BMP unit process or a series of unit processes strung together in a treatment train. A treatment train can be an appropriate design choice if the train offers an improved ability to target individual pollutants, provide greater overall effectiveness, result in a better fit to the available space, or result in a lower overall treatment cost.

A summary of the physical, biological, and/or chemical treatment mechanisms utilized by various BMPs is provided in Table 6-1. Details on the listed BMPs are included in the attached BMP fact sheets, including design features needed to obtain the desired performance for each BMP type.

Following treatment, BMPs may discharge stormwater to surface receiving waters or alternatively may be designed to promote infiltration of treated stormwater directly into the soil. Infiltration BMPs may be designed to provide only minimal treatment prior to infiltration, as treatment of stormwater can occur in soil through a variety of processes. Depending on the geochemical and biological properties of soils beneath the infiltration BMP, both particulate and dissolved pollutants in infiltrated stormwater can be treated in the upper soil layers prior to reaching the groundwater table.

The majority of BMPs in this chapter and in the BMP fact sheet target the removal of sediment from runoff. Removal of sediment can also result in the removal of pollutants from the water column that are attached to sediment such as heavy metals and organic compounds. Other BMPs can be designed to target removal of non-sediment-bound pollutants such as dissolved inorganics or organics through mechanisms other than TSS removal.

6.2.2 Flow Control BMPs

6.2.2.1 Peak Flow Control

Stormwater BMPs that provide peak flow control are designed to manage the flow of water such that the peak flow rate of the BMP discharge is reduced from the peak rate of the inflow. Controlling peak flow rates often involves matching post-development peak flows to predevelopment conditions. The mechanism for peak flow control may involve including a flow restriction at the BMP outlet combined with providing storage capacity to detain incoming stormwater until it can be discharged at a reduced flow rate.

Although the Port has not established specific peak flow control requirements to limit discharges to receiving waters, peak flow control may be necessary to meet the Port's objectives for controlling on-site flooding within Port facilities, as described in Section 4.4, Water Quantity Control SWM standard. Additionally, the Port has the option to establish specific peak flow control requirements on a project-specific basis, as determined to be necessary to address site-specific capacity or flooding issues. Requirements may vary by project depending on the point of discharge and receiving drainage system.

BMPs designed primarily for water quality treatment may also provide some peak flow attenuation for small and frequently occurring storms; however, since those BMPs are primarily designed for water quality treatment, they may not provide the full level of peak flow control that is required to meet the standards. Designers must verify that BMPs and BMP ***treatment trains*** that serve the dual purpose of water quality and flow control meet the requirements for both.

6.2.2.2 Flow Control to Manage Treatment Effectiveness

Aside from controlling flow rates to meet the DSM standards, designers may also choose to control flow rates into water quality treatment BMPs to increase the BMP's effectiveness in removing pollutants. For example, sub-surface flow wetland performance may be improved if flows are managed to achieve relatively consistent influent flows and pollutant loadings.

6.2.2.3 Volume Reduction

Stormwater BMPs may reduce the volume of runoff from the development site that is discharged to surface waters through infiltration, evapotranspiration, and/or rainwater harvesting. Volume reduction has many benefits, both in terms of hydrology and pollution control. Volume reduction helps to mimic the predevelopment hydrologic condition, which minimizes the effects of stream channel hydromodification. From a pollution perspective, decreased runoff volume achieved through infiltration to the soils generally translates to decreased pollutant loads to surface waters for nearly all pollutants. Volume reduction has economic benefits, including potential reductions in detention storage requirements for minor and major events, reduced extent and sizing of conveyance infrastructure, and cost reductions associated with addressing channel stability issues.

Infiltration BMPs are widely used for volume reduction. They are designed to create conditions where the majority of stormwater infiltrates into the soil beneath the facility. BMPs that reduce volume through infiltration, if appropriate for the site, may help to meet Chapter 4 requirements for a site-specific infiltration strategy (Section 4.3, Infiltration). For any BMPs where infiltration is utilized, the potential negative effects of routing runoff with high pollutant concentrations to groundwater should be considered. The ability of the soil to treat the pollutants should be considered. The potential for “short-circuiting” of infiltrated runoff to perforated soil drains or poor condition stormwater infrastructure that might allow inflow should be carefully considered. See implementation considerations under Section 4.3, Infiltration, including a discussion about infiltration feasibility at PDX.

The most substantial volume reductions are generally associated with BMPs that have well-drained sub-soils and allow infiltration to deeper soil strata and eventually groundwater. BMPs can also be designed with underdrains, which provide a means of conveying to the surface waters the portion of flow that cannot infiltrate because of low soil permeability. BMPs designed with underdrains generally have a lower potential for significant volume reduction because some portion of the flow still discharges to the surface waters via the underdrain connection. However, some water percolates into the native soils below the underdrain system and some water is retained as soil moisture. An underdrain located in a raised position above the bottom of the subsurface storage layer in the BMP enhances the potential for infiltration to occur compared to a system designed with the underdrain located at the bottom of the BMP. Soil moisture held within the root zone of the BMP eventually evaporates or is taken up by vegetation. Runoff that drains from BMP soils via gravity to the underdrain system behaves like interflow from a hydrologic perspective, with a delayed response that reduces peak rates. Although the runoff collected in the underdrain system is ultimately discharged to the stormwater drainage system or receiving waters, on the time scale of a storm event, there may be volume reduction benefits. Therefore, depending on site conditions (primarily soil type), infiltration BMPs may be designed to fully or partially infiltrate the water quality design volume. Refer to Section 4.3, Infiltration, for additional implementation considerations and site-appropriate infiltration strategy requirements.

BMPs designed for temporary detention of water can promote evapotranspiration or provide a source for beneficial use (e.g., for irrigation or equipment wash water). Evapotranspiration BMPs typically detain runoff in ponds above vegetated areas. Although the effects of evapotranspiration are inconsequential for a discrete storm event, on an annual basis, volume reduction due to evapotranspiration for vegetated BMPs can be an important component of the water budget. Seasonal changes in weather and vegetation, however, make for inconsistent evapotranspiration rates. Between storm events, evapotranspiration lowers soil moisture content and permanent pool storage (where applicable), providing additional storage capacity for subsequent events.

BMPs for “stormwater capture and beneficial use” store runoff in vessels such as underground tanks and vaults or above ground cisterns. The water can then be used indoors (such as for toilet flushing, although additional treatment would be required for indoor use to meet potable water standards) or outdoors for vehicle/equipment washing or landscape irrigation. To glean the full benefits of volume reduction from rainwater harvesting, water demand must exist during the rainy season. The water demand, availability of water, and storage volume should be analyzed to find the optimal cost point.

Other surface BMPs may also provide volume reduction through a combination of infiltration and evapotranspiration or evaporation. The volume reduction provided by a particular BMP type depends on site-specific conditions and BMP design features, such as storage volumes, surface areas, and soil amendments.

BMPs that promote infiltration could result in volume reductions for flood storage. These volume reductions are most pronounced for frequently occurring events, but even in a major event, some reduction in downstream the flood storage can be achieved if volume-reduction BMPs are widely used on a site.

6.2.2.4 Flow Duration Control

Flow duration control BMPs are designed to maintain the magnitude and duration of post-project flows to match pre-project conditions for the range of geomorphically significant flows. The BMPs achieve this through infiltration and/or use of specialized detention and discharge structures to meter flows at a rate below the flow that produces the critical shear stress and initiates receiving channel bed movement.

6.2.3 Water Quality Treatment and Flow Control Mechanisms

The BMPs included in this chapter may be categorized according to their primary treatment or flow control mechanisms. The main categories are infiltration, detention/retention, and filtration/***biofiltration*** practices, which are described in further detail in the following sections.

6.2.3.1 Infiltration BMPs

Infiltration refers to the downward movement of rainfall and surface runoff into existing native soils and the groundwater table via percolation through soil pore spaces. Infiltration can provide multiple water quality and quantity control benefits, including pollutant removal, volume reduction, peak flow control, and flow duration control. From a water quality perspective, infiltration BMPs take advantage of filtration and adsorption of pollutants to soil particles, as well as biological activity within the soils to remove pollutants as water passes through the soil profile. Typically infiltration BMPs are designed to intentionally promote conditions that increase the volume of stormwater that infiltrates. Conditions that can limit the application of infiltration BMPs include:

- Concern for extended surface ponding of water such that it creates a wildlife attractant for the airport (may change over time if soils become clogged)
- Poorly drained soils that may lead to slow infiltration and increase the likelihood of long-term clogging
- Shallow groundwater
- Existing soil or groundwater contamination
- Pollutant concentrations in the runoff entering the BMP that are greater than what is expected from typical urban runoff
- Where the separation distance between infiltrated water and perforated sub-drains is less than 5 feet, such that there is potential for short-circuiting and insufficient filtration through the underlying soils.

- Proximity to structures, drinking water wells, steep slopes, or other landscape features that could be disturbed by infiltrated water

See Section 4.3, Infiltration and Section 6.3.6 for additional information about procedures for assessing infiltration constraints at Port facilities, particularly at PDX. Use of Infiltration BMPs, especially in poorly draining areas, should be applied only after careful consideration. Note that there may be infiltration constraints at PDX primarily due to a shallow depth to groundwater. Infiltration BMPs may be feasible at other Port facilities, including T6, where there are numerous infiltration-based BMPs already implemented. The Port will make an assessment about the feasibility for infiltration at Port facilities on a site-specific basis. If the Port determines that infiltration could be feasible, site-specific infiltration testing shall proceed to verify infiltration feasibility and to determine design infiltration rates required to size the BMP.

6.2.3.2 Detention/Retention BMPs

Detention refers to the temporary storage of stormwater, with release of the stormwater to surface waters at a specific design rate over a period of time, generally ranging from hours to days after the end of the rainfall event. Detention BMPs can be used to provide pollutant removal through settling of suspended solids, peak flow control, and flow duration control. The full volume of stormwater that enters the facility is eventually released, so this type of BMP generally provides minimal volume reduction. There may be some volume reduction from incidental infiltration, if the facility is unlined, and evapotranspiration if the facility is vegetated and exposed to the atmosphere. The primary water quality treatment mechanism for detention facilities is settling.

Retention BMPs refer to BMPs which have a permanent wet pool as part of their design. Retention BMPs are designed to promote sufficient infiltration and evaporation such that there is no outflow to surface waters up to the design event for structure. Emergency overflows for flows above the design storm event are typically installed. Retention BMPs (e.g., wet ponds and pocket wetlands) may also provide pollutant reduction through sedimentation and biological treatment processes. Biological treatment mechanisms include plant uptake and microbial transformation of pollutants. The extent of biological treatment from microbial transformation can be highly variable and depends upon the ambient and process conditions (e.g., temperature, detention time, presence of nutrients, presence of carbon sources, etc.), and the affinity of the pollutant to be treated by biological processes. Uptake through vegetation can be seasonal, therefore harvesting and appropriate disposal may be required to remove the pollutants in the plant material and avoid re-release of pollutants as plants break down. Removal of sediment may also be required to take the settled pollutants out of the system.

6.2.3.3 Filtration/Biofiltration BMPs

Filtration refers to the physical and chemical removal of pollutants as stormwater percolates through pore spaces, typically in an engineered media. Filtration provides water quality benefits by removing pollutants, and can provide some peak flow control benefits for smaller storms by attenuating flows. Where filtration BMPs promote ponding water, minor evaporation-driven volume reduction can also occur. Filtration BMP engineered media may include sand, perlite, zeolite, compost/other organic material, activated carbon or a combination of media to remove sediment and a variety of dissolved and sediment-bound pollutants from stormwater. Pollutant removal can occur from the following mechanisms as stormwater passes through the media:

- Filtration of particulates

- Adsorption of dissolved organic and inorganic substances
- Ion exchange of dissolved metals

Filtration systems can be configured in the form of horizontal beds, trenches, or in proprietary devices such as cartridge systems in underground vaults or catch basins (see Section 6.2.5.2 for a discussion of proprietary devices).

In comparison to filtration BMPs, biofiltration BMPs incorporate vegetation and engineered soil media which supports plants. These BMPs may provide additional pollutant removal mechanisms beyond those available in unvegetated filtration BMPs, although pollutant removals due to vegetation are not well defined and have the potential to be relatively small. These additional mechanisms include plant uptake and enhanced bacteriological treatment provided by the biological community present in the rhizosphere (root zone). These BMPs are typically unlined, so they can also provide volume reduction through infiltration (depending on soil conditions) and evapotranspiration. Biofiltration BMPs require slow treatment flows and limited ponding depth to avoid damage to vegetation.

6.2.4 BMP Application Areas

6.2.4.1 Land Surface BMPs

Many of the BMPs at Port facilities will be associated with construction of impervious areas not related to the construction of buildings. This type of construction requires collection and treatment of runoff from the land surface.

6.2.4.2 Building BMPs

Building BMPs include a variety of engineered devices that are intended to provide water quality treatment and/or volume reduction of roof drainage. These BMPs are designed to be built on or directly adjacent to buildings, and are typically compact, lined (unless designed for infiltration), and include engineering considerations appropriate for structures. In the case of stormwater harvesting and use, cisterns may be built adjacent to the building, but additional conveyance and pumping infrastructure along with treatment systems (e.g., disinfection) may be required depending on the ultimate use.

6.2.5 BMP Design and Acquisition Sources

6.2.5.1 Engineered BMPs

Many of the BMPs in this DSM will require project-specific design of the core BMP elements, including the physical containment structure, flow conveyance structures, and elements such as media and vegetation that are essential to the core water quality treatment. Engineered BMPs may use vendor-provided components, but the core elements are designed specifically for the project by the designer.

6.2.5.2 Proprietary BMPs

Proprietary BMPs are a broad class of manufactured commercial devices that can provide a variety of stormwater management functions depending on the design and application. For a BMP to be categorized as a proprietary BMP, the core stormwater management element or structure needs to be supplied by a manufacturer. The vendor typically performs an initial BMP customization based on project and site-specific information supplied by the project designer, and may provide supporting design documentation such as drawings and technical specifications. The vendor also typically provides detailed documentation of selection, sizing, and maintenance requirements. It is the responsibility of the project designer to review this information for appropriateness and incorporate it into the overall project design, including coordination of the BMP design with site features, conveyance and utilities, and other BMPs in the treatment train. Structures, earthwork, and underdrain systems associated with the proprietary BMPs typically require project-specific engineering.

The specific functions performed by each proprietary BMP vary depending on the vendor, and some BMPs may perform multiple functions for water quality treatment and/or flow control. Some proprietary devices employ patented technologies. The proprietary water quality treatment BMPs described in this DSM include those that employ separation or filtration mechanisms. These can be particularly useful for providing stormwater treatment in space-limited applications and/or for pretreatment prior to discharge to a downstream BMP. These are typically applicable for the removal of larger solids, sediment, or petroleum products, depending on the type of BMP. Some specialized devices remove dissolved and particulate metals as well as organics through the use of specialized filtration media. Other BMPs may offer flow control functions, either as a stand-alone function or in combination with water quality treatment mechanisms.

Mechanical separation proprietary BMPs are underground structures with internal components that direct stormwater flows such that pollutants may be physically removed based on their mass and density. Hydrodynamic separators, which can only be used for pretreatment, use gravity or centrifugal separation to separate coarse sediment and the pollutants absorbed to it, as well as floatables, such as trash and oil, from stormwater runoff. Oil/water separators allow oil to rise to the surface of the water. Oil/water separators are appropriate as pretreatment facilities and should be located as close to the source of petroleum as possible. While many oil/water separators can be purchased from vendors as proprietary devices, oil/water separators that treat large flow rates may need to be custom engineered.

Filtration structure (or media filter) proprietary BMPs utilize an engineered media mix in underground vaults, manholes, or catch basins to remove a variety of targeted pollutants from stormwater runoff. Cartridge filter manufacturers often provide an array of media types designed to target specific pollutants and particle size ranges. These may include media that target solids, such as perlite, or media mixes that target both dissolved and non-dissolved constituents, such as compost, zeolite, activated carbon, and iron-infused polymers, among others.

Flow control proprietary BMPs are provided in the form of underground structures that include a flow restriction at the outlet (e.g., an orifice or weir) to detain flows temporarily until they can be discharged. The structure capacity may be provided in the form of a large vault, oversized buried pipe, or other buried tanks or chambers, and may be made of concrete, plastic, fiberglass, or other materials. These structures may be modular or expandable to adapt to site-specific storage capacity requirements. Depending on the vendor, these BMPs may be closed systems or may be open at the bottom to allow stormwater to infiltrate into the ground or filter through a media to an underdrain before discharging. Some vendors that provide water quality treatment BMPs may also offer flow control chambers for larger storm flows that bypass the primary treatment element. Designers should coordinate with the Port for acceptable vendors and/or models for proprietary devices. For example, acceptable devices may be listed in categories such as sediment pretreatment, oil treatment, suspended solids treatment, dissolved metals treatment, and phosphorus treatment. Use of proprietary BMPs not on the Port's list requires explicit Port approval.

6.3 BMP Selection Process

An overview of the BMP selection process is provided in this section. This process is considered part of the overall DSM Compliance Process discussed in Chapter 3. Guidance for a step-wise process for selecting site-appropriate and project-specific BMPs is provided in the sections below, in accordance with the following steps:

Step 1: Review Overall Stormwater Management Approach

Step 2: Investigate Site-Specific Conditions and Constraints

Step 3: Determine Needed BMP Functions and Basis-of-Design

Step 4: Determine Performance Requirements

Step 5: Develop a BMP Selection Strategy

Step 6: Identify Potentially Applicable BMPs

Step 7: Consider Potential BMP Configurations

Step 8: Perform Alternatives Analysis

Step 9: Select Site-Appropriate and Project-Specific BMPs

6.3.1 Step 1: Review Overall Stormwater Management Approach

As described in Chapter 3 and in the introduction of this chapter, project designers will coordinate with the Port in development of an overall stormwater management approach aimed at achieving compliance with regulatory requirements and Port operational needs. As part of that strategy, the Port may provide designers with results of analysis conducted in the planning phases, including, but not limited to, the following:

- Identify activities as the development site that may result in pollutants
- Identify POCs that require BMPs
- Provide information on means by which designers need to modify BMP system sizing or design to meet regulatory permit requirements beyond the MS4 permit that typically drives BMP function and design
- Suggest potential sites for the BMPs
- Define needs for integrating the BMPs required for the development project into existing BMPs, including regional treatment facilities at the Port sites
- Indicate LID measures that have been considered or integrated into the project concept as well as providing direction on additional LID measures
- Identify source controls that may affect BMP design
- Define potential limitations based on flood elevations

The information provided by the Port may vary by project. Individual scopes of work provided by the Port or tenants to designers may request that designers assist in developing this information to varying degrees. Upon receipt of the information, designers should use the guidance and standards provided in Chapter 4 to identify the project-specific stormwater management requirements that must be fulfilled by the BMP(s).

For cases where the development or redevelopment project is on Port land leased by a tenant, the tenant may provide details on the approach directly to designers with whom they are contracted. The tenants shall coordinate with the Port on aspects of the approach related to compliance with the Port's MS4 permit.

6.3.1.1 Assess the Pollutants of Concern Requiring Water Quality Treatment

The type, size, and capabilities of required water quality treatment BMPs are determined in part by the pollutants that require treatment. The Water Quality – Capture and Treat SWM standard in Chapter 4 requires that project designers implement BMPs to capture and treat 80 percent of a post-construction site's average annual stormwater runoff for sediment-bound pollutants (as sized for the WQ_V or WQ_F). In addition to this requirement, the Port may require designers to provide treatment for additional pollutants as needed to comply with water quality regulatory requirements that are applicable to the project area, including industrial permits, total maximum daily loads (TMDLs), and 303(d) lists. Although the "potential pollutants of concern (POCs)" (potential POCs) listed in these regulatory documents will require consideration on each project, not all will require treatment. This section provides an overview of the process for identifying the "pollutants of concern (POCs) requiring water quality treatment" from the initial list of potential POCs.

Table 6-2 provides a list of the potential POCs that require consideration on projects, based on pollutants listed in applicable regulatory documents. The Port or tenant holding applicable permits will refine this initial list with consideration for ongoing facility water quality initiatives, including other programs or evaluations that are in place to address the pollutants outside of the project design (such as Port Stormwater Management Plan initiatives). The Port or tenant, as applicable, will also consider if any of the pollutants are already addressed by existing facility BMPs or operational source control activities (for example, the PDX Deicer Management System). Additionally, the Port or tenant will consider which of the remaining potential POCs are likely to be associated with the completed project, including the project site, planned industrial activities, or exposed materials. Pollutants that are not associated with the project or are not expected to be present at levels that have a reasonable potential to exceed regulatory limits will be removed from the list. Additional pollutants that have a potential to be present in site runoff may be added to the list at the discretion of the Port or tenant. The Port or tenant will also consider whether the remaining POCs are best managed through source control or treatment approaches (Section 4.6, Source Controls).

The Port or tenant will provide designers with the initial project-specific list of POCs requiring water quality treatment, and designers are required to select appropriate BMPs to address these POCs. When considering BMPs for the POCs, designers may need to be aware of the following:

- Activities occurring in the development area and whether the runoff from the development area is likely to contain additional pollutants that may affect BMP performance
- Whether the POCs might be present in concentrations greater than those expected from typical urban runoff

- Benchmarks in Industrial NPDES permits for POCs that may affect the sizing and selection of the BMPs

The designer is responsible for developing BMPs to address all of the POCs requiring water quality treatment, and discussing these with the Port at the preliminary design meeting. In the SWM submittal (as described in Chapter 3), the designer shall document the pollutants to be treated, pollutants that may pass through BMPs with no treatment or limited treatment, measures taken to avoid negative impacts of stormwater constituents on BMP performance (e.g., pretreatment measures), and how the BMPs will be compliant with all applicable permits.

Knowledge of the characteristics of the POCs may be beneficial to the designers in considering approaches to address them. The sections following Table 6-2 provide more detailed information on the potential Port POCs.

Table 6-2: Potential Port Pollutants of Concern
(Pollutants listed in Applicable Regulatory Documents)

Pollutant	Permits/ Regulatory Applicability					
	303(d) Willamette	303(d) Columbia Slough	1998 Columbia Slough TMDL	2006 Willamette Basin TMDL	1200-COLS	1200-Z[1]
Aldrin	x[2]					r[3]
Aluminum					b[4]	b
Biol. Crit.	x					
BOD					b	
Chlordane	x					
Chlorophyll-a	x		x		s[5]	
Copper					b	b
Cyanide	x					
DDT/DDE	x		x		s[6]	r
Dieldrin	x		x		s[6]	r
Dissolved Oxygen			x		s[7]	
Dioxin			x		s[6]	
E. coli			x	x	b	
Hexachlorobenzene	x					
Iron	x	x			b	b
Lead			x		b	b
Manganese	x	x				
Mercury				x[8]		
Oil and Grease					b	b
Orthophosphate			x		s[5]	
PAHs	x					r
pH			x		b	b
PCBs	x		x		s[9]	r
Pentachlorophenol						r
Temperature				x[10]		
Total Phosphorus			x		b	

Pollutant	Permits/ Regulatory Applicability					
	303(d) Willamette	303(d) Columbia Slough	1998 Columbia Slough TMDL	2006 Willamette Basin TMDL	1200-COLS	1200-Z[1]
TSS			x		b	b
Zinc					b	b

[1] *Reference concentrations included based on Terminal 2 Discharge Monitoring Report (DMR).*
[2] *Included in TMDL or 303(d) listing.*
[3] *Reference concentration included in 1200-Z or 1200-COLS.*
[4] *Benchmark included in 1200-Z or 1200-COLS.*
[5] *Total Phosphorus is used as a surrogate for chlorophyll-a and orthophosphate in 1200-COLS*
[6] *TSS is used as a surrogate for DDT/DDE, dieldrin, dioxin, and PCBs in 1200-COLS.*
[7] *BOD is used as a surrogate for dissolved oxygen in 1200-COLS.*
[8] *Addressed in TMDL, but no wasteload allocations established for stormwater.*
[9] *TSS is used as a surrogate for DDT/DDE, dieldrin, dioxin, and PCBs in 1200-COLS when considering the ability to treat those pollutants and the degree of treatment.*
[10] *Addressed in TMDL, but no wasteload allocations established for stormwater*

6.3.1.2 Sediment

Sediment may include natural organic or inorganic material such as sand, soil particles and vegetative matter, as well as manufactured material such as bits of plastic and metal. For the purposes of this manual, this includes sediment measured TSS. TSS includes the portion of sediment suspended in the water column. Turbidity, which a measure of the light-scattering tendency of particulates dispersed in water is also included. While a certain amount of naturally-originating sediment is present in water bodies, large amounts of sediment produced by erosion can lead to ecological problems such as clogging of fish spawning beds or interference with fish sensory function, among other potential impacts. There is a TMDL addressing TSS for the Columbia Slough and there is a benchmark for TSS in the Industrial permits.

6.3.1.3 pH

The hydrogen ion activity of water (pH) is measured on a logarithmic scale, ranging from 0 to 14. While the pH of “pure” water at 25 ºC is 7.0, the pH of natural waters typically ranges between 6.5 and 8.5. Normal rain is slightly acidic because carbon dioxide (CO_2) dissolves into it forming weak carbonic acid, resulting in a pH of approximately 5.6 at typical atmospheric concentrations of CO_2. Acid rain, which forms as the result of higher than normal amounts of nitric and sulfuric acids in the atmosphere further lowers the pH. Receiving water pH values which deviate from the neutral range (e.g., 6.5 to 8.5) may impair water quality and adversely affect aquatic life, which can be highly sensitive to pH. There is a pH TMDL for the Columbia Slough and there is a benchmark for TSS in the Industrial permits.

6.3.1.4 Petroleum Hydrocarbons

Petroleum hydrocarbons include oil and grease and polycyclic aromatic hydrocarbons (sometimes called polynuclear aromatic hydrocarbons or PAHs), which are compounds used in or created as a byproduct of many industrial processes. These constituents typically originate from automotive/jet fuel sources, leakages/spills, and illegal or improper disposal. Some petroleum hydrocarbons are toxic to aquatic organisms and may present bioaccumulation risks. Many produce unsightly sheens on water, even at low concentrations. PAHS are on the 303(d) list for the Willamette River, and there is a reference concentration in the 1200-Z Industrial permit. Oil and grease has a benchmark concentration in the Industrial permits.

6.3.1.5 Metals

Metals that may be pollutants of concern include aluminum, cadmium, copper, iron, lead, manganese, mercury, nickel, and zinc. Metals may include constituents sorbed to sediment particles (particulate fraction) and/or those that are dissolved in the water. Potential sources of metals include natural sources, automobiles, illegal or improper disposal of lead batteries, and building materials (e.g., galvanized metal, paint, preserved wood, etc.). Metals can be toxic to aquatic organisms and contaminate drinking water supplies. Some metals may bioaccumulate and affect beneficial uses such as sports fishing (mercury is an example). Various metals are on the 303(d) lists for the Willamette River or Columbia Slough and are subject to TMDLs for these waterbodies, and/or have Industrial permit benchmarks.

6.3.1.6 Nutrients

Nutrients that may be of concern include phosphorous and orthophosphate. While nitrogen species (e.g., nitrate, nitrite, ammonia, Kjeldahl nitrogen) are also often considered nutrients of concern for stormwater, the Columbia Slough is phosphorus limited and has not been listed as impaired by nitrogen. Nutrients are important for vegetative growth; however, excessive nutrients can cause eutrophication of receiving waters. Eutrophication consumes dissolved oxygen, which subsequently leads to ecological impacts as fish and other aquatic species become starved of oxygen. The limiting nutrient in Port receiving waters is phosphorus, which can occur in particulate and dissolved form. Orthophosphate is considered the bioavailable form of phosphorus. The Columbia Slough has a TMDL for total phosphorus and orthophosphate.

6.3.1.7 Chlorophyll-a

Chlorophyll-a is an indirect measurement of algal growth, and thus an estimate of the degree of eutrophication of a water body. The Columbia Slough has a TMDL for chlorophyll-a, but only waste load allocations for total phosphate and BOD have been established to address eutrophication concerns.

6.3.1.8 Pesticides

Pesticides include insecticides, herbicides, fungicides, and rodenticides. Landscaped areas are potential sources of pesticides entering stormwater. Some pesticides are toxic to aquatic organisms, even at low concentrations, and can bioaccumulate. Several chemical formulations have been banned, however legacy pesticide contamination and some allowed pesticides still present health risks to aquatic organisms and humans. Potential problem pesticides include organophosphate pesticides and chlorinated compounds, especially aldrin, chlordane, DDT/DDE, and dieldrin. The Columbia Slough has TMDLs for DDT/DDE and dieldrin due to elevated levels in fish tissue. In addition, aldrin, chlordane, DDT/DDE and dieldrin are on the 303(d) list for the Willamette River.

6.3.1.9 Hexachlorobenzene (HCB)

HCB has been used in fireworks and ammunition, rubber manufacturing, and as a pesticide, but nearly all commercial use was ceased in the 1970’s. It is currently formed as a byproduct during the manufacture of other chlorinated organic compounds, solvents, pesticides, or during the burning of municipal waste. Industrial stormwater is one of the primary current sources of HCB in the environment. The Willamette River is on the 303(d) list due to HCB.

6.3.1.10 Pentachlorophenol (PCP)

PCP is currently used as a pesticide and commercial wood preservative on utility poles, fence posts, piers, docks, beams, etc. PCP can cause health concerns, but some of the harmful effects are due to other pollutants present as impurities such as chlorinated dioxins and furans. PCP has a reference concentration of 0.02 mg/L in the 1200-Z permit.

6.3.1.11 Polychlorinated biphenyls (PCBs)

PCBs are legacy pollutants historically used in electrical transformer operations, hydraulic fluids and lubricants, as well as for caulk and other building materials. The Columbia Slough has a TMDL for total PCBs due to elevated levels in fish tissue.

6.3.1.12 Dioxins

Chlorinated dibenzo-p-dioxin refers to a class of 75 toxic organic compounds that form during the combustion of various organic compounds. Fossil fuel and forest fires are common sources of environmental dioxins, but processes involving chlorination, including wastewater and drinking water treatment, can also produce dioxins. The Columbia Slough has a TMDL for dioxins.

6.3.1.13 Oxygen Demanding Substances

Oxygen demanding substances are those that promote eutrophication, reducing dissolved oxygen available for aquatic life. The biochemical oxygen demand (BOD) test measures the oxygen consumed by a bacterial seed in a water sample over a five-day period. There is a Columbia Slough TMDL for dissolved oxygen, which is principally addressed through the PDX deicing NPDES permit and the PDX deicer management system.

6.3.1.14 Bacteria

Bacteria are typically human or animal derived, and can be associated with failing septic systems, feedlots, or animal feces. Bacteria are numerous and often difficult to representatively sample, thus a surrogate such as *Escherichia coli* (E. coli) is used as an indicator of fecal contamination. The Columbia Slough and Willamette River have TDMLs for E. coli and there is a reference concentration in the 1200-COLS Industrial permit.

6.3.1.15 Cyanide

Cyanide is a chemical compound or class of compounds that contains the cyano group (carbon bonded to nitrogen). It has been used in a variety of industries from mining, to pest control, to medical uses. It is known to be toxic to aquatic life and is currently on the 303(d) list for the Lower Willamette River.

6.3.2 Step 2: Investigate Site-Specific Conditions and Constraints

The Port may identify potential sites for BMPs based upon development plans and operational needs. The Port may also ask designers to assist in site identification. Once potential BMP sites are identified, they should be further screened for BMP applicability based on specific site conditions and constraints. Site characteristics such as anticipated Port operations, topography, slope, soils, depth to groundwater, and others affect which BMPs will function appropriately at the site and where the BMPs can be located. Depending on these conditions and constraints, the

BMP type appropriate for the site can be refined. For instance, use of infiltration BMPs requires a higher level of evaluation compared to other BMP types, as described below. Site characteristics that could be constraints for effective BMP design are described in the section below, and additional detailed considerations are incorporated into individual BMP fact sheets.

6.3.2.1 Soil Characteristics and Infiltration Concerns

Chapter 4 includes a SWM standard for infiltration that requires a minimum infiltration volume to be incorporated into project designs, based on site applicability considerations. Poorly drained soils may preclude the use of infiltration BMPs, or require design modifications such as soil amendments and/or an underdrain to ensure proper BMP function. Hydraulic conductivity is the rate at which water flows through the soil pore structure given as a velocity (e.g., inches per hour). Hydraulic conductivity is a function of the porosity (volume of voids to total volume of soil), the connectivity of the pore spaces, the degree of saturation, the chemistry and temperature of the pore fluids, and the hydraulic gradient. The NRCS classifies soils into Hydrologic Soil Groups based on hydraulic conductivity as follows:

- <u>Group A</u> – soils having high infiltration rates, even when thoroughly wetted. These soils consist of deep, well-drained to excessively-drained sands or gravels and have a high rate of water transmission (rate at which water moves through the soil).
- <u>Group B</u> – soils having moderate infiltration rates when thoroughly wetted. These soils consist of moderately-fine to moderately-coarse textures and have a moderate rate of water transmission.
- <u>Group C</u> – soils having slow infiltration rates when thoroughly wetted. These soils consist of a layer that impedes downward movement of water or soils with moderately fine to fine textures. These soils have a slow rate of water transmission.
- <u>Group D</u> – soils having very slow infiltration rates when thoroughly wetted. These soils consist of clay soils with a high swelling potential, soils with a permanent high water table, soils with a hardpan or clay layer at or near the surface, and shallow soils over bedrock or other nearly impervious material and have a very slow rate of water transmission.

Generally, only A or B type soils are appropriate for infiltration facilities designed to infiltrate the entire water quality design volume. However, C type soils may be used for partial infiltration designs.

If infiltration BMPs are being considered near a steep slope, a geotechnical engineering report is required to be produced by a licensed geotechnical engineer that designates which areas are suitable for infiltration. Considerations included in the geotechnical report shall include unstable slopes (not suitable for any BMPs), slopes which may become unstable if infiltration and/or BMP excavation occurs, and very steep slopes, which would disallow proper infiltration or drainage or could become unstable. Minimum setback requirements for infiltration facilities are provided in Section 6.4.1. In some cases, BMPs may be sited on steeper slopes if they are lined, provided that ponded water does not occur. Any recommendation for lining of BMPs due to geotechnical constraints should be validated by the geotechnical engineer.

Use of infiltration BMPs requires site-specific testing to determine if the long-term infiltration rate (design infiltration rate) will infiltrate the water quality design volume within the BMP (see Appendix **D** for information on soil and groundwater testing and a process for determining the design infiltration rate).

6.3.2.2 Topographic relief

In areas of low relief, deeper and more costly excavations may be required for basins or subsurface BMPs to allow them to receive runoff and discharge treated flows by gravity. In addition, some BMPs such as cartridge filters require several feet of hydraulic head to function and drain effectively, which may not be available in low relief areas. Areas without sufficient relief (e.g., slope < 1 percent) may require that subsurface BMPs incorporate a pump station or have existing subsurface storm drain infrastructure that could be utilized to allow the BMP to drain properly. Site slope limitations could prohibit diversion and subsequent return of treated water by gravity. A very shallow slope may cause ponding and backwater effects, while a very steep slope may cause scour at BMP inlets and outlets. Typically, given adequate vertical relief at the site, most designs may compensate for unfavorable site slopes with grading and excavation or by using modifications such as check dams, energy dissipaters, or underdrains.

6.3.2.3 Groundwater Considerations

Hydrogeological and groundwater constraints should be considered prior to selecting and siting BMPs. Groundwater concerns include a seasonally high groundwater table elevation and groundwater contamination issues:

- Seasonally High Groundwater Elevation – A seasonally high groundwater elevation relative to the BMP elevation can preclude the use of infiltration BMPs. If the groundwater elevation is too close to the ground surface for even part of a year, it can significantly impact the ability to infiltrate stormwater. This condition has been observed at multiple locations at PDX. In addition, when the groundwater elevation is near the ground surface, there is greater potential for groundwater contamination resulting from infiltrated stormwater. Separation of 5 feet from the bottom of the BMP to the seasonally high groundwater elevation is required for all infiltration BMPs that are designed to infiltrate the full WQ_V or WQ_F (infiltration strategy #1, as described in the Infiltration SWM standard in Chapter 4). Separation of 3 feet from the bottom of the BMP to the seasonally high groundwater elevation is required for BMPs that are designed to partially infiltrate the WQ_V or WQ_F (infiltration strategy #2, as described in the Infiltration SWM standard in Chapter 4). BMPs that partially infiltrate the WQ_V or WQ_F shall be designed with underdrains that discharge to the stormwater drainage system.
- Base flows – The presence of base flows can preclude the use of some BMPs such as infiltration BMPs, largely because they are indicative of shallow groundwater and/or a shallow lense of groundwater that would disallow additional percolation of water into the soil. Secondarily, it is not desirable to mix base flow with stormwater with little potential for the natural treatment processes of native soil filtration. Base flow may additionally require design modifications such as low flow drains (e.g., gravel trench or swale). BMPs that are compatible with base flows include wet basins and wetlands.
- Existing Soil and Groundwater Contamination – Infiltrating BMPs shall not be sited in a location where an underlying soil (vadose zone) or groundwater contamination plume could be mobilized due to influx of stormwater. Additionally, non-infiltrating BMPs must be lined if sited near shallow groundwater contamination.

6.3.2.4 Tributary Area

The size of drainage area is a consideration in selecting a BMP. For example, swales and sand filters are specifically designed to handle smaller flows and could become overwhelmed if treating runoff from a large drainage area. Tributary area guidelines for individual BMPs are provided in the BMP fact sheets and in Table 6-4. While many BMPs can be designed to accommodate larger drainage areas than listed, very large footprint areas may be required along with additional pretreatment and energy dissipation. Explicit Port approval is needed if the planned tributary area exceeds the BMP-specific guidelines.

6.3.2.5 Proximity to Infrastructure

BMPs should be sited considering existing infrastructure. BMPs should be sited away from structures, foundations, and drinking water wells, which could be negatively impacted by stormwater influx. However, BMPs should be sited within a reasonable distance of existing conveyance systems, if possible, to minimize piping and connection costs. Minimum setback requirements are discussed in Section 6.4.1. Additional considerations related to the proximity of BMPs to existing infrastructure include the following:

- Foundations and Footings – Except for ***building BMPs*** that are lined and receive runoff only from rooftops, BMPs being considered for placement near existing foundations and footings require a geotechnical investigation to ensure that the structural integrity of the underlying soils are not compromised. Infiltration should generally be avoided unless the design is approved by a licensed geotechnical or structural engineer.
- Conveyance Infrastructure – BMPs that are designed to receive flows from upstream conveyance and discharge flows to downstream conveyance (e.g., detention basins, wetlands, swales, etc.) should be sited adjacent to associated conveyance infrastructure, to the extent feasible. The ability to locate these BMPs near connecting infrastructure minimizes piping costs, reduces chances for utility conflicts, reduces construction times, and may also minimize the depth of the facility and connecting conveyance. BMP types that only require conveyance to the facility (e.g., infiltration practices and cisterns) are less susceptible to this constraint, while other BMP types such as pervious pavement may require no connection to conveyance at all. When connecting to existing conveyance infrastructure, availability of hydraulic head must be assessed. Shallow conveyance infrastructure may require pumping or downstream connections.

6.3.2.6 Wildlife Hazards

As described in Section 4.7, Hazardous Wildlife Attractants, wildlife attractants are a concern at Port facilities within specific PDX zones because of the potential for interactions between wildlife and aircraft that threaten human safety. Stormwater facilities designed in accordance with traditional BMP design guidelines may provide food and shelter for wildlife, therefore increasing the likelihood of a hazardous wildlife-aircraft conflict. The primary features of stormwater BMPs that are attractive to hazardous wildlife are vegetative cover and open water.

BMPs installed within and adjacent to PDX need to meet the requirements indicated in the Hazardous Wildlife Attractants SWM standard, for the Primary, Intermediate, Secondary, and Five Mile Separation Zones, which are consistent with the requirements of the PDX WHMP, FAA ACs, and ORS 836.623. BMPs shall comply with the requirements of the Hazardous Wildlife Attractants SWM standard, based on the BMP's location relative to defined wildlife zones. In all cases, designers of projects at PDX shall coordinate potential project hazardous wildlife attractants with the Port to determine if selected BMPs are acceptable and if any additional design or siting requirements are applicable. The Port may ask the designer to supply BMP design information to facilitate the evaluation of potential BMPs in a BMP bird strike risk analysis tool that was developed by the Airport Cooperative Research Program (TRB 2013).

Key wildlife hazard management considerations for BMP design include, but are not limited to, the following:

- To reduce attraction to of waterfowl and other birds to stormwater facilities, open standing water and BMPs that provide food, cover, and nesting habitat should be avoided. Only those types of vegetation that generally are not favored by waterfowl for food or cover should be used in airport BMPs. See the WHMP for a list of approved vegetation for the Primary and Intermediate zones at PDX.
- BMPs at PDX should be designed to draw down surface ponding in 48 hours or less.
- In accordance with ORS 836.623 and the SWM standard for Hazardous Wildlife Attractants, "new water impoundments of one-quarter acre or larger" are not permitted "within the approach corridor and within 5,000 feet from end of runway; or on land owned by the airport or airport sponsor where the land is necessary for airport operations," (ORS 836.623)[26], unless the BMP incorporates deterrents in accordance with the SWM standard requirements for the Intermediate Zone.
- Stormwater BMPs that include deep organic soils attractive to earthworms may represent a risk where gulls are common. If chemical worm repellents are used, appropriate source control measures must be implemented to prevent chemicals from entering receiving waters.
- Stormwater facilities and adjacent landscaping shall be configured to reduce line of sight for wildlife. This includes using steeper embankments, narrower/longer configurations, shrub vegetation, fences, or other installations that disrupt sight lines and reduce comfort and habitat suitability for hazardous wildlife (primarily waterfowl).
- Stormwater facilities shall not be located in a way that encourages wildlife to migrate/travel from existing stormwater facilities or natural habitats on one side of the air operations area to new facilities located on the other side, causing the wildlife to cross the runway or paths of aircraft.
- The BMP design shall be customized for specific wildlife species of concern.
- As described in the Chapter 4 SWM standard, BMPs with open water surfaces in the Primary and Intermediate Zones are required to incorporate wildlife deterrents, including specific design criteria to make the BMP less attractive (as defined by FAA and summarized in Chapter 4), and the use of a solid cover (e.g., bird balls or floating cover) to reduce the visibility of the BMP to wildlife. Designers may also consider the selection of a subsurface BMP with no exposed water surface to eliminate access to and visibility of the BMP to wildlife. Designers are required to incorporate these deterrents into their BMP design, and then coordinate with Port wildlife management staff at the preliminary design meeting to confirm if the selected deterrents are sufficient or if additional measures may be required.

6.3.3 Step 3: Determine Needed BMP Functions and Basis-of-Design

The minimum needed functions for the BMP and the quantitative basis-of-design (water quality treatment, flow control) can be determined by applying the Chapter 4 Stormwater Management Standards to the project characteristics for the pollutants of concern provided by the Port and/or tenant to the designer. Additional functions, sizing requirements, and treatment performance

[26] ORS 2011 Edition, Volume 17, Chapter 836, "836.623 Local compatibility and safety requirements more stringent than state requirements; criteria; water impoundments; report to federal agency; application to certain activities."

information, as driven by project-specific Industrial NPDES Permit or facility operational needs, may also be integrated into the BMP sizing and design.

See Chapter 4 for definitions of the applicable project site area for calculations determining the water quality and flow control capacities of the BMPs.

Facilities combining both water quality treatment and water quantity control are specialized and provide detention to control flows, and also provide treatment processes to remove or degrade pollutants of concern. It may not be feasible to meet water quantity control and treatment requirements with a single BMP, in which case a treatment train type approach may be needed.

6.3.4 Step 4: Determine Performance Requirements

Water quality BMPs should be selected based on the treatment mechanisms that are effective at removing site-specific POCs requiring water quality treatment (Table 6-1 and Table 6-3). The Port has established a pollutant removal effectiveness performance goal to maximize the reduction of pollutant discharges. The performance goal is an effluent quality goal rather than a percent reduction goal for pollutant removal between the influent and effluent concentrations. It is based on an analysis of TSS effluent quality from the International Stormwater BMP Database (Geosyntec Consultants 2012). The Port has selected a BMP effluent quality goal of 25 mg/L for TSS, which is the median effluent quality achieved for a dry extended detention basin. This 25 mg/L TSS goal is also 50 percent of the water quality benchmark for the 1200-COLS permit. It is presumed that BMPs designed in accordance with the design criteria in this DSM will achieve the TSS effluent goal of 25 mg/L on average, for storm events that cause discharge.

If any pollutants of concern have benchmarks for applicable Industrial NPDES permits, those benchmarks may also be a factor in selecting and designing the BMPs. This could result in the need for a higher performing BMP.

6.3.5 Step 5: Develop a BMP Selection Strategy

A BMP selection strategy can be used to select the BMPs to meet the project goals. The BMP selection strategy should include identification and assessment of the factors that may affect selection of the BMPs. This includes an analysis of the potential BMP site(s), identification of potential applicable BMPs, and an alternatives analysis that leads to selection of BMPs. The following considerations should be factored into a project-specific BMP selection strategy:

- Documentation of baseline information:
    - Identify the POCs requiring water quality treatment, for which BMPs are required.
    - Identify the potential for unusually high concentrations of pollutants to be treated, the activities/conditions driving those high concentrations, and whether other procedures, controls, or systems are in place to manage the high concentrations.
    - Calculate the BMP capacity requirements for water quality treatment and flow control based upon application of the Stormwater Management Standards to the project site characteristics.

- Coordination with the Port on existing or planned BMPs:
    - Identify existing local and regional BMP facilities and their available capacities.
    - Review BMPs included in the Stormwater Master Plan for the drainage basin in which the development project resides.

  - Investigate other development projects which could potentially share a regional BMP with the specific project of interest.

- Consideration of options for the flow control basis:
  - Gain an understanding of downstream effects and how the BMP can mitigate those effects.
  - Determine where BMP inlets and outlets could tie into the existing drainage system and where they could discharge (outfalls).
  - Perform an evaluation of whether the BMP should be designed as an on-line or off-line facility (see Section 6.3.7.1 for more details).

- Consideration of facility layout options:
  - Determine whether distributed, on-site BMPs will be used as opposed to centralized or regional BMPs.
  - Determine whether water quality treatment and flood control functions can be integrated into a single facility (see Section 6.3.7.2 for more details).
  - Investigate whether a treatment train is more effective than a single BMP for treating multiple pollutants of concern.
  - For facilities at PDX, consider a layout that has multiple wildlife deterrents (e.g., steep side slopes, narrow and linear drainage features, selected and sparse vegetation, etc.).

- Evaluation of site constraints and characteristics:
  - Identify potential sites where BMP siting is feasible based on the above considerations and available space for the footprint of the BMP system that is needed.
  - Investigate site specific conditions and characteristics, including soil suitability.
  - Review site restrictions such as available space, layout, height restrictions, airspace restrictions, safety area restrictions.
  - Examine site access.
  - Confirm construction restrictions and impacts.

- Determination of operational and maintenance needs and requirements:
  - Verify operational restrictions or needs such as minimization of wildlife attractants.
  - Establish types and frequency of maintenance tasks and responsibility.

- Identification of time frame for BMP design and implementation.
- Consideration of potential costs for BMP alternatives.
  - Develop initial costs for design and implementation.
  - Determine reasonable operations and maintenance budget requirements.

Key aspects of this strategy are further detailed in subsequent BMP selection steps.

6.3.6 Step 6: Identify Potentially Applicable BMPs

Potential BMPs should be identified with considerations of the factors introduced in the sections above and listed here:

- BMP functional needs (water quality, water quantity control, or both)
- Pollutants requiring BMPs
- BMP performance needs

- BMP site characteristics and constraints

The selection matrices provided in Table 6-3 and Table 6-4 should be used to identify potential BMPs that will function effectively for a site's pollutants of concern, flow control requirements, and site characteristics and constraints.

BMPs with performance that is rated in Table 6-3 as "Very High" or "High" for particular pollutant groups are considered as "primary" BMPs for those pollutants. If a pollutant is listed in the BMP fact sheets as "primary" for that BMP, the BMP is primarily intended for treating that pollutant and its performance in removing that pollutant is considered by the Port as sufficient for MS4 permit compliance purposes.

If a pollutant is listed in the BMP fact sheet as "secondary", the BMP in question can only treat that pollutant to a moderate degree as indicated in Table 6-3. While the BMP might remove secondary pollutants, the BMP is considered by the Port to be insufficient for MS4 permit compliance purposes and additional BMPs may be needed for that pollutant.

To achieve compliance with DSM and the MS4 permit, therefore, each pollutant of concern identified by the Port derived from the 303(d) and TMDL lists must be treated by at least one BMP in the treatment train with a Very High or High performance (primary) rating in Table 6-3. It is the designer's responsibility to determine the necessary BMP performance to achieve compliance with any industrial permit requirements that the Port indicates must be addressed in the design.

Additional site constraints at PDX include the risk of attracting hazardous wildlife, and the feasibility of installing BMPs that do not function properly in the presence of a high water table. Table 6-4 reflects the initial wildlife risk associated with each BMP type before mitigating features and deterrents are incorporated. It is recommended that designers consider BMPs for PDX that have wildlife risks classified as "Low" or "Not Applicable." Designers may select other BMPs provided that the BMP aligns with FAA design criteria and incorporates appropriate deterrents as described in the Hazardous Wildlife Attractants SWM standard in Chapter 4 and in the BMP fact sheets. The use of BMPs that are not appropriate for a shallow groundwater table at PDX would require additional evaluation by the Port before such BMPs are approved.

Table 6-3: BMP Selection Matrix-BMP Function

BMP (See Fact Sheets)	Volume Reduction	Peak Flow Control[1]	Compatible with Flood Control Facility[2]	Water Quality Treatment: TSS	Nutrients (P)	Metals (Dissolved and Particulate)	Bacteria	Oil & Grease	Organics
FS1: Dry Extended Detention Basin	◉	●	◓	◉	◒	◉	◒	◉	◉
FS2: Wet Basin	◒	◓	◉	●	◓	◓	◉	●	●
FS3: Subsurface Flow Wetland	◒	◓	◒	●	◓	◓	◉	●	●
FS4: Bioretention Basin	◓	●	◒	●	◓	◓	◓	●	●
FS5: Infiltration Trench	●	●	◒	●	●	●	●	●	●
FS6: Vegetated Swale	◉	◓	○	◉	◒	◉	○	◉	◉
FS7: Vegetated Filter Strip	◓	◒	○	◓	◒	◉	○	●	◉
FS8: Media Filter	○	◒	○	●	◉	◓	◓	●	●
FS9: Infiltration USCF	●	●	◒	●	●	●	●	●	●
FS9: Detention USCF	◉	●	◉	◉	◒	◉	◒	◉	◉
FS9: Wet USCF	◒	◓	◒	●	◓	◓	◉	●	●
FS10: Pervious Pavement	◓	●	○	●	◉	◓	◓	◓	◓
FS11: Building BMPs	◉	◉	○	Treatment effectiveness not comparable to other BMPs that treat runoff from a wide range of impervious surfaces, which generally have higher pollutant concentrations than roofs.					
Proprietary BMPs FS12, FS13, FS14	○	The hydrologic and treatment effectiveness for specific proprietary BMPs must be provided by the manufacturer. Select proprietary BMPs from the list of BMPs approved by the Port.							

Notes:
[1] Smaller More Frequently Occurring Storms
[2] 10 Year Peak Flow Control
USCF= Underground Stormwater Control Facility

Key:

Very High	High	Moderate	Low	Very Low
●	◓	◉	◒	○

Table 6-4: BMP Selection Matrix-Applicability Considerations

BMP	Tributary Area [acres unless otherwise noted]	Footprint [% of Contributing Impervious Tributary Area]	Hydraulic Head1 Required [ft]	Maximum Site Slope [%]	Appropriate for Shallow Water Table (< 3 ft separation)? [Y, N]2	Hydrologic Soil Group	Potential Hazardous Wildlife Concerns at PDX? [H, L, N/A]3	Capital Cost (per Acre of Drainage Area) [$, $$, $$$, $$$$]	O&M Annual Labor Hours [H, M, L]4
FS1: Dry Extended Detention Basin	> 10	1-5	6-8	15	N	Any	H	$$	H
FS2: Wet Basin	> 10 ≤ 10 for pocket wetland	2-3	4-8	15 8 (pocket wetland)	Y	Any, however a liner may be needed to maintain a permanent pool in A & B soils	H	$$	H
FS3: Subsurface Flow Wetland	Variable	Up to 10%	0.33	8	N (unless for groundwater treatment)	Any	L	$$$	H
FS4: Bioretention	≤ 5	4-10	2-5 Use of an underdrain reduces head requirements	8	N	A&B for infiltration Underdrains required for C&D	H	$$	M
FS5: Infiltration Trench	≤ 2	3-10	1	15	N	A&B	L	$$	M

BMP	Tributary Area [acres unless otherwise noted]	Footprint [% of Contributing Impervious Tributary Area]	Hydraulic Head1 Required [ft]	Maximum Site Slope [%]	Appropriate for Shallow Water Table (< 3 ft separation)? [Y, N]2	Hydrologic Soil Group	Potential Hazardous Wildlife Concerns at PDX? [H, L, N/A]3	Capital Cost (per Acre of Drainage Area) [$, $$, $$$, $$$$]	O&M Annual Labor Hours [H, M, L]4
FS6: Vegetated Swale	≤ 5	3-5	3-5	10	N	A&B for infiltration Underdrains required for C&D	H	$	M
FS7: Vegetated Filter Strip	≤ 2	Up to 2, but can substitute for an open drainage feature	< 1	4 (check dams may be used for steeper slopes)	Y	Any	L	$	L
FS8: Media Filter	< 10 surface media filter < 2 perimeter media filter < 1 underground media filter	2-5	Surface: 5 Underground: 5-7 Perimeter: 2-3	15	N	A&B if designed for infiltration Any if BMP is lined or enclosed	L	$$	L

BMP	Tributary Area [acres unless otherwise noted]	Footprint [% of Contributing Impervious Tributary Area]	Hydraulic Head[1] Required [ft]	Maximum Site Slope [%]	Appropriate for Shallow Water Table (< 3 ft separation)? [Y, N][2]	Hydrologic Soil Group	Potential Hazardous Wildlife Concerns at PDX? [H, L, N/A][3]	Capital Cost (per Acre of Drainage Area) [$, $$, $$$, $$$$]	O&M Annual Labor Hours [H, M, L][4]
FS9: Infiltration USCF[6]	≤ 25	1-3 (underground) Minimal surface footprint	5	Not applicable	An anti-flotation analysis is required to check for buoyancy problems in high water table areas	A&B	N/A	$$$	M
FS9: Detention USCF	≤ 25	1-3 (underground) Minimal surface footprint	5	Not applicable	An anti-flotation analysis is required to check for buoyancy problems in high water table areas	Any	N/A	$$$	M

BMP	Tributary Area [acres unless otherwise noted]	Footprint [% of Contributing Impervious Tributary Area]	Hydraulic Head1 Required [ft]	Maximum Site Slope [%]	Appropriate for Shallow Water Table (< 3 ft separation)? [Y, N]2	Hydrologic Soil Group	Potential Hazardous Wildlife Concerns at PDX? [H, L, N/A]3	Capital Cost (per Acre of Drainage Area) [$, $$, $$$, $$$$]	O&M Annual Labor Hours [H, M, L]4
FS9: Wet USCF	≤ 25	1-3 (underground) Minimal surface footprint	5	Not applicable	An anti-flotation analysis is required to check for buoyancy problems in high water table areas	Any	N/A	$$$	M
FS10: Pervious Pavement	Own footprint Runoff from adjacent areas ≤ 3 times the pervious pavement footprint area	100	2-4	5	N	A&B without underdrains C&D with underdrains	L	$$	L
FS11: Planter Box Filters	≤ 15,000 ft2	5	2-5 Use of an underdrain reduces head requirements	Not applicable but adequate relief is required7	N	Any	L	$$$	M
FS11: Green Roofs	Own footprint	100	No restrictions	< 10 (roof)	Y	Not applicable (imported soil media is used in the BMP)	L	$$$$	H

BMP	Tributary Area [acres unless otherwise noted]	Footprint [% of Contributing Impervious Tributary Area]	Hydraulic Head1 Required [ft]	Maximum Site Slope [%]	Appropriate for Shallow Water Table (< 3 ft separation)? [Y, N]2	Hydrologic Soil Group	Potential Hazardous Wildlife Concerns at PDX? [H, L, N/A]3	Capital Cost (per Acre of Drainage Area) [$, $$, $$$, $$$$]	O&M Annual Labor Hours [H, M, L]4
FS11: Cisterns	Limited to cistern design capacity	Varies	Depends on the ultimate water use (e.g., is pumping required or not)	No restrictions	Y	Any	N/A	$$$	H
FS11: Dry Wells	Roof area only	Surface footprint is limited to access cover	1	15	N	A&B	N/A	$$$	L
Proprietary BMPs FS12, FS13, FS14	Due to the numerous types of devices, site applicability data should be provided by the manufacturer.								

1 *Hydraulic Head is the difference in elevation between the surface drainage and the bottom elevation of a site*
2 *Y = Yes, N = No*
3 *H = High, L = Low, N/A = Not Applicable*
4 *H = High, M = Medium, L = Low*
5 *Not applicable, but the site must have adequate relief between land surface and the stormwater conveyance system to permit vertical percolation through the planting media and underdrain to the stormwater conveyance system. The final box must be level or designed as a cascading series of level boxes*
6 *USCF = Underground Stormwater Control Facility*
7 *Not applicable, but the site must have adequate relief between land surface and the stormwater conveyance system to permit vertical percolation through the planting media and underdrain to the stormwater conveyance system. The final box must be level or designed as a cascading series of level boxes*

6.3.7 Step 7: Consider Potential BMP Configurations

6.3.7.1 Determining On-Line versus Off-Line BMP Configurations

With potentially applicable BMPs identified, an important BMP consideration is the decision to make the BMP "on-line", or sited such that all tributary runoff flows through the BMP, or "off-line", such that only the design volume or flow is diverted to the BMP and excess volume or flow bypasses. Off-line facilities are typically used for water quality treatment. A few BMP types are typically designed as on-line facilities, including filter strips and distributed bioretention areas, which are typically designed to receive sheet flow from small catchments areas. Off-line systems should be used where peak flows could damage an on-line facility and/or negatively affect treatment performance. Flow control BMPs may or may not be designed to be on-line depending on the flow control goal. For instance, control of a specified range of flows may only require diversion of flows up to a certain threshold, whereas flood control BMPs are typically designed to capture all runoff from the tributary catchment.

It is not recommended that a BMP be designed as on-line if it would be serving an area where the new or redevelopment area is less than 50 percent of the total area tributary to the BMP. If this situation arises, designers will need to coordinate with the Port to determine if additional treatment capacity may be required for incorporation into the design.

Flow-based on-line water quality facilities such as vegetated swales require a larger design flow rate (and hence footprint area) than off-line BMPs to achieve a similar level of average annual treatment (e.g., 80 percent). However, swales may also be designed primarily for conveyance of stormwater to other downstream water quality facilities (see Section 6.3.7.3 for additional guidance on designing treatment trains). Larger design flow rates are needed for on-line facilities because the treatment functions (e.g., sedimentation) rapidly decline after the design flow rate has been exceeded. Due to the upstream diversion structure, flow-based, off-line facilities can continue to treat up to the design flow rate for all flows. Although the footprint area for on-line volume-based BMPs may not increase compared to the off-line configuration, on-line facilities require higher freeboard and a larger overflow structure (e.g., spillway) compared to off-line facilities, which increase construction and maintenance costs.

If a choice can be made between an on-line and off-line water quality facility, generally overall treatment performance is better for off-line facilities because there is less of a chance for mobilization of previously captured pollutants.

6.3.7.2 Integration of Water Quality Treatment with Flood Control Function

If both water quality treatment and flow control BMPs are needed, it is often efficient to combine flow control and water quality control BMPs since the land requirements for a combined facility are lower than for two separate facilities. Consideration for combined BMPs may provide opportunities for retrofitting existing infrastructure such as flood control basins.

Dry extended detention basins, wet basins, and wet USCFs, can be designed as combined facilities. The typical design technique for combined facilities is to dedicate the lower volume for water quality treatment and the upper volume for detention storage. The basin volume required to provide water quality treatment should be assumed to be unavailable for peak flow storage when designing a basin as a combination dry extended detention water quality facility and peak flow detention facility. Also, a multistage outlet structure is typically needed to ensure adequate residence time for the water quality design event and effective peak flow control to meet flood control requirements.

Any consideration of combining water quality treatment and flow control functions should consider potential negative impacts, especially on water quality BMP performance.

6.3.7.3 Treatment Trains

If potentially applicable individual BMPs cannot provide both flow control and water quality treatment, or if single water quality BMPs cannot serve as a primary treatment BMP for all pollutants of concern, multiple BMPs in a treatment train may be needed.

Treatment trains may result in better performance, lower cost, smaller footprint, and less maintenance. In a treatment train, each unit process BMP has a discrete function. Treatment trains are most commonly used to target multiple pollutants, to separate the water quality and flow control functions, or to provide pretreatment which acts to reduce maintenance for downstream BMPs. Pretreatment often targets removal of coarse sediment and gross solids prior to draining to the primary BMP.

In general, BMPs utilizing the same primary treatment mechanisms should not be placed in series (unless redundancy or protection from breakthrough is desired). The general order of treatment BMPs in treatment train should be as follows:

- Bulk solids removal
- Settleable solids and liquid floatables removal
- Suspended and colloidal solids treatment
- Dissolved, and volatile solids, and pathogens treatment

6.3.8 Step 8: Perform Alternatives Analysis

Once potential BMPs, sites, and configurations have been identified, an analysis of BMP alternatives should be undertaken (unless only one BMP is capable of meeting all requirements). To select the most appropriate BMP or combination of BMPs, a concept-level alternatives analysis should be conducted.

6.3.8.1 Conceptual Sizing of Facilities

To determine the placement of BMPs, conceptual sizing should be conducted to estimate the footprint of the facility or facilities as well as the conceptual layout. The conceptual layout should include: pretreatment needs, placement of multiple BMPs in treatment trains, on-line/off-line placement of BMPs, and treated and bypassed flow discharge points should be developed for the selected alternatives. BMPs that convey runoff without significant detention (e.g., filter strips) require less space than on a per acre treated basis than BMPs that detain runoff without significant volume reduction (e.g., pocket wetlands).

The Section 4.5, Water Quality – Capture and Treat SWM standard requires that BMPs be sized at minimum for the WQ_V or WQ_F to meet the 80 percent runoff capture objective. The WQ_V would apply to volume-based BMPs, whereas the WQ_F would apply to flow-based BMPs. Chapter 4 defines equations for calculating WQ_V and WQ_F based on tabulated storm depth and rainfall intensities that were identified as meeting the percent capture objective. Designers shall use the BMP-specific design criteria within the BMP fact sheets to determine required drawdown time corresponding to those criteria. From there, designers should refer to the tables within the Water Quality – Capture and Treat SWM standard to determine the minimum water quality storm depth or intensity, and calculate the required WQ_V or WQ_F. Nomographs have been developed to size volume- and flow-based BMPs and the methodology is included in Appendix **L**. Each point on the nomograph reflects the percent of runoff captured by a single BMP scenario, assuming a BMP that is sized for a particular design storm depth and a discharge rate that corresponds to a particular BMP drawdown time. Each curve on the nomograph reflects a specific drawdown time and each point reflects the percent capture achieved by various BMP sizes (design storm depths) when sized to that drawdown time.

The storage volume and footprint for infiltration and filtration-based BMPs should be based on the design storage depth and the design media filtration rate (if there is an underdrain) or the design infiltration rate of the native soils (if there is no underdrain). For example, media filters require a design filtration rate of 1 in/hr and a maximum ponding depth of 3 feet, which results in a design drawdown time of 36 hours. From the SWM standard tables, a 36-hour drawdown time requires a design storm depth of 0.56 inches to achieve 80 percent capture. Similarly, a bioretention system with an underlying design infiltration rate of 0.5 in/hr and a design ponding depth of 6 inches would drain in 12 hours, thereby requiring a design storm depth of 0.31 inches to achieve 80 percent capture. See the BMP fact sheets for more information.

Proprietary flow-based BMPs are sized by the supplier, using the WQ_F. For engineered flow-based BMPs, such as filter strips or swales, sizing is conducted using Manning's equation. BMP length, bottom width (for swales), and design flow depth are adjusted until the required residence time is achieved within the constraints of the site and BMP dimension limitations (included in the BMP fact sheets).

Sub-surface flow wetlands can be sized using volume-based and/or flow-based sizing methodologies. If no equalization storage is provided, then the off-line, flow-based criteria apply for determining the design flow rate (<u>sub-surface flow wetlands cannot be on-line</u>). If equalization storage is provided to meter flows to the sub-surface wetland, then the minimum drawdown time allowed is 12 hours (e.g., 0.31 inch design storm from the SWM standard tables). In this case, the design flow rate for the sub-surface wetland is equal to the equalization storage divided by the drawdown rate. In either case, the pore volume required in the substrate of the sub-surface flow wetland shall be determined based on a minimum hydraulic residence time (HRT) of 24 hours as determined by multiplying the design flow rate by the HRT. See the sub-surface flow wetlands fact sheet for more information.

One exception to the SWM standard approach for determining WQ_V or WQ_F based on drawdown time is for wet basins. Wet basins shall be sized for a 1-inch design storm with the permanent pool consisting of at least 20 percent of the total storage volume. Extended detention provided above the permanent pool shall drain in no less than 24 hours. For example, a wet basin could be designed with a permanent pool volume equal to 0.2 inches and an extended detention of 0.8 inches. See the wet basin fact sheet for more information.

In addition to the minimum water quality sizing criteria above, the overall BMP sizing and layout should account for other design requirements and features. The total BMP facility footprint area needs to accommodate any necessary pretreatment structure, each BMP in the treatment train (as sized using the WQ_V or WQ_F, or based on other treatment objectives as defined by the Port), additional storm drain piping, treatment zone (the BMP), primary and auxiliary (overflow) outlets, maintenance access road, and maintenance operational areas. Facility footprints may vary from spanning the entire length of a project's area to being localized to a small, downgradient area within a project. Additionally, designers shall coordinate with the Port to determine if there are treatment objectives other than MS4 permit capture and treat requirements that may affect BMP sizing and design.

6.3.8.2 Comparison of Alternatives

Once conceptual layout and sizing has been completed for the alternatives, a comparison of the alternatives should be performed. This comparison should examine the following factors for each alternative:

- Ability to meet performance functions (per Table 6-3 and Table 6-4 Operational impacts
- Conceptual level costs (see Table 6-4 and BMP Capital Costs Estimation Methods in Appendix **N**)
- Conceptual-level O&M requirements (see Table 6-4 and BMP Operations and Maintenance Level of Effort in Appendix **O**)
- Sustainability considerations for BMP selection (see Sustainability Considerations for BMPs in Appendix **P**)
- Synergy with overall stormwater management approach.

Some additional considerations which may guide the alternatives analysis include (but are not limited to) the following details:

- <u>Space Availability</u> – The footprint needed depends on the BMP type. BMPs that replace project functional areas or are built underneath project functional areas are less susceptible to site constraints. A pervious pavement parking lot takes up no more room than a parking lot made from traditional pavement. Similarly, sub-surface storage can be placed under paved areas without requiring additional space.
- <u>Integration of BMPs into Development Footprint</u> - Designers should consider how the potential BMPs may affect site access or operations. For example, although a vegetated swale may replace the function of other surface or sub-surface conveyance facilities, it requires coordination with access routes and operational activities that may otherwise have taken place over the top of a piped conveyance. Alternately, the cost of sub-surface facilities may increase with anticipated structural loadings.
- <u>Costs</u> – Costs must be balanced when considering BMPs. The most integrated solution may not always be the lowest cost even if it saves space. For example, underground structural BMPs (e.g., detention vaults) may be incorporated underneath parking lots or other development without taking up additional site buildable area, but tend to be more costly than a surface facility. However, the land area savings may counteract some of those additional costs. Some BMPs that require a small space are relatively expensive (i.e., sand filter), or do not have high treatment capabilities compared to other BMPs (i.e., grassed swale). Note that some green infrastructure BMPs will likely displace undevelopable landscape buffers, thus minimizing the impact of the BMPs on available land area. The optimal balance between buildable area and cost may vary between projects depending on project constraints, priorities, and stormwater management goals.

6.3.9 Step 9: Select Site-Appropriate and Project-Specific BMPs

BMP(s) should be selected based on the outcome of the alternatives analysis. The conceptual-level design of the selected BMP(s) can be a helpful tool when working through Step 3.

6.4 BMP Design Requirements and Considerations

This section provides design requirements and considerations applicable to particular types of BMPs, as defined in the sections below. The designer must identify and characterize applicable detailed design parameters for the BMP(s) selected. The design criteria must be followed to achieve proper functionality of the BMP. The BMP fact sheets will aid in this process and contain design criteria that must be followed to achieve proper functionality of the BMP. Additional considerations required before completing detailed design are discussed below.

6.4.1 Setback Requirements

Setbacks are measured from the outer edge of the stormwater facility to the adjacent boundary, structure or facility. The following minimum setbacks shall apply as design criteria for infiltration BMPs:

- Sited at least 50 feet away from slopes steeper than 15 percent unless an alternative setback is established by a geotechnical engineer.
- Setback 5 feet from property lines.
- Setback 10 feet from building foundations.
- Sited 100 feet upslope of a drain field.

In addition, permeable pavement designed without an underdrain or impermeable membrane shall not be placed within 100 feet upgradient or 10 feet downgradient of a structural foundation. Swales and basins shall be setback 100 feet from slopes 10 percent or greater. Trenches and dry wells shall be setback 100 feet from slopes 20 percent or greater. Other BMP-specific setback requirements are included in the BMP fact sheets.

6.4.2 Health and Safety Hazard Requirements

BMPs shall be designed to manage the following health and safety issues, as applicable:

- BMPs that include open water surfaces and steep side slopes that may prohibit egress are a potential drowning hazard. If such BMPs are selected, the need for fencing shall be coordinated with the Port.
- Vegetated swales may be a vehicle hazard if they are alongside roads with insufficient width for vehicle maneuvering and recovery and have a steep slope. Swales shall not be used where they could impede emergency vehicle response.
- Vector control, specifically mosquito control, may be an issue if there will be standing water for more than a few days. For this reason, BMPs should be designed to completely drawdown ponded surface water in 48 hours or less and be designed to minimize stagnant conditions (drawdown times for subsurface storage in a BMP can be up to 72 hours).

6.4.3 Pretreatment Requirements

The goal of pretreatment is to extend the life and efficiency of the primary stormwater treatment facility by removing pollutants such as coarse sediment and debris, as well as oil and grease transported by stormwater runoff. Pretreatment can reduce clogging and BMP maintenance requirements of the main facility while centralizing more frequent maintenance activities to the pretreatment BMP. Pretreatment can be integrated within the primary treatment facility or provided as a stand-alone facility.

For infiltration BMPs, pretreatment is required to reduce sediment loading to the BMP to maintain the long term infiltration rate. Pretreatment BMPs approved by the Port include vegetated swales, vegetated filter strips, forebays, sedimentation manholes/vaults and hydrodynamic separation devices. The Port does not consider catch basin insert filters, alone, as adequate pretreatment devices for infiltration BMPs. If designers wish to implement BMPs others than those included in the DSM, a variance request is required.

A sediment forebay is a pretreatment facility intended to slow the flow of stormwater enough to allow coarse sediment and debris to settle out before entering the primary treatment facility. Forebays are often integrated within the primary treatment facility, but can be placed separately upstream. Dry extended detention basins, bioretention areas, vegetated swales, wet USCFs, wet basins, and media filters can be designed with a forebay. The recommended size of the forebay depends on the BMP and site-specific sediment loading factors. The BMP fact sheets provide information for the designer on whether a forebay is a required or optional pretreatment measure.

Pretreatment for distributed (small) facilities may be achieved using landscaped areas, curb cuts, catch basins, and hydrodynamic separators. Regional facilities that utilize detention or retention basins must use appropriately designed proprietary devices and/or engineered BMPs such as filter strips and biofiltration swales prior to discharge into the basin.

6.4.4 Requirements for Common BMP Design Elements

The sections below describe common components, media, and other design elements that may be incorporated into the design of various BMPs, where applicable, as well as specific design requirements that shall be met when these elements are incorporated into the selected BMP. Additional BMP-specific considerations for these design elements are provided in individual BMP fact sheets.

6.4.4.1 Aggregate

Aggregate generally refers to a uniform gravel mixture that is used for a number of different purposes in a BMP. Uses and their associated design criteria for Port facilities subject to this DSM are as follows:

- Infiltration Facilities – Aggregate is used in infiltration facilities to store water prior to percolation into underlying soil (such as infiltration trenches, dry wells, and infiltrating bioretention facilities). The specification for aggregate used in infiltration facilities shall be 1½ – ¾-inch washed drain rock.
- Treatment Facilities – Aggregate may be used in non-infiltrating facilities in low-flow channels, as underdrain bedding, or for storage. When it is used in this manner, the primary purpose is

flow storage and attenuation. The design criteria for aggregate used in non-infiltrating BMPs is ¾-inch washed drain rock.

- Conveyance – Aggregate may also be used in conveyance trenches to convey flows to BMPs or within different cells of a BMP (such as in sub-surface flow wetlands). The design criteria for aggregate used for conveyance is ¾-inch washed drain rock.

Aggregate may also be used for pervious pavement sub-base or slope stabilization, among other uses. In these cases, an engineer with knowledge of designing these features should supply the appropriate aggregate specifications.

6.4.4.2 Choke Stone

Choke stone is used in BMP applications to separate two different media layers and it is recommended instead of filter fabric in media filtration facilities because filter fabric tends to clog and may adversely affect BMP function. The design criteria for choke stone shall meet the requirements of ASTM D448 No. 8 or No. 89 washed stone.

6.4.4.3 Riprap

Riprap is a stone blanket used for energy dissipation of BMP inflows and outflows, to prevent erosion of BMP surfaces as well as downstream areas and slopes. Riprap is generally placed at the base of BMP inlet and outlet pipes to attenuate the velocities from influent and effluent flows. Riprap may consist of stones sized from the gravel range to small boulders, depending on the quantity of flow. The extent of the stone blanket also depends on the magnitude of flow, but typically varies from 2 inches to 24 inches in diameter (EPA 2013b).

6.4.4.4 Filter Fabric

If filter fabric is used within the BMP, it shall be a woven geotextile that meets the specifications in the City of Portland Standard Construction Specifications, Table 02320-1 or WSDOT Standard Specifications Section 9-33 for subgrade geotextile fabrics. Generally filter fabric facilitates clogging in the BMP which impedes infiltration and may otherwise adversely affect proper BMP function. For many applications, choking stone may serve the same function as filter fabric (e.g., separating two different media layers), and is the preferred alternative because it is less prone to clogging in a BMP design.

6.4.4.5 Diversion Structures for Off-Line BMP Treatment

Water quality BMP systems may be designed to divert a defined portion of the influent flow to an off-line water quality BMP for treatment via a diversion structure. The remaining flow continues to flow through the conveyance piping or channel and bypasses the BMP without receiving treatment. The diversion structure is sized based on the quantity of flow that needs to be captured in order to meet the specific BMP water quality capacity requirements (see Section 6.3.8.1). This flow can be calculated using hand/Excel calculations or more detailed hydraulic modeling.

6.4.4.6 Flow Splitters (Inlet Structure)

Flow splitters are generally used to deliver the water quality design flow rate or volume to a BMP while allowing the overflow to bypass during large events. The two most common types of flow splitters incorporate either a weir or an orifice. These structures are built into manholes and vaults to allow runoff flows up to the water quality design flow to be routed to a BMP facility. Flows that exceed the water quality design flow spill over the weir, or pass through an elevated orifice, and continue to a stormwater discharge point or downstream flood control facility. An orifice can also be used to divert the water quality design flow to the facility and allow higher flows to continue downstream. For both flow splitter types, flows entering the BMP facility should not exceed the water quality design flow rate by more than 10 percent, thus necessitating the design of sufficient bypass capacity. In addition, it is recommended that orifices smaller than 6 inches incorporate a removable screen to prevent pipe clogging, and that all weirs be made of corrosion resistant materials. However, the use of galvanized metal should be eliminated to the extent feasible to avoid the introduction of zinc into the stormwater.

6.4.4.7 Flow Spreaders

Flow spreaders are used in BMPs that receive influent via sheet flow. Flow spreaders temporarily detain inflow and discharge it such that runoff is uniformly distributed into the BMP. This prevents channelized flow that may be flowing to the BMP from causing erosion on the BMP surface. It is recommended that the top surface of the flow spreader be 6 inches above the surface of the BMP.

6.4.4.8 Emergency Overflow

The emergency overflow spillway or riser is a secondary outlet that is provided in basin-type BMPs. For an on-line basin, the main outlet pipe is typically designed to pass most of the flow, up to the 100-year, 24-hour event, with the provided freeboard. However, if a flow larger than the 100-year event occurs and/or two very large events occur in close succession, an emergency overflow spillway is needed to safely convey large flows downstream. The spillway shall be constructed with reinforced concrete. Adequate energy dissipation in the form of riprap or similar structures must be provided to slow large flows. The spillway shall allow for at least 12 inches of freeboard above emergency overflow water surface elevation (24 inches of freeboard is preferred).

An off-line basin shall be designed with an overflow spillway or riser designed to pass the 100-year 24-hour event peak flow directly to the downstream conveyance system or other acceptable discharge location. The minimum freeboard shall be 12 inches above the maximum water surface elevation over the emergency spillway.

6.4.4.9 Underdrains

Underdrains are located at the base of some BMP facilities and convey treated flows to the downstream storm drain system and/or outfall. Underdrains are typically made of slotted (preferred) or perforated PVC pipe with a minimum diameter of 6 inches, but may be sized larger as needed to convey larger flows. Underdrains must be placed with aggregate bedding of at least 1 foot on all sides, and have a minimum slope of 1 percent. Underdrains shall be installed with perforations facing down, to allow for treated water that is ponding in the bottom of the facility to enter into the pipe as the water level rises and drain downstream. A vertical cleanout pipe must be provided every 250 to 300 feet to allow for maintenance of the underdrain. Woody vegetation should not be placed near underdrains to avoid the intrusion of roots into the pipe, causing clogging.

6.4.4.10 Outlet Structures

An outlet control structure controls the flow leaving a BMP. There are several different types of outlets, as listed below, that may be configured as a single stage outlet structure or several outlet structures combined to provide multistage outlet control:

- Orifices
- Perforated risers
- Pipes/culverts
- Sharp-crested weirs
- Broad-crested weirs
- V-notch weirs
- Proportional weirs
- Siphons
- Combination outlets

For a single stage system, the outlet structure can be designed as a simple pipe or culvert. For multistage control structures, the outlet is designed considering a range of design flows. The design engineer should size the BMP and select an outlet type that meets the flow control and water quality control design objectives. More detailed information on sizing outlet control structures may be found in various hydraulic engineering design guidance manuals and textbooks.

Water quality, baseline flood protection, and channel protection flows are normally managed with smaller, more protected outlet structures such as reverse slope pipes, hooded orifices, orifices located within screened pipes or risers, perforated plates or risers, and V-notch weirs. Larger flows, such as overbank protection and extreme flood flows, are typically managed through a riser with different sized openings, through an overflow at the top of a riser (drop inlet structure), or a flow over a broad crested weir or spillway through the embankment.

A combination outlet such as a multiple orifice plate system or multistage riser is often used to provide adequate hydraulic outlet controls for the different design requirements (e.g., water quality and extreme flood protection) for stormwater detention facilities. Separate openings or devices at different elevations are used to control the rate of discharge from a facility during multiple design storms. The design of a combination outlet requires the development of a composite stage-discharge curve that reflects the sum of flows through all outlets on the multistage riser.

More details on BMP outlet structure design are included in the BMP fact sheets.

6.4.4.11 Engineered Soil Media

Soil amendments are an important design element for vegetated BMPs including bioretention areas, planter boxes, vegetated swales, filter strips, and green roofs. The amendment of soil media can enhance overall BMP performance through improved hydraulic performance, increased water quality treatment (by increasing the cation exchange capacity and/or number of sorption sites on the media), and decreased operations and maintenance needs.

Engineered soil media shall be designed to achieve the long-term hydraulic characteristics required for each BMP facility design and be capable of supporting desired plant growth. The recommended media is generally classified as loamy sand and shall have the following composition (by volume):

- 80 percent to 88 percent sand (e.g., meeting ASTM C33 specifications)
- 8 percent to 12 percent soil fines (in the form of topsoil)

- 1 percent to 5 percent organic matter (in the form of aged compost or shredded hardwood bark mulch). If compost is used as the source of organic matter, it shall be tested and determined to meet U.S. Composting Council specifications (2013). It is further recommended that the compost is certified by the US Composting Council's Seal of Testing assurance program.

Additional nutrients may be supplied to the vegetation in the BMP by adding a two- to three-inch layer of aged (at least 6 months) shredded hardwood bark mulch to the surface of the engineered soil media. The mulch will provide a slow-release source of plant nutrients as the product decomposes over time.

A key issue regarding the use of compost-amended media is that compost could result in the export of phosphorus from the BMP (at least during the early operational stages), which is problematic for BMPs that would discharge to the Columbia Slough because the slough is on the 303(d) list due to impairment caused by phosphorus. Consequently, the phosphorus index (P-index) of the engineered media shall be monitored and controlled to minimize phosphorus export from the BMP. The P-index provides an estimate of the plant-available phosphorus, which also correlates to the mobility of phosphorus and its potential to be exported from the BMP and be discharged to surface waters. The P-index of the soil media should be tested to ensure that it is between 10 and 30, which corresponds to a phosphorus concentration range of 7 mg/Kg to 23 mg/Kg in the media (as determined by the P-index test). A variety of test methods may be used to determine the P-index; Oregon State University recommends the Bray P1[27] soil test for western Oregon (OSU 2003). In addition, a primary factor in interpreting the desired P-index of a soil media is the bulk density. The expected bulk density of the loamy sand amendment described above shall be in the range of 1.6 grams per cubic centimeter to 1.7 grams per cubic centimeter.

6.4.5 Construction Considerations for Design

BMPs may require special considerations for construction that need to be incorporated into the design documents. It is important to avoid activities during construction that would prevent a BMP from functioning as it was designed over its lifetime. Designers should incorporate measures for addressing the following considerations in the design documents, as appropriate to the project:

1. Install all temporary erosion and sediment control practices (e.g., silt fence, inlet protection, check dams) prior to land disturbance. Refer to Section 4.9, Erosion and Sediment Control SWM standard for site construction phase erosion and sediment control requirements.
2. Grade and stabilize other areas of the site, not including the BMP, prior to BMP grading.
3. Excavate and grade the BMP to the elevation of the interface with existing ground specified in the construction documents. For infiltration BMPs, grading shall be accomplished using low-impact earth moving equipment to prevent compaction of the underlying soils. Wide-tracked, low ground-pressure vehicles such as trackhoes, small dozers and Bobcats are recommended. Care should be taken to avoid following the same path in and out of the BMP.

[27] The Bray P1 (or Bray-Kurtz P1) method is a colorimetric analysis that uses a dilute hydrochloric acid and ammonium fluoride solution as the extract.

4. For infiltration BMPs, in the event that sediment is introduced into the BMP, the sediment shall be removed prior to further BMP construction. Sediment washed into the BMP can seal permeable soils and significantly reduce their long-term infiltration capacity.
5. Loosen sub-material below infiltration BMPs using mechanical means such as a rototiller to encourage infiltration. Avoid soil compaction in these areas.
6. Install any structural or paved features (e.g., vaults, tanks, pervious pavement) and backfill with appropriate materials to ensure stability.
7. Install any conveyance features (e.g., underdrain and/or pipes) and backfill with aggregate material (e.g., gravel). Installation of drainage bed materials should be completed with appropriate lift depths for the material placed.
8. Backfill media materials (e.g., planting media, sand, other media blends) as specified in the construction documents. Installation of media materials should be completed with appropriate lift depths for the material placed.
9. Vegetate (seed and/or plant) and mulch BMPs as specified in the plans.
10. Remove temporary erosion and sediment control measures after the site is fully stabilized and upon inspection approval. Stabilize the entire drainage area prior to placing the BMP in operation.

Throughout the entire construction process, designers or Port staff should observe construction activities to ensure compliance with the construction documents. Improper installation related to facility dimensions and elevations, and underdrain elevations are examples of errors that may occur. In addition, construction of an impermeable geomembrane liner system requires an appropriate QA/QC protocol, which shall be signed by a professional engineer.

6.4.6 Operations and Maintenance Considerations for Design

Table 6-3 and the BMP fact sheets summarize high-level O&M considerations for various BMPs, to be used for planning and comparison purposes only. The basis for the O&M anticipated level of effort is summarized in Appendix **O**, O&M Level of Effort. O&M requirements are presented as “level of effort” rather than annual costs, due to potential variations in cost depending on whether O&M is performed by the Port, contractors, or other entities. Additionally, site-specific O&M requirements may deviate from the general requirements. O&M costs should account for local labor rates for maintenance staff and the level of effort required as documented in a project’s BMP O&M Plan.

The BMP fact sheets also identify BMP-specific O&M considerations, including specific O&M tasks and typical frequencies. An O&M Plan that establishes the minimum inspection, operation, and maintenance requirements for the BMP shall be submitted to the Port, and the Port will integrate the requirements into their overall O&M program. See O&M Plan submittal requirements in Chapter 3.

Every BMP installed must be accessible for maintenance, with consideration for access points by staff and particular vehicles or equipment. Both physical access and safety of the maintenance crews must be addressed in the BMP design. Access roads must be wide enough for equipment to get in, maneuver and get out. At PDX, stormwater facilities that require routine maintenance should be located in areas where the maintenance activities would not hinder or disrupt airport operations. If underground proprietary BMPs are proposed, there should be a contract with the vendor or trained contractor authorized by the vendor for annual or biannual maintenance.

6.4.7 Cost Considerations for Design

Table 6-3 and the BMP fact sheets summarize high-level capital cost information for various BMPs, to be used for planning and comparison purposes only. The basis for capital costs is summarized in Appendix **N**, BMP Capital Cost Estimation Methods. As previously discussed, Similarly, the basis for O&M requirements is summarized in Appendix **O**, O&M Level of Effort. Site-specific O&M requirements may deviate from the general requirements. O&M costs factor in local labor rates for maintenance staff and the level of effort required as documented in a project's BMP O&M Plan.

Capital costs for BMPs vary widely depending on BMP type, site constraints, and other factors. Capital costs should be developed using the most current cost information and will generally require obtaining current construction cost data from a reputable source, as well as vendor quotes for specific components (e.g., vaults, outlet structures, valves, etc.) and installation costs. Engineer's estimates for site investigations, permitting, design, and contingency or unexpected costs will also be needed and shall be separated from the costs for stormwater-related items. The following is a brief description of some major factors affecting costs for BMPs:

- Project scale and unit costs. Typically, stormwater controls can be built at much lower costs as part of a larger project rather than as stand-alone projects.
- Retrofits vs. new construction. These two scenarios exhibit very different costs, with retrofit costs being much higher and uncertain.
- Permitting requirements. Various permits may be needed from various agencies depending on the design and location, such as a grading permit, an erosion and sediment control permit, 401/404 certification, etc. Costs for preparing permit applications and fees should be considered in the capital costs.
- Flexibility in site selection, site suitability. Stormwater control cost can vary considerably due to local conditions (i.e., the need for traffic control, shoring, availability of work area, existing infrastructure and/or site contamination, etc.).
- State of the economy at the time of construction. Another consideration is the strength of a local economy when a control is bid and built. If work is plentiful, the work may be less desirable and the cost may rise due to less competition and scarcity of supplies, such as concrete, steel, and engineered media.
- Soil type/groundwater vulnerability. These will dictate whether infiltration methods can be used to dispose of excess runoff volumes on site, or whether additional storage and attenuation will be required.
- Planting vegetation. The availability of suitable plants and required level of planting planned for a particular control component will have a significant influence on costs, including irrigation and maintenance requirements.
- Existing soil contamination. The removal of soil classified as hazardous waste can drastically increase the costs of a project. Early site investigations should be made to determine whether removal and proper disposal of contaminated soils may be required.

6.5 Additional BMP Resources

6.5.1 Introduction to the BMP Fact Sheets

The BMP fact sheets provide additional considerations for the planning, selection, design, and implementation of individual BMPs, and should be used in conjunction with the content of this chapter, as well as the SWM standards in Chapter 4 that pertain to BMP sizing. The BMP fact sheets include minimum design criteria that must be achieved for each BMP to function properly and achieve compliance with the Port's DSM requirements. If a designer proposes a BMP design that does not meet applicable design criteria or SWM standards, a variance request must be submitted to the Port, as described in Chapter 3. In addition to required design criteria, the BMP fact sheets also include supplemental information, design options, and recommendations that can enhance the benefits and performance of the BMP. Design options and recommendations are suggested good practices that may be followed at the discretion of the designer. Deviation from recommendations and guidance does not require a formal variance request but should be discussed with the Port.

Sites that drain to impaired or sensitive receiving waters or that include onsite operations requiring additional treatment may need to implement measures that go beyond the minimum criteria provided in the fact sheets and in this chapter. These requirements will be defined by the Port as part of the project scope.

The BMP fact sheets are divided into three major sections. A description of structure of the fact sheets is provided below.

1. BMP Selection and Planning

- Table 1 in each BMP fact sheet provides an overview of BMP characteristics to assist with selection. It lists the primary and secondary functions, drawing on criteria included in Table 6-3 in this chapter. Targeted pollutants are also divided into primary and secondary pollutants. Primary pollutants are identified as having a "very high" or "high" pollutant removal efficiency per Table 6-3. Secondary pollutants are identified as having a "moderate" level of pollutant removal per Table 6-3. The other factors are based on the information in Table 6-4.
- The rankings of "low," "medium," and "high" for the relative BMP footprint (as a percent of the contributing tributary area) are as follows: low = ≤3 percent; medium = >3 to 10 percent; large = >10 percent. The cost and O&M level of effort is based on information in the supporting appendices. The cost refers to the capital cost per acre of impervious area treated by the BMP. The O&M level of effort refers to the annual number of maintenance hours needed to maintain a typical BMP.
- Functional Description: Provides a basic description of the BMP and how it performs its treatment or control function.
- Site Suitability and Limitations: Identifies factors such as soil characteristics and infiltration concerns that can make use of a specific BMP infeasible at a site (Table 2).
- Footprint Considerations: Generally describes the surface area requirements for the BMP and associated components as a percentage of the tributary area.
- Hazardous Wildlife Attractant Considerations: Discusses issues associated with the use of the BMP in areas subject to the SWM standard for Hazardous Wildlife Attractants (Section 4.7).

- General O&M: Identifies maintenance-related factors that should be considered during the BMP selection and design phase.
- Cost Considerations: Describes the major cost components such as BMP structural components and vegetation.

2. BMP Design and Implementation

- Overview of Design Criteria: The primary minimum design criteria are summarized in Table 3 of each BMP fact sheet. Additional required design criteria may also be included in narrative from in the subsequent sections of the fact sheet under BMP Design and Implementation; these sections also describe design options and recommendations that are not considered to be minimum design criteria but may enhance BMP performance.
- BMP Geometry: Some BMP fact sheets include additional information about the size, shape, and embankment slopes of the BMP.
- Soils Suitability: Some BMP fact sheets include additional information about how the condition of on-site soils could affect BMP performance.
- Groundwater Considerations: Some BMP fact sheets include additional information about how the groundwater conditions could affect BMP performance
- Considerations for locating the BMP on-line with runoff conveyance.
- Pretreatment Requirements: Includes requirements for forebays or other sediment capture devices that facilitate proper BMP function by reducing sediment loading.
- Major BMP Components: Describes BMP components such as outlet control structures, vegetation and growing media, and other required media layers.
- Design Schematic: Illustrates the primary BMP components in plan and profile views.
- Considerations for Future Expansion: Discusses whether the BMP design can be modified to accommodate future development in the tributary drainage area.

3. BMP Post-Design and Implementation

- Construction Considerations: Identifies construction-phase related factors that can affect long-term performance of the BMP.
- O&M Considerations: Summarizes typical maintenance activities that will need to be performed for the BMP (however actual O&M requirements will be site-specific and may deviate from the typical activities). The O&M Plans provided by the designer to the Port should include the maintenance activities identified in this section unless they are determined not to be applicable to the project.

The designer should also refer to Section 6.4 for additional BMP design requirements and considerations, including design components common to many BMPs.

BMP Fact Sheets

FS1- Dry Extended Detention Basin

FS2- Wet Basin

FS3- Subsurface Flow Wetlands

FS4- Bioretention

FS5- Infiltration Trench

FS6- Vegetated Swale

FS7- Vegetated Filter Strip

FS8- Media Filter

FS9- Underground Stormwater Control Facilities

FS10- Pervious Pavement

FS11- Building BMPS

FS12- Cartridge Filter

FS13- Oil/Water Separator

FS14- Hydrodynamic Separator

FS1- DRY EXTENDED DETENTION BASIN **FS1-1**

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FS6- VEGETATED SWALE **FS6-1**

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FS9- UNDERGROUND STORMWATER CONTROL FACILITIES FS9-1

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FS10- PERVIOUS PAVEMENT FS10-1

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FS13- OIL/WATER SEPARATOR **FS13-1**

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FS14- HYDRODYNAMIC SEPARATOR FS14-1

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FS1-DRY EXTENDED DETENTION BASIN

BMP SELECTION AND PLANNING

Photo Credit: Georgia Stormwater Management Manual

Table 1: Dry ED Basin Overview	
BMP Functions	*Primary:* • Peak Flow Control • Water Quality Treatment *Secondary*: • Flow Duration Control
Targeted Pollutants	*Primary*: • Nutrients • Bacteria *Secondary*: • TSS • Metals • Organics • Oil & Grease
Pretreatment	Required
Typical Wildlife Risk	High
Cost	$$
O&M Requirements	High
Tributary Area	>10 acres
Relative Footprint	Small-Medium

Functional Description

Dry extended detention basins (dry ED basins) do not have permanent pools and are designed to drain completely between storm events (Figure 1). The slopes, bottom, and forebay of dry ED basins are typically vegetated. Dry ED basins can also be designed for flow duration control and flood control by modifying the outlet control structure and providing additional detention storage. Dry ED basins could be implemented by the Port as regional treatment facilities.

Dry ED basins include a temporary open water surface that has the potential to create a hazardous wildlife attraction risk to PDX. The selection of a dry ED basin as a new stormwater BMP should be coordinated with the requirements and guidance in the PDX WHMP. Additional considerations for siting and design of these BMPs to manage wildlife risk are provided in the following subsections of this fact sheet.

Site Suitability and Limitations

The main suitability concern at PDX pertains to the potential for detention basins to attract waterfowl. Siting considerations as well as attention to design components such as appropriate drawdown times, vegetation, and other factors are critical when designing dry ED basins that will not be attractive to hazardous wildlife. In addition, compatibility with flood control basins should be considered when evaluating the use of a dry ED basin. Table 2 summarizes the site considerations for evaluating whether a dry ED basin would be appropriate at a specific location.

Table 2: Site Suitability Considerations for Dry ED Basins	
Soil Characteristics and Infiltration Concerns	• Slopes that exceed 15% require a geotechnical investigation • May be constructed on any NRCS HSG. May need to line basin if infiltration constraints are present
Groundwater	≥3 feet separation from bottom of the basin and seasonal high groundwater table
Wildlife Considerations	• New dry ED basins are prohibited in the PDX primary zone. They are allowed in the PDX intermediate zone provided certain requirements are met and are allowed in the secondary zone. • Comply with FAA ACs and PDX WHMP requirements for siting and design criteria
Tributary Area and Land Use	Dry ED basins typically best suited for tributary areas greater than 10 acres

Footprint Considerations

Dry ED basins are typically installed to treat larger drainage areas or regional areas, and will need adequate open space for siting. Typically a dry ED basin can be expected to require a footprint equivalent to 1 to 5 percent of the impervious portion of the tributary drainage area, but could vary depending on the site conditions (i.e., density of imperviousness) and size.

Dry ED basins shall incorporate a maintenance access road with adequate clearance for a maintenance vehicle into the design. Additionally, landscaping and safety setbacks are required to avoid trips or falls into the facility.

Wildlife Attractant Considerations

Dry ED basins may contain surface ponded water for up to 24 hours after large rain events, and also include vegetation. Thus they are considered to have a high risk for attracting hazardous wildlife. Various design modifications can be made to make basins less attractive to hazardous wildlife by reducing the visibility of standing water and selecting vegetation that would be compatible with the WHMP.

General O&M Considerations

Normal O&M considerations for dry ED basins mainly consist of clearing accumulated trash, debris, and sediment from outlets and forebay. If vegetation is included, management of plants will also be a regular O&M activity. Additionally, basin drain time and functionality of inlets and outlets should be inspected after major storms, and clearing of debris should be scheduled when it affects basin functionality. Maintenance of vegetation in-basin should also be regularly scheduled (see O&M considerations in subsequent section). Major maintenance, such as replacing/repairing embankments and inlets/outlets, should be needed infrequently.

Cost Considerations

Major cost components for BMP installation include site preparation (clearing vegetation, excavation, and grading), design and construction of embankments, purchasing and planting vegetation (seed, sod, or low-growing herbaceous perennials/shrubs), and purchasing and structural components (inlet and outlet structures and underdrain, where needed). Additional costs may include upstream pretreatment, if needed in addition to the facility forebay.

Typical maintenance cost components include debris and sediment removal from the forebay and main cell and potential replacement of vegetation. If other pretreatment BMPs are present, maintenance costs for those BMPs should also be considered.

BMP DESIGN AND IMPLEMENTATION

Overview of Design Criteria

Table 3 summarizes minimum design criteria for dry ED basins. More detailed information is provided in the sections that follow.

Table 3: Minimum Design Criteria for Dry Extended Detention Basins

Design Parameter	Unit	Design Criteria
Water quality volume	acre-feet	See Chapter 4 of the DSM
Drawdown time for WQ volume	Hours	36-48 (minimum-maximum)
Maximum depth (below freeboard)	ft	4
Minimum freeboard	ft	1 for off-line basins 2 for on-line basins
Maximum interior side slopes	H:V	3:1 2:1 where wildlife of concern
Minimum flow path length to width ratio	L:W	3:1 (at maximum water surface elevation)
Minimum orifice diameter	in	2 (Port-owned and operated facilities) 1 (private facilities)
Other		• The base of the facility shall be sloped at 1% minimum towards the orifice outlet • A low flow channel shall be provided to drain dry weather flows. The low flow channel shall have a minimum depth of 6 inches and width no greater than 5% of the basin bottom width

Considerations for Locating On-line with Runoff Conveyance and Providing Flood Control Capacity

Dry ED basins can be designed either on-line or off-line. If designed just for water quality treatment, it is recommended that the basin be off-line from runoff conveyance. For off-line basins, a flow diversion structure (i.e., flow splitter) is used to divert the water quality volume to the basin. For on-line basins, storm events exceeding the water quality volume will be routed through the basin and discharged from a primary overflow structure at rates that do not exceed predevelopment storm event peak flow rate for the required flood control storm event (e.g., 10-year storm, 100-year storm event). Storm events that exceed a specific design storm event (depending on the requirements) will exit the basin over an emergency spillway. If basins are designed as on-line facilities, they shall pass the appropriate flow without damaging the basin, and shall minimize re-entrainment of pollutants. In addition, flood control and water quality functions may be combined into one facility and an existing flood control basin can be retrofitted to provide water quality treatment. A combined facility can be designed to provide peak flow control for the 100-year event (or small flood control event, if required). Perforated risers, multiple orifice plate outlets, or similar multistage outlets are required for flood control retrofit applications to ensure adequate detention time for small storms, while still providing peak flow attenuation for the flood design storm.

Major BMP Components

Outlet Control Structure

- Dry ED basins shall be free-draining (no outflows should be required to be pumped).
- The outlet structure shall be designed to release the bottom 50 percent of the detention volume (half-full to empty) over 24 to 32 hours, and the top half (full to half-full) in 12 to 16 hours. Drawdown schemes that detain low flows for longer periods than high flows result in enhanced treatment of low flows (which comprise the majority of incoming flows). This type of design also allows for greater flood control capabilities.
- The outflow device (i.e., outlet pipe) shall be oversized (18-inch minimum diameter) to prevent bypass of flows through the emergency overflow. Recommended outlet structure options include:
    - Uniformly perforated riser structures
    - Multiple orifice structures (orifice plate)
    - Weir structures
- The outlet structure shall be placed in a catch basin, manhole, or vault and shall be accessible for maintenance.
- A primary overflow (a riser pipe connected to the outlet is typical) shall be sized to pass flows larger than the water quality design storm (if the dry ED basin is sized only for water quality) or to pass flows larger than the peak flow rate of the maximum design storm to be detained in the basin (i.e., 10-year event) without causing flooding of the contributing drainage area.
- If a multiple orifice structure is used, an orifice restriction (if necessary), such as an inlet grate or valve, shall be used to limit orifice outflow to the maximum discharge rates allowable for achieving the desired water quality and flow control objectives. Orifice restriction plates shall be removable for emergency situations.
- Orifices shall be protected within a manhole structure by a minimum 18-inch-thick layer of 1½- to 3-inch evenly graded, washed rock. Orifice holes shall be externally protected by stainless steel or galvanized wire screen (hardware cloth) with a mesh of ¾ inch or less. Chicken wire shall not be used for this application.

- An anti-seep collar shall be installed for the outlet or any other pipe that penetrates the basin embankment.
- Orifices less than 3 inches shall not be made of concrete. A thin corrosion-resistant material (e.g., stainless steel, high density polyethylene [HDPE], or PVC) shall be used to make the orifice plate; the plate shall be attached to the concrete or structure.
- An easily removable trash rack or rock pile shall be provided at the outlet to prevent clogging of the outlet and trash from being discharged from the dry ED basin. If a riser pipe outlet is used, it shall also be protected by an anti-vortex plate. If an orifice plate is used, it should be protected with an easily removable trash rack with at least 10 feet of open surface area.
- A maintenance drain valve is highly recommended to allow manual drainage of a basin in the event the outlet becomes clogged and fails to drain in the specified acceptable amount of time.

Embankments and Side Slopes

Embankments are earthen slopes or berms used for detaining or redirecting the flow of water and shall be designed by a civil engineer licensed in the State of Oregon and according to the guidance provided in the ODOT Hydraulics Manual (2011).

Emergency Spillway

An emergency overflow spillway is required to convey flows greater than the water quality volume, in the case that storage within the dry ED basin is occupied when such an event occurs.

- The spillway elevation shall be designed assuming the outlet structure is completely clogged to provide the most conservative spillway design.
- The spillway shall be designed to convey these extreme flows around the embankments and to discharge in the downstream conveyance system. Spillways shall be designed to protect the structural integrity of the embankments.
- The spillway subgrade shall be set at or above the specified overflow elevation (e.g., for 10-year storm event) of the control structure.
- The spillway shall be located in existing soil wherever feasible and shall be armored with riprap or other flow-resistant material that will protect the embankment and minimize erosion. The riprap shall be designed according to required standards and shall extend to the toe of each face of the embankment.

Energy Dissipation Structures

Energy dissipation shall be provided at dry ED basin inlets and outlet discharge points to prevent high velocity flows from causing erosion.

- Inflow velocities can be reduced by directing inflows through a pipe that passes through the side embankments rather than flowing down the sidewalls of the basin. The pipe outlet shall be at least 1 foot from the edge of the basin wall.

- Energy dissipation controls shall be constructed of sound material such as stones, concrete, or proprietary devices that are rated to withstand the energy of the influent flow, and shall be installed at the inlet to the sediment forebay. Flow velocity into the basin forebay shall be controlled to 4 feet per second (ft/sec) or less.
- Energy dissipation controls must also be used at the outlet/spillway from the detention basin unless the basin discharges to a storm drain or hardened channel.

Vegetation

Vegetation within dry ED basins provides protection from wind and water erosion and also provides additional water quality treatment benefits. Follow the requirements and consider the guidelines below when selecting and designing dry ED basin vegetation:

- The bottom and slopes of the dry ED basin shall be vegetated. A mix of erosion-resistant plant species that effectively bind the soil shall be used on the slopes and a diverse selection of plants that thrive under the specific site, climatic, and watering conditions shall be specified for the basin bottom. The basin bottom shall not be planted with trees, shrubs, or other large woody plants that may interfere with sediment removal activities (refer to Special Wildlife Considerations for exceptions). The basin shall be free of floating objects (unless they are part of an engineered wildlife control). Only native perennial grasses, forbs, or similar vegetation that can be replaced via seeding shall be used on the basin bottom.
- The facility area is equivalent to the area of the basin, including the bottom and side slopes, plus the 10-foot buffer around the basin. The emergent plant zone shall be at least 25 percent of the total basin water surface area.
- Landscaping outside of the basin is required for all dry ED basins and must adhere to the following criteria so as not to hinder maintenance operations:
  - No trees or shrubs may be planted within 15 feet of inlet or outlet pipes or manmade drainage structures such as spillways, flow spreaders, or earthen embankments. Species with roots that seek water, such as willow or poplar, shall not be used within 50 feet of pipes or manmade structures. Weeping willow (*Salix babylonica*) shall not be planted in or near detention basins.
- A landscape professional should be consulted for project-specific planting recommendations, including recommendations on appropriate plants, fertilizer, mulching applications, and irrigation requirements (if any) to ensure healthy vegetation establishment and growth.
- The planting design shall minimize solar exposure of open water areas. Trees and other appropriate vegetation should be located around the east, south, and west sides of the ED basin to maximize shading. This is to reduce the heat gain in water prior to discharge and to help the basin maintain a healthy and aesthetically pleasing ponded condition.

Pretreatment Requirements

Pretreatment shall be provided in the form of a sediment forebay or other engineered BMP. If a forebay is used, it may be constructed using an internal berm constructed out of compacted and stabilized embankment material, riprap, gabion, stop logs, or other structurally sound material.

- The forebay is recommended to be sized at approximately 10 percent of the design surface area of the basin, and should temporarily detain 5 to 10 percent of the total water quality volume. An additional 0.5 foot of depth, minimum, should be provided at the bottom of the forebay (beyond the 5 to 10 percent of the water quality design volume) to allow for sediment accumulation.
- The forebay shall have a minimum bottom width of 4 feet to allow for the required storage and maintenance access, and a flat bottom surface.
- The forebay outlet shall be offset (horizontally) from the inlet to the forebay to mitigate the potential for short-circuiting through the forebay.
- At the option of the designer, a gravity drain outlet from the forebay may be installed to allow complete drainage of the forebay. If used, the gravity drain should extend the entire width of the internal berm separating the forebay from the main basin, and an anti-seep collar shall be installed around the drain pipe.
- Permanent steel post depth markers shall be placed in the forebay to define sediment removal limits at 50 percent of the forebay sediment storage depth.

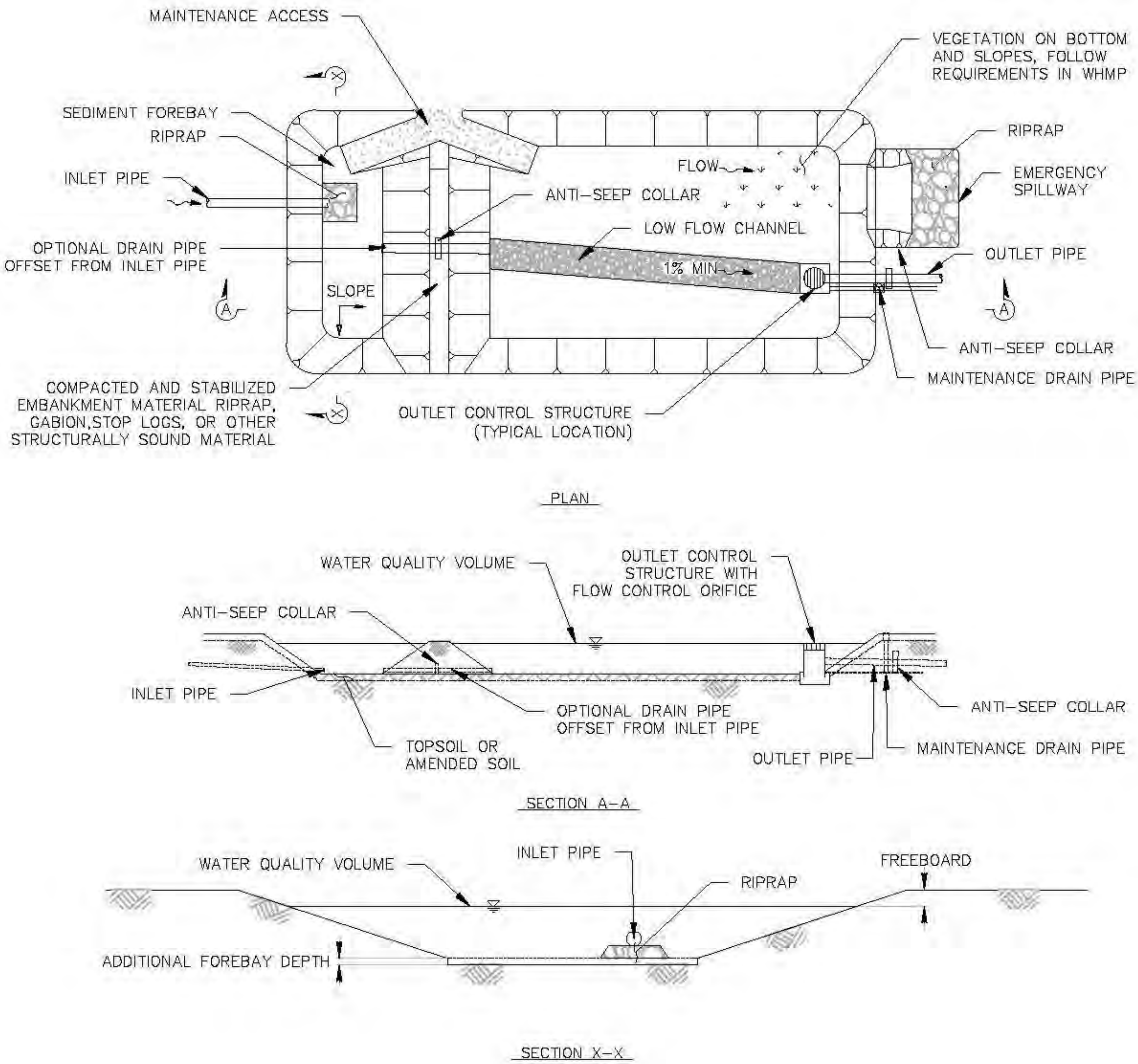


Figure 1: Dry Extended Detention Basin Schematic Plan and Section Views

Special Wildlife Considerations

In areas with wildlife concerns, designs that reduce the visibility of standing water shall be used. The forebay, which would have ponding water, should be excluded and other types of pretreatment BMPs such as vegetated filter strips, vegetated swales, and hydrodynamic separators, should be used to provide sediment reduction.

For basins that are planned for implementation within the PDX WHMP-defined intermediate and secondary zones (as basins are prohibited in the PDX primary zone), the following design features and dimensions shall be utilized:

- All vegetation in or around detention basins that provide food or cover for hazardous wildlife should be eliminated. Refer to PDX WHMP, Appendix J (List of Approved PDX plants).
- The WHMP requires that basins be completely covered to reduce visibility of the water surface to waterfowl. This may be accomplished by using dense shrub vegetation to hide open water (although shrub vegetation may hinder sediment removal). Floating ball covers have been shown to be effective at reducing the access and visibility of open water to waterfowl. Netting is not allowed on the intermediate zone because it does not reduce the visibility of the water surface.
- Avoid irregular-shaped basins (basins should have linear edges) and maximize length-to-width ratio (ideally, a 3:1 minimum length-to-width ratio).
- Steeper embankments and side slopes shall be used (2H:1V or steeper) to reduce the basin surface area and reduce the attractiveness to waterfowl.
- The width of the basin shall not exceed 30 feet at the riser elevation. This will reduce the take-off and landing area that waterfowl prefer.

Considerations for Future Expansion

Dry ED basins shall be designed for full build-out of the tributary drainage area. If development is phased, the dry ED basin may be oversized for the first phase(s) of development. If outlet control is a concern for early phase(s) of development, orifices and/or weirs can be sized initially for the flows from the first phase(s), and upgraded as tributary areas become more developed.

Alternatively, baffles or berms could be installed within the basin so that only a small area of the BMP is being frequently utilized until a larger treatment area is routed to it. This design option could reduce the maintenance costs if there is a long delay between development phases.

BMP POST-DESIGN AND IMPLEMENTATION

Construction Considerations

- The dry ED basin should not be put into operation until areas of exposed soil in the drainage area have been stabilized and catchment vegetation has been established. If used in a phased development area where construction is ongoing, appropriate construction controls must be provided upstream in areas where construction is occurring.
- The use of treated wood or galvanized metal anywhere inside the facility is prohibited.

O&M Considerations

In general, maintenance activities focus on vegetation control, removal of trash, debris, and sediment from forebay/pretreatment facility and basin bottom, and maintaining structural integrity of inlet and outlet structures.

Maintenance access shall be provided for all dry ED basin areas. Maintenance access roads shall be provided to the control structure and other drainage structures associated with the dry ED basin, and a ramp to the base should be constructed near the basin outlet (for main cell) and into the forebay. It is recommended the access roads be at least 8 feet wide with a slope of 10 percent or less. Weir and orifice structures must be accessible for maintenance; manholes or catch basin lids should be in or at the edge of the access road. To allow for access to underdrains and other outlet infrastructure, it is recommended that clean-out stand pipes with clear access to the underdrain be provided along the span of the underdrain within the facility (recommended at intervals of 250 to 300 feet).

Dry ED basins may need small backhoes or similar equipment to remove sediment from the forebay or the main cell of the basin. If underdrains are provided, cleaning requires manual or mechanical tools and/or pressurized water to be directed into vertical clean-out pipes (which shall be provided). If pressurized water is used, the resulting discharge should be diverted at the facility outlet to avoid discharge of sediment that has built up in piping infrastructure to receiving waters.

Table 4 summarizes typical dry ED basin O&M activities.

Table 4: Maintenance Activities and Frequency	
Schedule	**Activity**
As needed (frequently)	• Remove trash and debris from forebay and basin • Remove contamination visible from floatables (i.e., oil and grease) • Thin vegetation and mow lawns/grass (4" to 9" in height before mowing) • Remove noxious weeds
As needed (within 48 hours after storms >1”)	• Clean out sediment from inlets and outlets if it hinders functionality • Stabilize slopes using erosion control measures (i.e., rock reinforcement, planting of grass, compaction) • Verify drainage of basin according to design standards
At least annually	• Verify basin embankments are not settling; consult a civil engineer to determine the source of settling and whether corrective action is needed • Verify there are no observed flows through basin embankments; consult a civil engineer to inspect/correct if flows exist • Remove trees or large shrubs growing on downstream side of berms
Major maintenance (as needed)	• Remove dead, diseased, or dying trees/vegetation adjacent to facility or that may impair maintenance activities • Clean out underdrains • Replant bare areas • Revegetate slope areas that have become bare; regrade eroded areas prior to revegetation • Replace missing rock and soil at top of spillway • Remove sediment from forebay when capacity in forebay has decreased by 50% • Remove sediment from basin bottom when accumulation reaches 4 inches across main basin floor or fills sediment capacity by 30% • Regrade eroded areas • Eliminate standing pools of water in low flow channel • Repair damage to gates/fences surrounding facility

Other Key Information

This fact sheet shall be used in conjunction with the BMP selection and design information presented in Chapter 6 of the DSM.

FS2-WET BASIN

BMP SELECTION AND PLANNING

Photo Credit: CASQA

Table 1: Wet Basin Overview	
BMP Functions	*Primary*: • Water Quality Treatment • Peak Flow Control
Targeted Pollutants	*Primary*: • Sediment • Nutrients • Metals • Oil & Grease • Organics *Secondary*: • Bacteria
Pretreatment	See text
Typical Wildlife Risk	High
Cost	$$
O&M Level of Effort	High
Tributary Area	≥10 acres <10 acres for pocket wetlands
Relative Footprint	Small

Functional Description

Wet basins are constructed naturalistic basins, lakes, and wetlands that incorporate design elements such as sedimentation pools (forebays), permanent or seasonal treatment pools, vegetation, and outlet control structures to allow them to function as stormwater treatment facilities (Figure 1). Wet basins have been defined for this fact sheet to include retention basins, wetland basins, and pocket wetlands, which maintain a permanent pool. Wet basins can be either single-celled or two-celled to include a forebay and main basin. Cells are typically separated by an internal berm (generally of earthen material) or baffles (generally of refined materials such as metal, wood, fibers, plastics, or concrete). Stormwater typically enters the wet basin at the inlet and displaces treated stormwater from a permanent pool (known as "dead storage"), which then discharges to the outlet typically located at the opposite end of the basin (and in the second cell of a two-celled system).

The effectiveness of pollutant removal capabilities in wet basins depends greatly on the length of time runoff resides in the permanent pool, known as HRT. Longer HRTs provide additional treatment capacity as flows are exposed to treatment mechanisms for longer durations. Plug flow hydraulic conditions, which can be achieved via berm/baffle and outlet control design, can also improve wet basin treatment.

Detention storage (known as "live storage") can be designed above the permanent pool to provide flow control. For example, the detention storage can be designed to provide extended detention (ED) as would be provided for a dry detention ED basin (see FS1-Dry Extended Detention Basin fact sheet for detention requirements). Based on the desired design configuration and storage components, wet basins can provide a combination of (1) effective pollutant removal, (2) peak flow attenuation, and (3) limited volume reduction. Pollutant removal typically involves biological and chemical degradation, plant uptake, and removal of sediment and sediment-bound particles from dry weather and stormwater flows. In general, larger wet basins provide greater pollutant reduction.

Wet basins could be implemented by the Port as regional treatment facilities. Wet basins include an open water surface that has the potential to present a hazardous wildlife attraction risk at PDX and are therefore prohibited in the PDX primary and intermediate zones. The selection of a wet basin as a new stormwater BMP shall be coordinated with the requirements and guidance in the PDX WHMP. Additional considerations for siting and design of these BMPs to manage wildlife risk are provided in the following sections of this fact sheet.

Site Suitability and Limitations

Table 2: Site Suitability Considerations for Wet Basins	
Soil Characteristics and Infiltration Concerns	• Can be constructed on any NRCS Hydrologic Soil Group • In highly permeable soils (such as Hydrologic Soil Groups A and B), a liner may be needed to maintain a permanent pool
Contamination Concerns	A liner shall be used if soil or groundwater contamination is a concern
Groundwater	A high groundwater table may assist permanent pool maintenance
Minimum Flows	Year-round base flow may be needed to maintain the wet basin and circulation within the basin
Wildlife Considerations	• Prohibited in PDX primary and intermediate zones • Allowed in PDX secondary zone, but should not create any new attractants or enhance any existing attractants • Comply with FAA ACs and PDX WHMP for siting and design criteria
Tributary Area and Land Use	• ≥ approximately 10 acres (except pocket wetlands are generally for 5 to 10 acre drainage areas) • Tributary areas less than 10 acres may require a small outlet orifice for rate control that is prone to clogging • It is typically not cost-effective to construct basins for smaller tributary areas
Downstream Sensitivity	Wet basins may pose a risk to cold water systems downstream as water discharged from wet basins is typically warmer than the receiving body

Footprint Considerations

Larger wet basins typically provide greater pollutant removal as they provide greater residence time in the BMP. In general, 2 to 3 percent of the tributary area is required for wet basins, or approximately 0.3 acre of surface area for each acre-foot of permanent pool volume.

Wildlife Attractant Considerations

Wet basins contain a permanent pool of water and thus shall not be used where there is a concern for attracting hazardous wildlife, as described in the PDX WHMP.

General O&M Considerations

In general, maintenance activities focus on vegetation control, sediment and pollutant deposition, and structural integrity.

Cost Considerations

Major cost components for wet basins include site preparation (clearing, grubbing, excavation and grading, preserving and amending topsoil if required), planting media, planting vegetation (seed and/or appropriate perennials/shrubs), and flow control components such as the liner, inlet and outlet structures, and the berms and baffles.

Major maintenance costs may include supply of additional water to maintain a permanent pool, removal of trash and debris, clearing vegetation, and dredging sediment.

BMP DESIGN AND IMPLEMENTATION

Overview of Design Criteria

Table 3 summarizes the minimum design criteria for wet basins and associated design components. More detailed design and information is provided in the sections that follow.

Table 3: Minimum Design Criteria for Wet Basins

Design Parameter	Unit	Design Criteria
Water quality design volume	acre-feet	See Chapter 4 of the DSM See Chapter 6 of the DSM for a discussion on sizing BMPs with a permanent wet pool
Drawdown time for extended detention (over permanent pool)	hours	12-48 (minimum-maximum)
Maximum side slopes	H:V	3:1 2:1 where wildlife attractant issues are of concern
Minimum inlet to outlet flow path length-to-width ratio	L[1]:W[2]	4:1 (at mid water surface elevation) for single-cell systems 3:1 (at mid water surface elevation) for two-cell systems
Permanent pool volume for single-cell design[3]	cf	≤ 4,000
Minimum basin depth	ft	4 for deepest part of treatment system
Maximum basin depth	ft	8 for either forebay or main basin
Minimum sediment storage depth	ft	6 inches for either forebay or main basin
Minimum freeboard	ft	1 for off-line basins 2 for on-line basins
Maximum HRT	Days	7 (dry weather)

[1] Flow path length = distance from inlet to outlet at mid-depth
[2] Flow path width = (average top width + average bottom width)/2 at mid-depth
[3] Designs requiring greater permanent pool volume shall use a two-celled design

Setbacks

- The water surface of the wet basin must be 20 feet from any structure or property line.
- The toe of the wet basin berm embankment must be a minimum of 5 feet from any structure or property line.

Considerations for Locating On-line with Runoff Conveyance

On-line wet basins shall have an emergency overflow spillway to prevent overtopping of the walls or berms should blockage of the riser occur. The minimum freeboard shall be 1 foot (but preferably at least 2 feet) above the maximum water surface elevation over the emergency spillway.

Provided adequate surcharge storage, a wet basin may be designed for flood control (up to the 10-year event). In this case, the detention storage above the permanent pool (see permanent pool design below) is sized to attenuate peak flows, and functions like a dry extended detention basin.

Major BMP Components

Basin Geometry and Configuration

Wet basins designed to function like wetlands shall be designed using a two-cell system, with a forebay for sediment load reduction and a wetland basin for treatment. Using varied depths is encouraged to mimic wetland functions and control the spreading of wetland vegetation. Depths for wetland basins shall range between 0 and 4 feet, with the center of the wetland at 4 feet deep and an average depth of approximately 1.5 feet plus the sediment storage depth.

For all wet basins, teardrop- or wedge-shaped basins have been shown to prevent dead zones that can develop in corners of rectangular basins. For safety considerations, incorporation of a bench along the margins of the permanent pool should be considered. Shallow side slopes of 3:1 or shallower will enhance public safety and avoid the need for fencing.

Berms, baffles, and embankments can be used within the wet basin to create a varied topography to encourage meandering of water, create a diverse array of pool depths, and encourage diversity in plant communities. Design requirements for wet basin berms, baffles, and embankments shall include:

- Extending all berms and baffles across the entire width of the wet basin and tying them into the side slopes.
- Constructing berms and embankments of compacted soil (95 percent minimum dry density), placed in 6-inch lifts.
- Constructing berms by excavating a key equal to 50 percent of the berm embankment cross sectional height and width.

- Utilizing submerged baffles or retaining walls in place of a berm. Interior berms submerged 1 foot under the permanent basin may have side slopes of 2:1. Taller berms shall be 3:1.
- Ensuring berms 6 feet or less in height have a minimum top width of 6 feet. Berms with maintenance access shall be 15 feet wide on top.

Permanent Pool Design

The depth of the permanent pool will vary based on the design functions (e.g., if the wet basin is designed to function like a wetland and/or if detention storage is incorporated). Basins deeper than 6 feet shall include a recirculation device to prevent stagnation and low dissolved oxygen conditions.

Wet basins shall be designed to maintain a permanent pool equal at least 20 percent of the water quality design volume plus 5 percent for sediment accumulation. If extended detention is provided above the permanent pool, the surcharge volume shall make up the remaining 80 percent of the water quality volume.

A water balance for permanent pool design should show that there will be adequate water supply to maintain the permanent pool, even during a drought year with 50 percent of normal precipitation. If the sum of base flow and precipitation is less than the sum of infiltration, evaporation, and outflow, designers should consider lining the bottom of the wet basin and/or providing additional water to maintain the target pool elevation.

A liner for the purposes of maintaining the permanent pool can consist of concrete, clay, or various types of membranes (e.g., rubber, plastic). Clay and membranes are generally covered with protective media (such as soils) to prevent damage to the liner. Some common liners include HDPE and linear low density polyethylene, PVC, geosynthetic clay liner, synthetic rubber, and flexible polypropylene.

Inlet and Outlet Control Structures

Design considerations for wet basin inlet and outlet control structures include the following:

- The inlet should include energy dissipation to reduce resuspension of sediment.
- The inlet should be submerged with the invert a minimum of 2 feet from the basin bottom (not including sediment storage volume). The top of the inlet should be submerged at least 1 foot.
- The outlet pipe should be sized to pass the on-line water quality design flow.
- Outlet structure designs may include:
  - Grated catch basins
  - Perforated standpipes placed within an embankment or strapped to a manhole
  - Manholes with a birdcage
  - Outlet pipes with back-sloped or turn-down elbows.

- A bypass or shutoff valve to take the wet basin offline may be beneficial for maintenance purposes.
- An 8-inch gravity drain that allows water to pass from the forebay to the treatment basin during maintenance activities should be installed at least 6 inches below the top of the water surface and 18 inches above the bottom of the basin.

Vegetation

The following design considerations should be taken into account for wet basin vegetation:

- Wet basins designed for phosphorus control should not incorporate plants within the basin (phosphorus is released from plants as they die back seasonally).
- Shallow basins of 3 feet or less should incorporate emergent wetland vegetation to stabilize sediment.
- Use of tall trees along the west and south side of the basin can provide shading and reduce evaporative loss.
- Trees and shrubs shall not be planted within 15 feet of inlets, outlets, or manmade structures that are part of the wet basin.
- The emergent plant zone shall be at least 25 percent of the total basin water surface area.
- The emergent plant zone shall be no greater than 25 percent of the total basin water surface area in pocket wetland or extended detention basins, and no greater than 50 percent of the total basin water surface area in constructed wetlands.

Pretreatment Requirements

Pretreatment is not required for a single-cell wet basin with a 4:1 or greater flow path length-to-width ratio. For a two-cell wet basin design, pretreatment is achieved in the forebay. Two-cell systems using a broad-crested weir, rather than a pipe, to connect adjacent basins are recommended to improve treatment capabilities by promoting plug flow hydraulic conditions and maximizing HRT.

The first pool should contain between 25 and 35 percent of the total water quality volume and should retain water year-round unlike the main treatment pool, which is allowed to go dry during the dry months of the year.

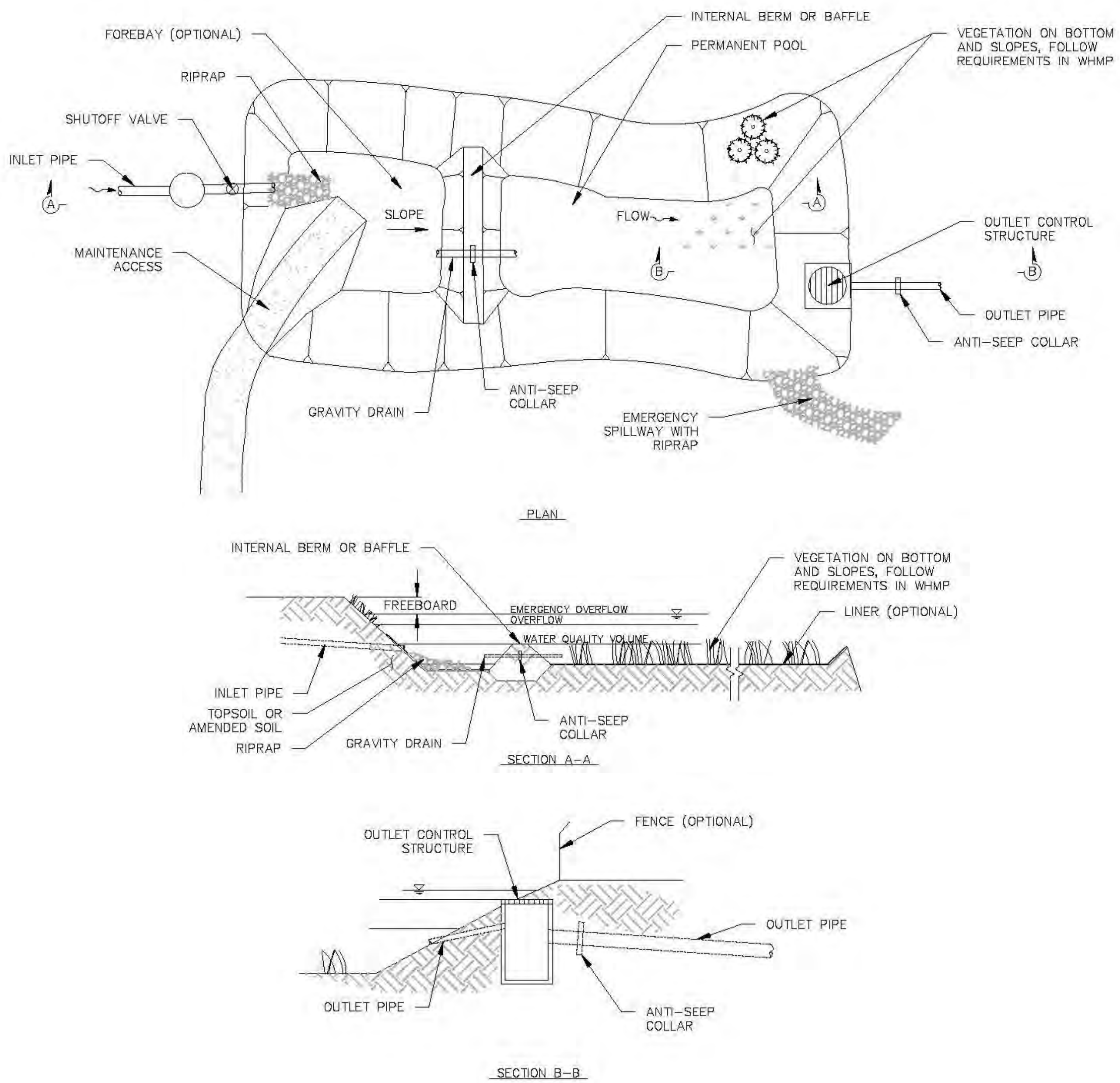


Figure 1: Wet Basin Schematic Plan and Section Views

Considerations for Future Expansion

Wet basins shall be designed for full build-out of tributary drainage area. No modifications for phased development can be made for pocket wetlands due to their small tributary drainage area. For other types of wet basins, if development is phased, the basin may be oversized for the first phase(s) of development. If outlet control is a concern for early phase(s) of development, orifices and/or weirs can be sized initially for first phase(s), and upgraded as tributary areas become more developed.

Alternatively, baffles or berms could be installed in a single-cell basin so that only a small area of the BMP is being frequently utilized until a larger treatment area is routed to it. This design option could reduce the maintenance costs if there is a long delay between development phases.

Special Wildlife Considerations

Wet basins shall not be used where there is a concern for attracting hazardous wildlife, as described in the PDX WHMP.

BMP POST-DESIGN AND IMPLEMENTATION

Construction Considerations

- Orienting the basin along the prevailing summer wind direction can enhance wind mixing within the basin.
- If the wet basin will be lined to maintain the permanent pool, sediment that has accumulated during the construction process may be used to meet the liner requirements if the soil is appropriate.
- Erosion control measures and/or good vegetation cover shall be implemented when the basin is initially filled.
- The use of treated wood or galvanized metal anywhere inside the facility is prohibited.

O&M Considerations

In general, maintenance activities focus on vegetation control, sediment and pollutant deposition, and structural integrity. A site-specific O&M plan shall be developed. Maintenance access shall be provided to reach both the inlet and outlet structures and be wide enough to allow for appropriate maintenance equipment. Maintenance routes shall not exceed 10 percent in slope. Table 4 summarizes common wet basin O&M activities.

Table 4: Maintenance Activities and Frequency

Schedule	Activity
As needed (frequently)	• Remove trash and debris in the middle and at the end of the wet season • Remove contamination visible from floatables (i.e., oil and grease) • Remove noxious weeds • Mow grass, remove clippings, and rake leaves as needed
As needed (within 48 hours after storms >1")	• Clean out sediment from inlets and outlets • Stabilize slopes using erosion control (i.e., rock reinforcement, planting of grass, compaction) • Verify drainage of basin according to design standards
As needed (infrequently)	• Remove algae mats when algae coverage is more than 20% of the water surface • Regrade and repair eroded areas, places where settling or piping is apparent, and locations where there are signs of animal burrowing • Slope areas that have become bare should be revegetated and eroded areas should be regraded prior to revegetation • Replace missing rock and soil at the top of the spillway • Remove sediment from forebay when sediment volume exceeds 10% of the basin volume • Remove sediment from basin bottom when accumulation reaches the sediment storage volume
Semi-annually	• Wet basins with plants should be inspected twice a year, during the wet and dry season to observe plant establishment • Inspect basin for animal burrows
Annually	• Wet basins without plants should be inspected annually • Thin vegetation by removing dead vegetation and overgrowth (preferably between June and September) • Verify basin embankments are not settling; consult an engineer to determine the source of settling and whether corrective action is needed • Verify there are no observed flows through basin embankments; consult an engineer to inspect/correct if flows exist

Other Key Information

This fact sheet shall be used in conjunction with the BMP selection and design information presented in Chapter 6 of the DSM.

FS3-SUBSURFACE FLOW WETLANDS

BMP SELECTION AND PLANNING

Photo Credit: University of New Hampshire Stormwater Center

Table 1: SSF Wetlands Overview	
BMP Functions	*Primary*: • Water Quality Treatment
Targeted Pollutants	*Primary:* • Sediment • Nutrients • Metals • Oil & Grease • Organics *Secondary:* • Bacteria
Pretreatment	Required
Typical Wildlife Risk	Low (unvegetated) High (vegetated)
Cost	$$$
O&M Level of Effort	High
Tributary Area	Variable
Relative Footprint	Medium

Functional Description

Subsurface flow (SSF) wetlands are engineered systems that can include a combination of wetland vegetation, porous media, and the associated microbial and physiological ecosystems (Figure 1). SSF wetlands have been defined for this fact sheet to include both systems that incorporate surface vegetation and engineered bioreactors. In the latter, biologically active environments with distinct oxygen-free (anaerobic) zones provide pollutant removal via oxidation-reduction mechanisms and microbial processes. A fixed film bioreactor, for example, may use the surface area of crushed rock media to filter, metabolize, and degrade pollutants with the growth of bacterial biofilms. In all cases, the wetland system is designed so that the water level in the bed does not exceed the top of the media layer and become exposed. SSF wetlands differ from natural wetlands by optimizing the treatment processes through a more planned and controlled process.

One of the challenges of systems that incorporate surface vegetation is that there may be insufficient dry weather flows to maintain moisture within SSF wetlands year-round due to periodic or seasonal lack of water, causing vegetation to be dormant during that time. Wetland vegetation can reestablish itself naturally when flows are restored, but the presence of surface vegetation can attract wildlife

The water surface in SSF wetlands can be designed to remain below the top of the media layer so there is no open water surface, thus lowering the potential to be a hazardous wildlife attraction risk at PDX. The engineered bioreactor wetland design has no surface vegetation, and thus greatly reduces the potential for the BMP to be an attractant to hazardous wildlife. The selection of SSF wetlands as a stormwater BMP shall be coordinated with the requirements and guidance in the PDX WHMP.

Site Suitability and Limitations

Table 2: Site Suitability Considerations for SSF Wetlands	
Soil Characteristics and Infiltration Concerns	• Any known geotechnical hazards require a geotechnical investigation prior to siting SSF wetlands in the vicinity of hazards • Can be constructed on all NRCS Hydrologic Soil Groups • Liners may be needed to maintain a saturated zone and to minimize interaction with underlying groundwater
Groundwater	≥ 3 feet separation between the seasonal high groundwater table and bottom of wetland
Wildlife Considerations	For SSF wetlands containing vegetation, comply with FAA Advisory Circulars and PDX WHMP requirements for siting and design criteria
Contamination Concerns	A liner shall be used if soil or groundwater contamination is a concern

Site-specific investigations shall be conducted to evaluate soil conditions and underlying infiltration rates. Losses via infiltration into subsoils shall be minimized and a liner may be used at the base of the SSF wetlands when needed. If an engineered bioreactor wetland design is used, a liner system shall be used regardless of soil type.

Subsurface wetlands shall be designed to minimize interaction with underlying seasonal high groundwater table. Improper wetland elevations may result in groundwater seepage into the facility, resulting in a permanent pool above the media surface that may attract hazardous wildlife.

Footprint Considerations

The surface area required for SSF wetlands as a percentage of tributary area varies depending on the configuration of the SSF wetland and treatment requirements. Generally, SSF wetlands have a medium footprint (i.e., up to 10 percent) as a percentage of the tributary impervious area treated.

Wildlife Attractant Considerations

SSF wetlands do not contain standing water, which reduces the potential to attract hazardous wildlife. The bioreactor type of SSF wetland does not contain vegetation and therefore poses a low risk of attracting hazardous wildlife. For SSF wetlands containing vegetation, repellent vegetation consistent with the WHMP shall be used.

General O&M Considerations

General O&M requirements are related to water level control, and maintaining the capacity of the SSF wetland to promote water quality treatment. Regular maintenance consists of vegetation management, sediment, and trash and debris removal. The functionality of inlets and outlets should be monitored after major storms. Major maintenance (replacing/repairing embankments and inlets/outlets) should be needed infrequently. More detailed O&M requirements are summarized in the following section on BMP Design and Implementation.

Cost Considerations

Major capital cost components include site preparation (clearing, grubbing, excavation and grading, and soil preparation), planting and/or treatment media, vegetation and flow control components such as the liner, and inlet and outlet structures.

Unknown site conditions such as the composition of subsurface materials (which can increase excavation costs), unknown underground utility locations (which require the SSF wetlands to be relocated), and unknown construction and monitoring costs (due to limited information available) are factors that may increase construction costs.

BMP DESIGN AND IMPLEMENTATION

Overview of Design Criteria

Table 3 summarizes minimum design criteria for SSF wetlands. More detailed design and information is provided in the sections that follow.

Table 3: Minimum Design Criteria for SSF Wetlands		
Design Parameter	**Unit**	**Design Criteria**
Water quality design flow rate or volume	cfs/cu-ft	See Chapter 4 of the DSM See Chapter 6 of the DSM for a discussion on sizing BMPs
Minimum hydraulic residence time	days	1
Stormwater drawdown time for equalization storage (if provided)	hr	12-48
Minimum gravel media depth	in	24
Longitudinal bottom slope	%	0.5-1
Length-to-width ratio	L:W	1:1 (minimum)
Maximum cell width	ft	200 (larger design widths may be divided into multiple 200 ft wide cells)
Minimum cell length	ft	50

Considerations for Locating On-line with Runoff Conveyance

SSF wetlands shall be designed as off-line systems designed to only treat the water quality design volume or flow rate.

Major BMP Components

Wetland Geometry and Configuration

Design considerations for SSF wetland geometry include the following:

- The depth of the gravel bed shall not be greater than ¼ of the bed length to promote plug flow through the length of the SSF wetland.
- The total bed length should be less than 10 times the bed width, but greater than 0.5 times the bed width.
- The average depth of media in the wetland treatment area is recommended to be from 12 to 24 inches. The maximum design water depth within the media is recommended to be 16, with a minimum of an additional 4 inches of media provided as freeboard to minimize the likelihood of water reaching the surface.
- Wetlands can be more effective when designed as multiple cells in series, rather than as a single large cell. This prevents short-circuiting of flows by redistribution between the outlet of one cell and the inlet of the next cell. Three or more cells are generally recommended. Cells can also be designed in parallel, with some cells initially off-line, to allow for expansion of tributary area.

Wetland Media

The stormwater treatment media within SSF wetlands can provide a combination of functions, including supporting vegetation, collecting and distributing flow at the inlet/outlet, providing surface area for microbial growth, and filtering and trapping pollutants. Wetland media design considerations include the following:

- If the wetland media will support vegetation, the uppermost layer of the media shall be conducive to root growth by providing sufficient void space to allow for vegetation establishment.
- Media in a vegetated SSF wetland treatment zone shall be between 0.75 and 1 inch in diameter to minimize the potential for clogging. To minimize settling, a Mohr's hardness of 3 or higher is recommended if available locally.
- Treatment media within an engineered bioreactor wetland is recommended to be ¾- to 1½-inch crushed rock.

Inlet and Outlet Zones

The inlet and outlet zones are designed with larger media to evenly distribute and collect flows without clogging. The use of gabions (wire rock baskets used for bank stabilization) may be used to simplify construction. Inlet and outlet zone design considerations include the following:

- Media in the inlet and outlet zones shall be between 1.5 and 3 inches in diameter to minimize clogging and shall extend evenly from the top to the bottom of the facility.
- It is recommended that the inlet zone extend across entire the width and be approximately 6 feet long; the outlet zone should be approximately 3 feet long to accommodate the variable design length of the treatment zone.

Design Considerations for Slopes

- The bottom surface of the wetland shall be gently sloping to allow for low velocity flow along the length of the channel while not causing ponding or stagnant water. The bottom surface shall be graded to eliminate low spots, channels, or side-to-side sloping.
- The top surface of the media shall be level to allow for planting, if applicable, and routine maintenance.

Design Considerations for Piping

- Inlet piping shall be designed to minimize the potential for short-circuiting, clogging of the media, and even flow distribution.
- To evenly distribute influent flows over the width of the SSF wetland, incorporation of reducing tees or rotatable 90-degree elbows are recommended. Piping with distributed orifices can also be used to distribute influent flows within the wetland and/or between distributed cells. The orifices shall be evenly spaced at a distance approximately 10 percent of the SSF wetland cell width.
- For underground engineered bioreactor wetlands, all piping shall have a minimum of 3 feet cover to the surface.

Vegetation

Vegetation selected for use in SSF wetlands shall be active colonizers, have considerable biomass or stem densities that can achieve the desired velocity gradient and enhanced treatment, and be composed of a mix of species that will provide coverage over the range of water depths encountered. For SSF wetlands at PDX, refer to the Wildlife Safety Considerations section below.

Berms

Berms that are external to SSF wetlands are constructed to prevent unregulated flow releases from the wetland area. For aboveground SSF wetlands, internal berms are designed to augment flow distribution between cells, if designed with more than one cell.

- Berm width shall be wide enough to provide for service vehicle access.
- The maximum side slopes created by the berms shall be 3H:1V (slopes of 2H:1V can be used where liners or erosion control blankets have been installed).
- Freeboard for aboveground facilities should not be required for the main cell, as typically these systems are designed to receive metered flows from a detention facility (basin, tank, or vault) that will not exceed the design flow rate through the system (i.e., designed off-line). The forebay or detention cell that captures diverted flows should have freeboard to allow for bypass of flows if needed.

Liners

Liners may be required below the treatment media layer in SSF wetlands to prevent infiltration or interaction with underlying soils or groundwater.

- Geotextile fabric shall be placed beneath the liner if the subgrade contains sharp stones.
- Geotextile fabric or a sand layer shall be placed on top of the liner if crushed rock is used in the SSF wetland system.
- For underground engineered bioreactors, the entire treatment cell shall be enclosed in an appropriately designed liner system.

Pretreatment Requirements

SSF wetlands shall have a pretreatment facility to reduce the sediment load to the inlet and prevent media clogging. Some potential pretreatment practices include grassy swales, vegetated filter strips, proprietary devices, or sediment forebays.

For subsurface engineered bioreactors, additional pretreatment or the addition of a substrate to the flows may be needed to create enhanced treatment conditions within the treatment cell. This may include the addition of electron donors to modify the oxidation-reduction potential or a carbon source to feed bacteria. If anaerobic conditions are present in the treatment media, a reoxygenation system may be needed prior to discharging the treated water to the outlet.

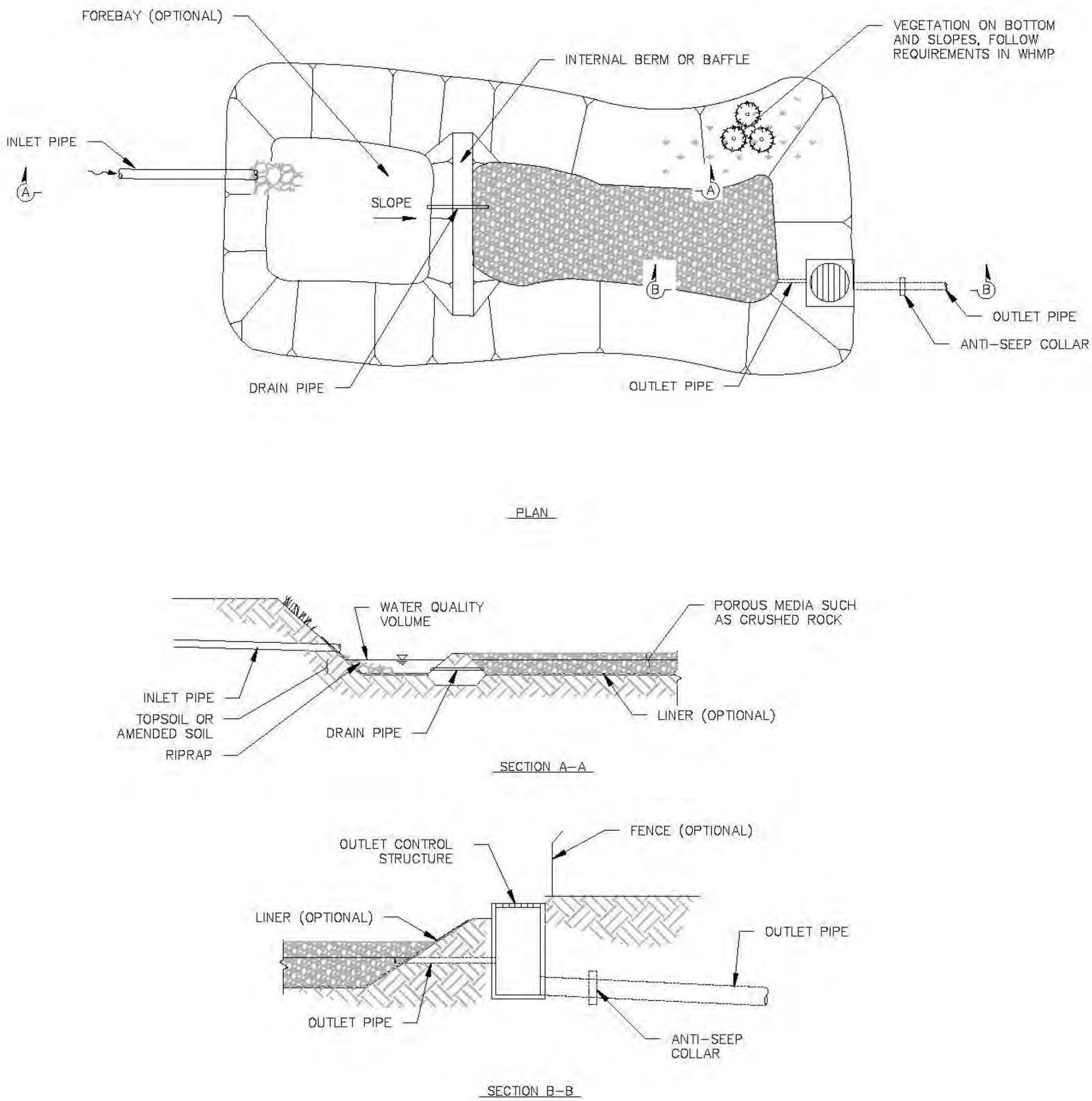


Figure 1: SSF Wetland Schematic Plan and Section Views

Considerations for Future Expansion

It is typically recommended that SSF wetlands be designed for full build-out of tributary drainage areas. However, a multicell system could include unused cells that are installed in a parallel configuration and placed on-line following additional build-out of the tributary area.

Wildlife Safety Considerations

SSF wetlands that incorporate surface vegetation shall follow the requirements in the WHMP. Vegetated facilities shall not be used in the PDX primary zone. The bioreactor wetland design has no surface vegetation, and thus eliminates the potential for the BMP to be an attractant to hazardous wildlife.

BMP POST-DESIGN IMPLEMENTATION

Construction Considerations

Avoid compaction of SSF wetland-engineered media during construction and grade SSF wetlands to attain uniform longitudinal slopes. The wetland shall not be put into operation until areas of exposed soil in the contributing drainage area have been sufficiently stabilized. Berms shall be wide enough to get heavy equipment into the construction area.

O&M Considerations

In general, maintenance activities focus on vegetation control, inlet and outlet performance, and monitoring of water levels. SSF wetland operation is primarily passive and requires little intervention by the operator.

Adequate access must be provided to safely enter and inspect the facility via maintained paths, gates, ladders, and covers. Access to each compartment of the SSF wetland is required. Access must allow for visual inspections of the inlet, media, and outlet, in addition to access to the bottom of the unit. Maintenance access shall be wide and supportive enough for typical maintenance equipment. Maintenance routes shall not exceed 10 percent in slope.

Table 4: Maintenance Activities and Frequency

Schedule	Activity
As needed (frequently)	• Perform periodic inspections and remove trash and debris • Remove sediment
As needed (within 48 hours after storms >1")	• Perform inspections to ensure proper wetland function. • Verify water levels in the wetland do not reach the media surface • Clean out sediment from drains, inlets, and pipes
Twice Annually (end of wet season and prior to the beginning of wet season)	• Inspect inlet and outlet structures • Manage vegetation to remove undesirable species, maintain appropriate heights, and replant bare areas
Annually	• Inspect and repair internal and external berms • Perform intermittent flooding/drying (if needed) • Clean treatment media of deposited sediment, pollutants, and/or byproducts

Other Key Information

This fact sheet shall be used in conjunction with the BMP selection and design information presented in Chapter 6 of the DSM.

FS4-BIORETENTION

BMP SELECTION AND PLANNING

Photo Credit: Geosyntec Consultants

Table 1: Bioretention Overview	
BMP Functions	*Primary*: • Water Quality Treatment • LID/GI • Peak Flow Control • Volume Reduction *Secondary*: • Flow Duration Control
Targeted Pollutants	*Primary*: • TSS • Metals • Organics • Nutrients • Bacteria • Oil & Grease
Pretreatment	• Required for regional facilities • Recommended for distributed facilities but not required
Typical Wildlife Risk	High*
Cost	$$
O&M Level of Effort	Medium
Tributary Area	<5 acres
Relative Footprint	Medium

Functional Description

Bioretention facilities are landscaped shallow depressions or basins that are constructed with engineered media and vegetation to capture and filter runoff (Figure 1). These facilities may also be referred to as bioretention basins, rain gardens, curb extensions, or infiltration planters. They are volume-based BMPs that are designed to filter out sediment and associated pollutants through a variety of physical, biological, and chemical treatment mechanisms. Where conditions are conducive for infiltration, bioretention facilities can also provide volume reduction and removal of pollutants via physical sorption and exclusion. Where full infiltration of the water quality design volume is not feasible, bioretention facilities can be designed with an underdrain to partially infiltrate runoff or function as a flow-through, media filtration facility, with minimal volume reduction.

Bioretention facilities are typically located directly adjacent to contributing impervious drainage areas. Bioretention facilities may be implemented as distributed BMPs by using several small facilities at intervals along a roadway or impervious surface, each of which treats a small tributary area. They may also be used as regional treatment facilities (bioretention basins), where stormwater is collected from a larger tributary area and conveyed to a single large facility.

Site Suitability and Limitations

Table 2: Site Suitability Considerations for Bioretention Facilities	
Soil Characteristics and Infiltration Concerns	• If the BMP is designed for infiltration, generally appropriate only for hydrologic soil groups A and B due to the required long-term design infiltration rate. • In any case where an infiltration constraint (i.e., groundwater contamination, slope stability concerns) is present, lined flow-through facilities must be used. • Facilities designed with an underdrain may be located in hydrologic soil groups C and D. A raised underdrain may be used to promote "partial" infiltration. • Bioretention areas located within 50 feet of a sensitive steep slope (>25%) shall incorporate an underdrain. A geotechnical investigation shall be performed to address the potential effects of infiltration on the steep slope if a bioretention area without an underdrain is sited within 200 feet of the slope or hazardous landslide area.
Groundwater	• For a flow-through or partially infiltrating facility, there shall be ≥3 feet of separation between the bottom of the facility and the seasonal high groundwater elevation. • For a facility designed to fully infiltrate the water quality volume, there shall be ≥5 feet of separation between the bottom of the facility and the seasonal high groundwater elevation.
Wildlife Considerations	• Use of bioretention facilities at PDX within the primary or intermediate zones requires approval by the Port wildlife management staff. • Comply with FAA Advisory Circulars and PDX WHMP requirements for siting and design criteria.
Tributary Area and Land Use	• Distributed bioretention facilities typically treat areas < 1 acre. • Bioretention basins may be used for treating drainage areas up to 5 acres. However, in some cases they could be designed as regional facilities treating much larger areas.
Contamination and Other Concerns	Bioretention is not appropriate for drainage areas where hazardous materials or fuels are used, stored, or transported, unless adequate source controls including spill control measures, and sufficient pretreatment (e.g., oil/water separator) is provided.

Footprint Considerations

Generally, bioretention can be expected to require a footprint equivalent to 4 to 10 percent of the tributary drainage area, but footprint requirements could vary depending on the site conditions as well as whether or not the facility is designed to infiltrate the water quality volume or is designed as a flow-through facility.

Footprint considerations also include the area needed for pretreatment of the runoff through the incorporation of vegetated swales, sediment forebays, or other pretreatment BMPs. Depending on the type of pretreatment selected, the overall footprint could be increased by up to 50 percent. Regional bioretention basins typically need to incorporate a maintenance access road with adequate clearance for a maintenance vehicle into the design, whereas distributed facilities set into sidewalks or walkways may need minimal additional footprints for maintenance access.

Wildlife Attractant Considerations

Bioretention facilities may contain surface ponded water for up to 24 hours after large rain events, and also include vegetation; thus, they are considered a moderate concern for wildlife. Small distributed facilities are less likely to attract wildlife than regional bioretention basins. As such, reduced ponding depth and/or repellent vegetation may need to be considered in the design when these facilities are proposed for an airport site. Refer to the Stormwater Management Standard for Hazardous Wildlife Attractants in Chapter 4 of the DSM for more information.

General O&M Considerations

Normal O&M requirements for bioretention facilities consist of vegetation management (e.g., pruning), media and mulch layer maintenance, and removing accumulated trash, debris, and sediment. Additionally, the inlet, outlet, and media bed are typically inspected after major storms for signs of limited functionality and/or erosion. Major maintenance, which mainly consists of replacing or adding vegetation, media and/or mulch, should be needed infrequently. More detailed O&M requirements are summarized in the following section.

Cost Considerations

Major cost components for BMP installation include:

- Site preparation (clearing vegetation, protection of the infiltration area, excavation and grading).
- Purchasing the planting media mix, purchasing and planting vegetation (seed, sod, or low-growing herbaceous perennials/shrubs), and purchasing structural components (inlet and outlet structures, and gravel and underdrain, where needed).
- Engineered and proprietary pretreatment devices.

Operational costs are minimal as there are typically no utilities, chemicals, or regular labor costs. Some operational costs may be associated with sampling and monitoring of performance. Typical maintenance cost components include debris and sediment removal and potential replacement of media and/or vegetation. If other pretreatment BMPs are present, maintenance costs for those BMPs should also be considered.

BMP DESIGN AND IMPLEMENTATION

Overview of Design Criteria

Table 3: Minimum Design Criteria for Bioretention Facilities		
Design Parameter	**Unit**	**Design Criteria**
Water quality volume	cu-ft	See Chapter 4 of the DSM
Minimum design infiltration rate[1]	in/hr	0.5 (underdrain needed if less than this)
Design filtration rate (for systems with underdrains)	in/hr	2
Maximum ponding depth	ft	• 1 (0.5 recommended) • The maximum ponding depth may need to be decreased where wildlife is a concern
Minimum freeboard above ponded storage	ft	1
Minimum media depth	ft	1.5
Maximum drawdown time for surface ponding	hr	24
Maximum drawdown time for gravel storage layer	hr	< 72
Underdrain	--	• Required for facilities that cannot fully infiltrate the water quality volume (design infiltration rate < 0.5 in/hr) • Required for facilities located within 50 feet of a sensitive steep slope (> 25%)
Maximum interior side slopes of ponded storage	H:V	3:1
Maximum influent velocity	ft/sec	1
Other		The base of the facility shall be flat.

[1] *The minimum design infiltration rate required to infiltrate the water quality volume. For lower design infiltration rates, the bioretention area shall be designed for partial infiltration (i.e., with a raised underdrain to promote some infiltration) or no infiltration of the water quality volume, depending on the design infiltration rate.*

Considerations for Locating On-line with Runoff Conveyance

Where the design infiltration rate is ≥ 2.4 in/hr, a bioretention facility can be designed to provide complete infiltration for flood control up to the 10-year event and can be configured as an on-line facility. In this case the facility shall be designed with ponding and freeboard allowances for large flows. Additionally, vegetation shall be selected with consideration of periods of inundation. On-line facilities shall be designed with an overflow route that can safely convey overflows to the downstream conveyance system or other acceptable discharge point. Where design infiltration rates are less than 2.4 in/hr, it is recommended that bioretention facilities be designed as off-line facilities, because clogging of the facility could be exacerbated by passing higher flows (and sediment) above the water quality volume through the facility.

Major BMP Components

Vegetation and Growing Medium

Vegetation that does not require mowing, can withstand both wet and dry periods, and can prevent erosion is recommended for bioretention facilities. Vegetation shall be provided on the surface area of the facility, including bottom and side slopes, and within a 10-foot buffer around the basin (typically a grass buffer is appropriate). Where vegetation is not appropriate, side slopes shall be protected against erosion using other means.

- Refer to the PDX WHMP Appendix J for a list of approved PDX plants.
- Vegetation shall be planted during a time of year when the plants can be established with minimal irrigation; however, supplemental irrigation may be needed until plants are established. Plants shall be selected that thrive under normal rainfall conditions, so that long-term irrigation during dry periods is not needed. Plants shall also be appropriate for the amount of sunlight at the site (for example, select shade-tolerant plants for use under tree canopies and in areas shaded by buildings or other structures).
- It is recommended that the planting density achieves a minimum of 70 percent coverage after two years; however, the ultimate planting density will depend on the system design.
- A bioretention planting medium shall be used that supports long-term infiltration and healthy vegetation. The bioretention mixture shall consist of 80 to 88 percent sand (e.g., meeting ASTM C33 specifications), 8 to 12 percent soil fines (in the form of top soil), and 1 to 5 percent organic matter (in the form of aged compost or shredded hardwood bark mulch) by volume. If compost is used as the source of organic matter, it shall be tested and determined to meet U.S. Composting Council specifications. It is further recommended that the compost be certified by the U.S. Composting Council's Seal of Testing assurance program. Onsite top soils may be used as a component of the media mix provided onsite soils are tested to ensure they have the appropriate grain size and organic matter content and do not contain any existing contaminants. The phosphorus index (P-index) of the engineered media shall be monitored and controlled to minimize phosphorus export from the BMP.
- A mulch layer is recommended for inclusion in bioretention facility design. The mulch layer is applied on top of media mix at a maximum depth of 2 to 3 inches. Mulch shall be shredded and free of all weeds, soil, roots, and other material that is not bole or branch wood and bark (hemlock bark is recommended by the City).

Outlet Components

- The maximum drawdown time for the ponding layer shall be 24 hours and the overall drawdown time (ponding plus media pores) of the facility shall be less than 72 hours.
- The underdrain shall be slotted PVC pipe, laid in a herring bone pattern and backfilled with approved granular drain backfill material.
- The underdrain diameter shall be ≥ 6 inches.

- The underdrain must drain freely (sloped to a minimum of 0.5 percent) to an acceptable discharge point in the storm drain system. It may be connected to another bioretention cell as part of a cascading treatment system.
- Clean-out risers with diameters equal to the underdrain pipe shall be connected to the underdrain from all lateral branch connectors (connector pipes typically spaced at equivalent intervals of 10 feet for small distributed facilities) and spaced at no more than 250 to 300 feet for regional facilities to provide maintenance access and an observation port to monitor dewatering rates.
- An overflow device shall be implemented at the top of the ponding depth. A vertical PVC pipe or an overflow riser (≥ 6 inches in diameter to allow for cleaning and maintenance) may be used. The inlet to the riser shall be screened to prevent floating mulch and debris from entering the pipe and prevent from tampering.

Pretreatment Requirements

Pretreatment is generally recommended for all bioretention facilities and is required for regional facilities to attenuate flows and provide sediment and coarse solids reduction.

- Pretreatment for distributed (small) facilities may be achieved using landscaped areas, curb cuts, catch basins, and hydrodynamic separators.
- Regional facilities (bioretention basins) shall use appropriately designed proprietary devices and/or engineered BMPs such as filter strips and vegetated swales prior to discharge to basin. Alternatively, the basin could be designed with a forebay.

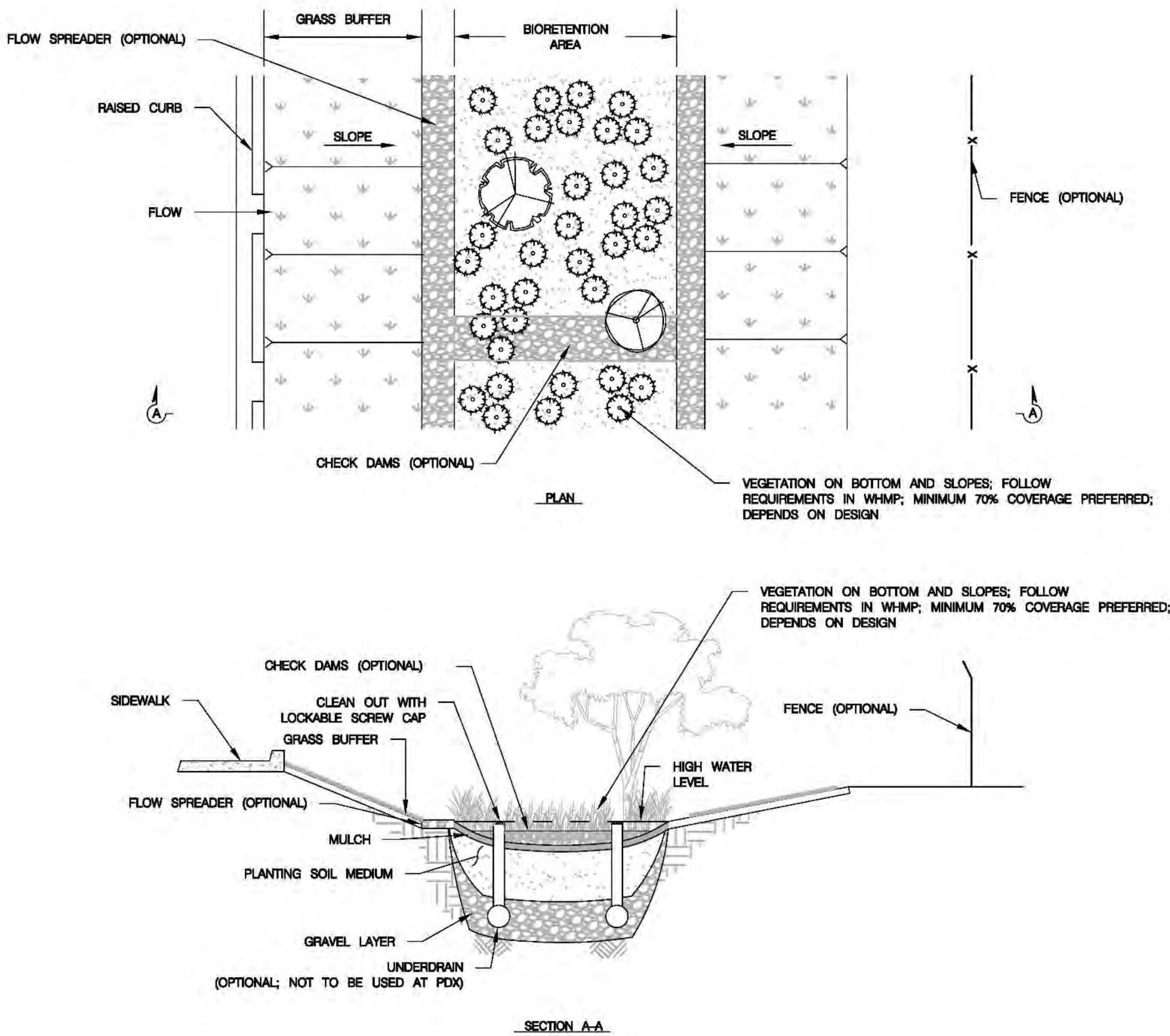


Figure 1: Bioretention Schematic Plan and Cross Section Views

Special Wildlife Considerations

- Refer to the Stormwater Management standard for Hazardous Wildlife Attractants in Chapter 4 of the DSM for more information.
- To reduce the attraction by hazardous wildlife, the BMP may be designed with steeper embankments, narrower/longer configurations, shrub vegetation, fences, or other installations that disrupt sight lines and reduce comfort and habitat suitability for hazardous wildlife (primarily waterfowl).
- Bioretention areas are allowed in the PDX secondary zone. Bioretention areas are allowed in the PDX primary and intermediate zones provided they are designed as flow-through facilities that drain completely to a subsurface facility.
- Refer to the PDX WHMP Appendix J (List of Approved PDX Plants).
- Properly designed bioretention facilities shall not have ponded water for more than 24 hours. This reduces the potential for growth of emergent vegetation that attracts wildlife.

Considerations for Future Expansion

As the tributary drainage area to distributed facilities is small, the entire drainage area should be developed and stabilized before the BMP is put into operation as heavy sediment loading will damage the BMP.

Regional bioretention basins with underdrains may be modified to accommodate phased development in the tributary drainage area by modifying the outlet design. One option would be to design the outlet with a removal orifice plate that can be changed with a larger diameter orifice upon complete build-out. Another option would be to have an adjustable upturned outlet structure that controls the flow rate. Alternatively, baffles or berms could be installed so that only a small area of the BMP is being frequently utilized until a larger treatment area is routed to it. This design option could reduce the maintenance costs if there is a long delay between development phases.

BMP POST-DESIGN AND IMPLEMENTATION

Construction Considerations

- Compaction of the base and sidewalls of facilities that are not designed as lined flow-through facilities shall be avoided during construction.
- The use of treated wood or galvanized metal anywhere inside the facility is prohibited.
- The bioretention facility shall not be put into operation until areas of exposed soil in the drainage area have been stabilized and catchment vegetation has been established.

O&M Considerations

Proper O&M is necessary for bioretention facilities to maintain proper design functionality. General maintenance activities focus on vegetation control, erosion prevention and control, inlet and outlet maintenance, and removal of accumulated sediment.

Distributed and small bioretention basins require only manual equipment (e.g., rake, shovel, etc.) to carefully remove debris and sediment and maintain vegetation. Larger facilities may need small backhoes or similar to remove sediment. Backhoes may also be needed for replacement of mulch and/or media (infrequent). If backhoes are used, they shall not be driven across media surface, as this will cause compaction that will adversely affect the potential to infiltrate runoff. Cleaning underdrains requires manual or mechanical tools and/or pressurized water to be directed into vertical clean-out pipes. Cleanout water shall not be discharged to the stormwater drainage system.

Maintenance access is required for all bioretention facilities. The entire bioretention surface shall be accessible, as well as the outlet structure and underdrain pipes. For larger bioretention basins, an access road shall be provided as needed to allow for maintenance of the media surface, outlet infrastructure as well as any pretreatment BMP or forebay. For distributed bioretention facilities, adequate space shall be provided on all sides to allow for safe maintenance of bioretention surfaces and underdrains. Traffic controls may be required for maintenance operations completed on distributed BMPs located on sidewalks or in roadway medians. To allow for access to underdrains and other outlet infrastructure, clean-out stand pipes with clear access to the underdrain shall be provided within the facility.

Table 5 summarizes typical bioretention facility O&M activities.

Table 5: Maintenance Activities and Frequency	
Schedule	**Activity**
As needed (frequently)	• Perform periodic inspections for trash and debris and remove as needed • Irrigate as recommended by a landscape professional
As needed (within 48 hours after storms >1 inch)	• Inspect inlet and pretreatment area for accumulated sediment and remove excess sediment as needed • Inspect for pools of standing water, which may be indicative of media clogging or outlet maintenance needs
Twice annually or as needed (end of wet season and prior to beginning of wet season)	• Inspect for erosion of media surface • Inspect for damage to vegetation, thin vegetation, and replant/reseed bare areas as needed • Remove noxious weeds without the use of herbicides or pesticides
At least annually	• Fill eroded ruts or rills with gravel or media • Clean and reset flow spreaders (if present) as needed to restore original function • Analyze soil if elevated phosphorus or nitrogen is of concern • If mulch is used, replace annually where metal deposition is high (2-3 years otherwise)
Major maintenance (as needed)	• Repair structural damage to flow control structures, including inlet, outlet, and overflow structure • Clean out underdrain(s) and outlet structure of accumulated sediment • Regrade and revegetate to repair damage from severe erosion/scour channelization and to restore sheet flow • Photographs taken before and after major maintenance is encouraged

Other Key Information

This fact sheet shall be used in conjunction with the BMP selection and design information presented in Chapter 6 of the DSM.

FS5-INFILTRATION TRENCH

BMP SELECTION AND PLANNING

Photo Credit: Washington State DOT Aviation Stormwater Design Manual

Table 1: Infiltration Trench Overview	
BMP Functions	*Primary:* • Volume Reduction • LID/GI *Secondary:* • Water Quality Treatment • Peak Flow Control • Flow Duration Control
Targeted Pollutants	*Primary:* • TSS • Metals • Organics • Nutrients • Bacteria • Oil and Grease
Pretreatment	Required
Typical Wildlife Risk	Low
Cost	$$
O&M Level of Effort	Medium
Tributary Area	≤2 acres
Relative Footprint	Medium

Functional Description

Infiltration trenches are long, narrow, stone-filled trenches used for the collection, temporary storage, and infiltration of stormwater runoff to groundwater (see Figure 1). Infiltration trenches may be designed with a shallow depression at the surface, but the majority of runoff is stored in the void space within the underlying gravel and infiltrates through the sides and bottom of the trench.

An infiltration trench would be considered a UIC system under federal regulations (specifically, a Class V Injection Well) if the trench is deeper than its largest surface dimension (i.e., width or length). UICs must be registered with the Oregon DEQ and classified as exempt, authorized by rule, or authorized by permit to be used as a stormwater BMP. DEQ has set minimum criteria for UICs, which can be found on the DEQ website at http://www.deq.state.or.us/wq/uic/akuthorization.htm. As described in Chapter 4 of the DSM, the Port has a policy that does not allow the creation of new UICs unless no other options are feasible and a variance is requested. Because infiltration trenches designed following the criteria in this fact sheet will be larger at their widest surface point than they are deep, and would not contain any perforated pipes or drain tiles to distribute and/or facilitate subsurface fluid infiltration, they would not be classified as Class V injection wells (USEPA 2013).

Site Suitability and Limitations

Infiltration trenches may only be used where it is feasible to infiltrate the entire water quality volume. Table 2 summarizes the various site suitability considerations for infiltration trenches.

Table 2: Site Suitability Considerations for Infiltration Trenches	
Soil Characteristics and Infiltration Concerns	• Do not locate where infiltrated water may affect the stability of downgradient structures, slopes and embankments • Use on slopes exceeding 15% require a geotechnical investigation • Generally appropriate only for hydrologic soil groups A and B due to the required long-term design infiltration rate • Infiltration trenches are not allowed in the Columbia South Shore Well Field Wellhead Protection Area
Groundwater	≥5 feet separation from bottom of trench and seasonal high groundwater table
Tributary Area and Land Use	≤10,000 square feet of impervious area
Contamination Concerns	• Not appropriate if hazardous chemicals/materials are stored within the drainage area unless adequate source controls are implemented • Not appropriate in areas with contaminated soil or groundwater

Soil suitability is a critical component of infiltration trench placement and design. The minimum required design infiltration rate of 0.5 in/hr precludes siting the BMP on hydrologic soil groups C and D. Site-specific infiltration testing shall be conducted and siting approved for infiltration facilities by the Port. The BMP size shall be determined using a site-specific design infiltration rate that applies an appropriate factor of safety (to account for a decrease in the infiltration rate over time due to factors such as compaction and clogging) to the measured short-term infiltration rate measured at the BMP location.

If the design infiltration rate of the underlying soil is ≥2.4 in/hr, runoff discharging to the infiltration trench shall first be treated by another water quality treatment BMP prior to discharging to the trench. Additional treatment is needed to protect groundwater quality as limited pollutants will be removed as the runoff infiltrates through the trench media.

Footprint Considerations

The surface area required for infiltration trenches as a percentage of tributary impervious area varies depending on site soil characteristics and slopes as well as the trench design (e.g., trench depth). However, generally the surface area required to achieve the trench design infiltration rate is approximately 3 to 10 percent of the tributary drainage area. Although infiltration trenches require a medium footprint, they can fit into narrow linear areas at a site.

Infiltration trenches designed as on-line facilities typically have higher measured site infiltration rates than off-line facilities (per the recommendations in this fact sheet for on-line versus off-line facilities). Therefore, on-line facilities have the capacity to pass larger storms, but may not require significantly larger footprint areas due to increased infiltration capacity of the trench. However, depending on the siting of the trench, an additional footprint area of 1 to 2 percent of tributary drainage area may be required for on-line facilities.

Wildlife Attractant Considerations

As linear treatment facilities that do not result in significant ponding above the surface when influent flow rates are less than the trench's capacity, infiltration trenches are less likely to attract hazardous wildlife than other types of infiltrating facilities in an airport environment. The surface of an infiltration trench is typically not vegetated; however, if it is desirable to use grasses as a surface cover, the vegetation selection shall be consistent with the Port's Wildlife Hazard Management Plan to reduce potential hazards.

General O&M Considerations

General O&M requirements are related to maintaining the infiltration capacity of the trench. There is a tendency for infiltration trenches to lose effectiveness over time due to clogging, if not properly constructed or maintained. Regular maintenance consists of cleaning clogged components, removing trash and debris, and performing periodic inspections to ensure the trench is functioning properly. Major maintenance (tilling of subgrade, decommissioning and/or replacement, etc.) should be needed infrequently. More detailed O&M considerations are summarized in the Design and Implementation section.

Cost Considerations

Major capital cost components include site preparation (clearing vegetation, protection of the infiltration area; excavation and grading; and structural components (inlet and outlet structures and backfill aggregate material).

Unknown site conditions, such as the composition of subsurface materials (which can increase excavation costs) and unknown underground utility locations (which require the trench to be relocated) are factors that may increase construction costs.

Operational costs are minimal as there are typically no utilities, chemicals, or regular labor costs. Some operational costs may be associated with sampling and monitoring of performance. Typical maintenance cost components include weed and sediment removal and potentially replacement of aggregate backfill material.

BMP DESIGN AND IMPLEMENTATION

Overview of Design Criteria

Table 3 summarizes the minimum design criteria for infiltration trenches. More detailed design information is provided in the sections that follow.

Table 3: Minimum Design Criteria for Infiltration Trenches

Design Parameter	Unit	Design Criteria
Water quality volume	cu-ft	See Chapter 4 of the DSM
Minimum Design Infiltration Rate[1]	in/hr	• 0.5 • The infiltration trench shall be sized using the design infiltration rate. An appropriate safety factor shall be applied to the field-measured short-term infiltration rate to obtain the design infiltration rate (see Chapter 6 of the DSM)
Drawdown time for design WQ design volume	hours	10 minimum < 48 maximum
Pore space of aggregate material	%	30-40
Longitudinal slope (swale bottom)	%	≤ 3
Aggregate depth	in	Minimum of 18 inches (see also maximum trench depth)
Minimum trench width	in	24
Maximum trench depth	—	As needed to maintain a minimum 5-foot separation from the groundwater table
Ratio of trench depth to largest surface dimension	—	To avoid classification as a Class V injection well under the Federal UIC program, the infiltration trench shall not be deeper than its largest surface dimension
Pretreatment	—	Required to maintain long-term infiltration capacity
Other		The bottom of the infiltration trench shall be level, or clay check dams may be used to prevent water from ponding near the downgradient end (multiple check dams may be necessary)

[1] *The design infiltration rate at the BMP location shall be determined using guidance in Chapter 6 of the DSM. The required minimum design infiltration rate of 0.5 in/hr precludes siting BMP on hydrologic soil groups C and D.*

Considerations for Locating On-line with Runoff Conveyance

Where design infiltration rates are ≥2.4 in/hr, an infiltration trench can provide flood control (up to the 10-year event) and can be configured as an on-line facility. On-line facilities shall be designed with an overflow route that can safely convey overflows to the downstream conveyance system or other acceptable discharge point. Where design infiltration rates are less than 2.4 in/hr, infiltration trenches are generally recommended to be designed as off-line facilities, because clogging of the facility could be exacerbated by passing higher flows (and sediment) above the water quality volume through the facility.

Major BMP Components

Media Layers

The following media shall be installed in the infiltration trench (in order from surface to bottom layers):

- If the trench will receive runoff via sheet flow that has not already received some form of pretreatment, the surface aggregate layer shall be consistent with the pretreatment requirements above.
- The second media layer is typically 18 inches to 5 feet of washed aggregate, depending on distance from bottom of the trench to the groundwater table. The aggregate shall be 0.75 to 3-inch round or crushed rock. The void space in the aggregates shall be between 30 to 40 percent.
- The third media layer is typically 6 to 12 inches of clean sand to encourage infiltration and prevent compaction of native soils due to aggregate placed on top.

Observation Wells

An observation well shall be installed at the downgradient end of the infiltration trench (or multiple wells may be installed depending on the total trench length) to check water levels, drawdown time, sediment accumulation, and to perform water quality monitoring.

- The observation well shall be constructed using perforated PVC pipe (4 to 6 inches in diameter) that is flush to the ground surface elevation. The top of the well shall be capped with a lockable screw cap.
- Larger trenches may have a 12- to 36-inch-diameter pipe installed to allow for maintenance operations, such as pumping out sediment.

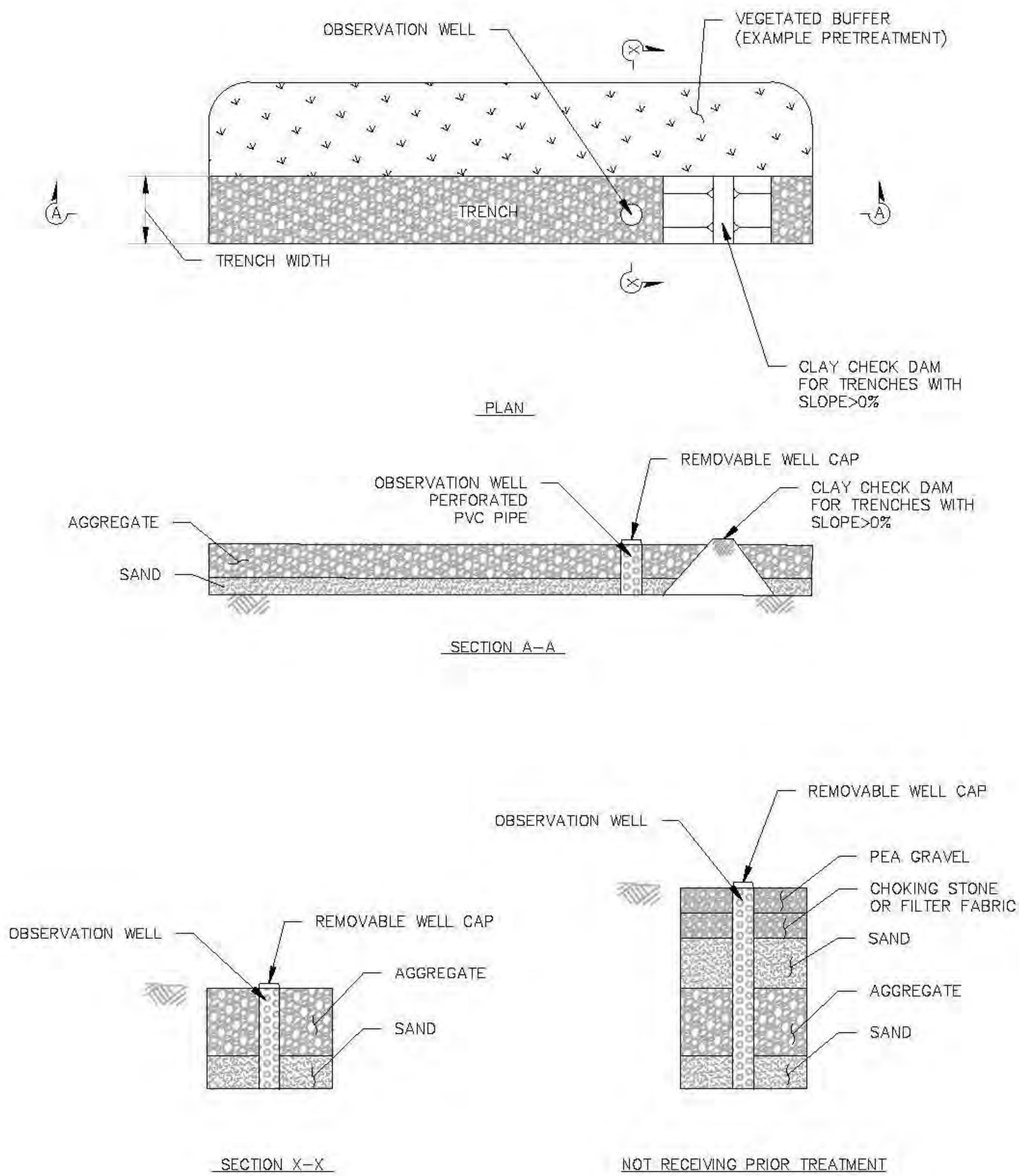


Figure 1: Infiltration Trench Schematic Plan and Section Views

Pretreatment Requirements

Infiltration trenches shall include pretreatment facilities to remove coarse sediment prior to infiltration to prevent clogging. Potential pretreatment facilities include grassy swales, vegetated filter strips, proprietary filtration sediment removal devices, and sediment forebays. Full treatment by another BMP considered to be acceptable for primary treatment is required if the trench is located in soil with an infiltration greater than 2.4 in/hr.

If runoff will enter the trench via sheet flow and has not received prior pretreatment, the infiltration trench shall be designed for sediment removal to occur in the top several inches of media as follows (see Figure 1 section view “Not Receiving Prior Treatment”):

- Top pretreatment layer: 2 inches of pea gravel
- Bottom pretreatment layer: 2 to 4 inches of sand
- Two inches of choking stone or a geotextile fabric shall be placed between the top and bottom pretreatment layers to capture sediment and keep the media separated. The fabric shall be a woven geotextile that meets the specifications in the City of Portland Standard Construction Specifications, Table 02320-1 or WSDOT Standard Specifications Section 9-33 for subgrade geotextile fabrics.

Special Wildlife Considerations

If it is desirable to use grasses as a surface cover, the vegetation selection shall be consistent with the Port’s WHMP to reduce potential hazards.

Considerations for Future Expansion

Because the tributary area for an infiltration trench is relatively small, and the entire drainage area shall be developed before the trench becomes operational, infiltration trenches are generally not amenable for expansion to accommodate phased development in the tributary drainage area.

BMP POST-DESIGN AND IMPLEMENTATION

Construction Considerations

The infiltration trench footprint area shall be clearly marked before any site work begins to avoid the disturbance of soils and compaction during construction. Vehicles are not permitted within 10 feet of the designated infiltration trench areas, except those used specifically to construct the trench. If vehicle and heavy equipment traffic cannot be avoided within the footprint area, the infiltration capacity shall be restored by tilling or aerating the soil prior to backfilling the trench with aggregate.

The drainage area shall be stabilized before the BMP construction begins. Alternatively, a diversion berm can be placed around the BMP footprint to protect it from sediment loading. A permanent perimeter curb could be constructed around the footprint except where flows would enter the trench (or construct periodic curb cuts to allow runoff to enter) to protect the trench from vehicular traffic.

An observation well shall be installed to facilitate water quality monitoring and O&M inspections.

O&M Requirements

The primary factor that affects the long-term function of the BMP is a decrease in the infiltration capacity due to clogging and compaction. The maintenance access road shall be able to support heavy equipment such as a vactor truck or track hoe, which would be used to remove sediment from the trench and/or pretreatment facility. To prevent damage and compaction in the infiltration trench, access must be able to accommodate a track hoe working at “arm’s length”. Vehicle traffic shall be prohibited within 10 feet of the trench. Table 3 summarizes common infiltration trench O&M activities.

Table 3: Maintenance Activities and Frequency

Schedule	Activity
As needed (frequently)	Perform periodic inspections and remove noxious weeds, trash and debris
As needed (within 48 hours after storms >1")	• Check observation wells to ensure proper trench function • Check pretreatment BMPs and remove sediment if needed • Clean out sediment as needed
At least Annually (prior to beginning of wet season)	• Inspect surface aggregate layer and replace as needed; till subgrade below aggregate prior to backfill. If slow drainage conditions persist, excavate entire trench and replace backfill material • Check integrity of geotextile fabric and replace if needed • Remove sediment from pretreatment BMPs as needed

Other Key Information

This fact sheet shall be used in conjunction with the BMP selection and design information presented in Chapter 6 of the DSM.

FS6-VEGETATED SWALE

BMP SELECTION AND PLANNING

Photo Credit: Geosyntec Consultants

Table 1: Vegetated Swale Overview	
BMP Functions	*Primary* • Water Quality Treatment *Secondary* • Peak Flow Control • LID/GI • Volume Reduction
Targeted Pollutants	*Primary* • Nutrients *Secondary* • TSS • Metals • Oil and Grease • Organics
Pretreatment	• No requirement unless designed for complete infiltration • May be used as pretreatment for other BMPs
Typical Wildlife Risk	High*
Cost	$
O&M Level of Effort	Medium
Tributary Area	≤5 acres
Relative Footprint	Small-Medium

**If designed to minimize wildlife attractiveness, can be reduced to low.*

Functional Description

Vegetated swales are shallow, open channels with dense, low-lying vegetation covering the side slopes and all or most of the bottom area. They receive runoff as concentrated flows at a single inlet and/or as lateral sheet flows (Figure 1). Use of amended media, an underlying gravel layer, and/or an underdrain add additional functionality. Primary treatment mechanisms include settling and filtration of sediment by the vegetation, planting media, and gravel (if present).

In addition to providing primary treatment, swales may be used as pretreatment for other BMPs such as infiltration trenches, bioretention areas and wet basins. Swales are also a GI alternative to curb and gutter systems, drainage ditches, and storm sewers for runoff conveyance.

Vegetated swales have a vegetated channel surface that has the potential to attract hazardous wildlife if not managed properly. If vegetated swales are to be used at PDX, their design and placement shall be coordinated with the requirements and guidance in the PDX WHMP.

Additional considerations to manage wildlife risk are provided in the following subsections of this fact sheet.

Site Suitability and Limitations

Table 2: Site Suitability Considerations for Vegetated Swales	
Soil Characteristics and Infiltration Concerns	• Can be constructed on any NRCS HSG • Lined facilities with underdrains are recommended if located within 50 ft of unstable slopes • In any case where an infiltration constraint is present, swales must be designed as flow-through facilities
Groundwater	• >3 feet separation between the seasonal high groundwater table and bottom of swale for flow-through swales with underdrains • >5 feet separation between the seasonal high groundwater table and bottom of the swale, for swales designed for complete infiltration
Wildlife Considerations	• Comply with FAA Advisory Circulars and PDX WHMP requirements for siting and design criteria • The presence of continuous base flows will result in saturated soil conditions, and requires a modified design to prevent standing water that may attract hazardous wildlife
Tributary Area and Land Use	• Approximately ≤ 5 acres • Swales can be used effectively in areas with natural topographic depressions and drainage courses
Contamination	Facilities may need to be lined to address specific infiltration constraints such as groundwater contamination. Placement of a swale in an area with contaminated soils requires Port approval.

Footprint Considerations

Vegetated swale footprints usually comprise up to 3 percent of their contributing drainage area if they are designed as flow-through facilities, but may comprise up to 5 percent of their contributing drainage area if designed for complete infiltration. Their linear nature makes swales a good candidate for treating road runoff and they are also useful as landscaping in parking lots for disconnecting impervious area. Vegetated swales can be incorporated into linear development applications (e.g., roadways) by utilizing the footprint typically required for open drainage features such as drainage ditches. On-line swales may also replace curb and gutter systems and storm sewers for runoff conveyance.

Wildlife Attractant Considerations

Vegetated swales have a vegetated channel surface that has the potential to attract hazardous wildlife if not managed properly. If vegetated swales are to be used at PDX, their design and placement shall be coordinated with the requirements and guidance in the PDX WHMP. Additional considerations to manage wildlife risk are provided in the following subsections of this fact sheet.

General O&M Considerations

General O&M requirements are related to maintaining the flow and infiltration capacity of the swale and maintaining a dense cover of vegetation to minimize erosion and promote water quality treatment. Regular maintenance consists of clearing sediment, trash and debris, mowing (if required), pruning and replacing plants as needed to cover barren areas, and performing periodic inspections to ensure the swale is functioning properly. Major maintenance (regrading swale bottom, reseeding, low flow channel restoration, etc.) should be needed infrequently. More detailed O&M requirements are summarized in the following section on BMP Design and Implementation.

Cost Considerations

Major cost components for BMP installation include site preparation (clearing, grubbing, excavation and grading, preserving topsoil and amending the topsoil with planting media), purchasing planting media, purchasing and planting vegetation (seed, sod, or low-growing herbaceous perennials/shrubs), and purchasing and installing the structural components such as the gravel and underdrain, and temporary erosion control measures to protect newly seeded areas.

Unknown site conditions, such as the composition of subsurface materials (which can increase excavation costs) and unknown underground utility locations (which require the swale to be relocated) are factors that may increase construction costs.

BMP DESIGN AND IMPLEMENTATION

Overview of Design Criteria

Table 3 summarizes minimum design criteria for vegetated swales. More detailed design and information is provided in the sections that follow.

Table 3: Minimum Design Criteria for Vegetated Swales (Geometry is for a Trapezoidal Channel)

Design Parameter	Unit	Design Criteria
Water quality design flow rate	cfs	See Chapter 4 of the DSM
Minimum design infiltration Rate[1,2]	in/hr	0.5 for complete infiltration
Design filtration rate	in/hr	2 (if underdrain used)
Minimum underdrain diameter	in	6 inches
Minimum bottom width	ft	4 feet (calculate using Manning's equation and a Manning's coefficient [n], see guidance in 'swale geometry' section] = 0.25)
Maximum bottom width	ft	10 (without a dividing berm)
Maximum side slopes	H:V	3:1
Minimum longitudinal slope	%	0.5 (underdrain required if <1.5% and soils are HSG C or D as these swales may promote standing water)
Maximum longitudinal slope	%	3 (without check dams) 6 (with check dams)

Table 3: Minimum Design Criteria for Vegetated Swales (Geometry is for a Trapezoidal Channel)		
Design Parameter	**Unit**	**Design Criteria**
Maximum flow depth for water quality treatment	in	2/3 of vegetation height or 4 inches, whichever is less
Minimum/Maximum flow length	ft	100/no maximum
Minimum target residence (contact) time	min	10
Maximum flow velocity for water quality storm	ft/sec	1
Maximum base flow	cfs	0.01 per tributary acre (greater flows require installation of a low flow drain)

[1]For swales designed to infiltrate the full water quality design flow rate. If the design infiltration rate is < 0.5 in/hr, the swale cannot be used for complete infiltration of the water quality design flow rate. Swales designed for partial infiltration may be located in areas with lower design infiltration rates.
[2] Unlined swales may not be located in areas where it is hazardous to infiltrate.

Considerations for Locating On-line with Runoff Conveyance

An on-line facility provides treatment and high flow conveyance in a single facility and can be used when peak flows will not damage the facility. Vegetated swales may be designed as on-line facilities that convey higher flows than the water quality flow rate. The BMP may also be designed to incorporate a high-flow bypass. Swales without high-flow bypass devices must be sized for flood conveyance utilizing the methods described in Chapter 5 of the DSM and must maintain a minimum of 1 foot of freeboard.

When sizing an on-line vegetated swale, verify that the flow velocity does not exceed 3 feet per second during the designated flood control event. Off-line facilities incorporate a flow control structure to divert the water quality design storm to the swale. Stormwater is treated before re-entering the conveyance system while higher flows are diverted around the facility.

Major BMP Components

Swale Geometry

- Trapezoidal channels are typically recommended, but other configurations, such as parabolic shapes, can also provide substantial water quality improvement and may be easier to mow (if required).
- Gradual meandering bends in the swale are desirable for aesthetic purposes and to promote slower flow. Note that designing a swale with meandering bends may not be appropriate in areas with wildlife concerns; consult Port wildlife management staff and refer to Special Wildlife Considerations in this fact sheet.
- The maximum bottom width of the swale shall be limited to 10 feet, unless multiple parallel swales or a dividing berm is used. The maximum width for a single swale with a dividing berm is 16 feet. Parallel swales, if used, shall include a device that splits the flow and directs the proper amount to each swale.

- Manning's equation can be used to iteratively calculate the required bottom width of the swale given desired flow depth and other geometry inputs. Manning's coefficient selection guidance is included in Table 4, below.

Table 4: Guidance for Manning's Coefficient for Different Soil and Cover Types	
Soil and Cover	**Manning's n**
Grass mix on compacted native soil	0.20
Grass mix on lightly compacted, compost-amended soil	0.22
Grass mix on lightly compacted, compost-amended soil with surface roughness features[1]	0.35
Default (if above information is not available)	0.25

[1]Acceptable surface roughness features are wattle check dams, gravel filter berms, or compost berms.
Reference: WSDOT Aviation Stormwater Design Manual

Underdrain

To prevent standing water conditions, an underdrain is required where the bottom slope is less than 1.5 percent, or in soils that do not provide the infiltration capacity to prevent standing water.

- The underdrain shall be a slotted PVC pipe with a minimum length of 2 feet and minimum diameter of 4 inches.
- Clean-out risers with diameters equal to the underdrain pipe shall be placed at the terminal ends of the underdrain and can be incorporated into the flow spreader and outlet structure to minimize maintenance obstacles in the swale. Intermediate clean-out risers may also be placed in check dams. The clean-out risers shall be capped with a lockable screw cap.

Gravel Layer for Enhanced Storage and Infiltration

Under suitable site conditions, a gravel layer may be added for additional temporary storage of stormwater to promote infiltration below the swale. A 3/4-inch washed drain rock shall be used for the gravel layer. The depth of the drain rock depends on the volume reduction goals and generally ranges from 1 to 4 feet. The drain rock and growing medium must be separated by filter fabric or a 2 to 3-inch layer of choking stone (such as ASTM No. 8). If filter fabric is used, it shall be a woven geotextile that meets the specifications in Chapter 6 of the DSM.

Low Flow Drain/Infiltration Trench

A low flow drain or infiltration trench is required if the vegetated swale will receive base flows or additional volume reductions are desired. A low flow drain is different from an underdrain and would not be used in a design where an underdrain would be used.

- The low flow drain shall run the entire length of the swale.
- The low flow drain shall be a minimum of 6 inches deep and no wider than 5 percent of the calculated swale bottom width.
- If an anchored plate or concrete sump is used for flow spreading at the swale inlet, the plate or sump wall will contain holes or a v-notch to allow for the preferential exit of low flows into the drain. If there is no plate or sump at the inlet, the low flow drain consists of the pea gravel surface drain.

Energy Dissipation Structures

- Check dams (e.g., riprap, earthen berms, removal stop logs, etc.) shall be used in swales with longitudinal slopes greater than 3 percent to decrease flow velocities and promote particulate settling.
- Check dams shall be as long as the width of the swale and perpendicular to the direction of flow and keyed into the side slopes a minimum of 6 inches.
- Check dams should be designed to maintain appropriate hydraulic grade.
- Energy dissipators (e.g., rip rap) shall be provided when the swale outlet pipe discharges into an outfall channel or sloped bank.
- An anchored plate flow spreader shall be used at the inlet of off-line swales (or an equivalent method for spreading flows evenly through the width of the swale may be used). Flow spreaders are not required at the inlet for swales that are on-line and parallel and adjacent to roads.
- Concrete sump flow spreaders may be used at the inlet of off-line swales with a minimum sump depth of 8 inches, a minimum length of 24 inches, and a width that extends 6 inches beyond both ends of the swale treatment path or bottom width. The sump wing walls shall be 4 inches higher than the bottom of the swale and the portion of the downstream wall that serves as the flow splitter must be 2 inches higher than the bottom of the swale.
- Additional flow spreaders shall be provided at intervals of 50 feet if the swale bottom width is ≥ 4 feet.

Vegetation and Growing Medium

- Native vegetation shall be used whenever feasible.
- Plants shall be appropriate for the amount of sunlight at the site (for example, select shade-tolerant plants for use under tree canopies and in areas shaded by buildings or other structures).
- It is recommended that the planting density achieves a minimum of 90 percent coverage after two years; however the ultimate planting density will depend on the specific swale design.
- Supplemental irrigation may need to be provided until plants are established. The designer may wish to consider selecting plants that thrive under normal rainfall conditions and are drought tolerant, so that long-term irrigation during dry periods is not needed.
- Media Mix for Swales with and without Underdrains:
    - Vegetated swales designed with underdrains shall include an engineered media mix. The media mix shall be at least 18 inches deep. The media shall be a loamy sand with about 80 to 88 percent sand (e.g., meeting ASTM C33 specifications), 8 to 12 percent soil fines (in the form of topsoil) and 1 to 5 percent organic matter (aged compost or shredded hardwood mulch) by volume. The phosphorus index (P-index)

of the engineered media shall be monitored and controlled to minimize phosphorus export from the BMP.

- Vegetated swales that are designed without underdrains do not need to include an engineered media mix, although the designer may consider using the same media mix as indicated above for swales designed with underdrains, but using only a 6-inch media depth. Alternatively, the swale shall be amended with 2 inches of organic matter (e.g., compost or shredded hardwood mulch), worked into the native soils to a depth of 6 inches. If onsite topsoils already contain 1-5 percent organic matter, amending the soils with additional organic matter is not required.
- If compost is used as the source of organic matter, it shall be tested and determined to meet US Composting Council specifications. It is further recommended that the compost is certified by the US Composting Council's Seal of Testing assurance program.

- As a design alternative, the designer may wish to integrate a media filter into the bottom of a vegetated swale, which consists of an engineered media mix with no vegetation. See the Media Filter Fact Sheet for details.

Impermeable Liner

- Geomembrane liners shall have a minimum thickness of 30 mils.

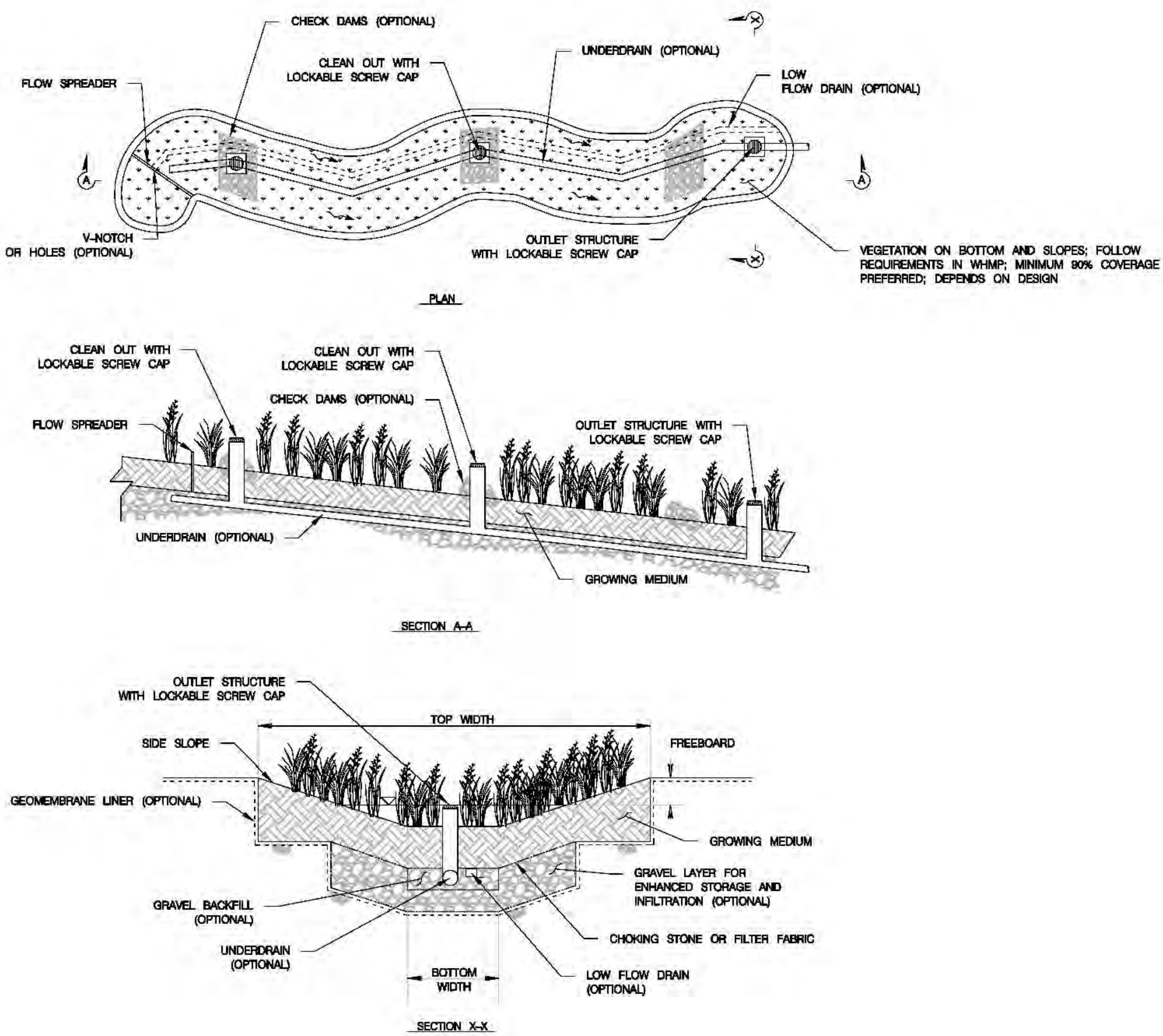


Figure 1: Vegetated Swale Schematic Plan and Section View

Pretreatment Requirements

Vegetated swales do not require pretreatment unless designed for complete infiltration of the water quality design flow rate, in which case a vegetated filter strip, sediment forebay, or approved equivalent should be used as the pretreatment BMP.

Special Wildlife Considerations

- Refer to the Stormwater Management standard for Hazardous Wildlife Attractants in Chapter 4 of the DSM for more information.
- To reduce the attraction by hazardous wildlife, the BMP may be designed with steeper embankments, narrower/longer configurations, shrub vegetation, fences, or other installations that disrupt sight lines and reduce comfort and habitat suitability for hazardous wildlife (primarily waterfowl).
- Vegetated swales are not allowed in the PDX primary zone (only rock lined systems are allowed). In the PDX intermediate zone, vegetated swales shall be planted entirely with scrub vegetation (or rock lined and devoid of vegetation) and must drain completely to a subsurface facility.
- Vegetated swales are allowed in the PDX secondary zone, but must follow FAA guidance.
- Select swale vegetation from the PDX WHMP, Appendix J (List of Approved PDX Plants).
- The designer may wish to use an unvegetated media filter in the PDX primary zone (as vegetated swales are not allowed). The designer may wish to incorporate a media filter design into the bottom of a vegetated swale in the PDX intermediate zone to provide enhanced treatment and reduce the vegetation density. See the Media Filter Fact Sheet for details.

Considerations for Future Expansion

As swales are designed to treat relatively small drainage areas, expanding the swale to accommodate future development is likely not applicable. Another parallel swale could be installed to accommodate the runoff from additional future impervious areas.

BMP POST-DESIGN IMPLEMENTATION

Construction Considerations

- Avoid soil compaction during construction to maintain the subsurface infiltration capacity.
- Grade swales to attain uniform longitudinal and lateral slopes; accuracy in grading is important as a departure from design slopes affect treatment effectiveness and conveyance.
- The swale shall not be put into operation until areas of exposed soil in the contributing drainage area have been sufficiently stabilized and the vegetation has been established. Erosion and sediment control measures shall remain in place until this time as soil deposition can inhibit the growth of vegetation and reduce effectiveness of water quality treatment.
- The use of treated wood or galvanized metal anywhere inside the facility is prohibited.

O&M Considerations

Maintenance access is required for swales. The entire swale surface shall be accessible, as shall the outlet structure and underdrain pipes. For distributed swale facilities, adequate space shall be provided on all sides to allow for safe maintenance of surfaces. Traffic controls may be required for maintenance operations completed on distributed BMPs located on sidewalks or in roadway medians. To allow for access to underdrains and other outlet infrastructure, clean out stand pipes with clear access to the underdrain shall be provided within the facility.

The access road must be able to support heavy equipment such as a vactor truck, dump truck, track hoe, or large mower. In general, maintenance activities focus on vegetation control, sediment removal, maintaining flow dispersion, and erosion repair. Avoid vehicular traffic on the swale bottom (other than grass mowing equipment).

Table 5 summarizes common vegetated swale O&M activities.

Table 5: Maintenance Activities and Frequency	
Schedule	**Activity**
As needed (frequently)	• Perform periodic inspections and remove trash and debris • Irrigate swale during dry periods when initially establishing vegetation
As needed (within 48 hours after storms >1")	• Perform inspections to ensure proper swale function. Verify drainage of swale according to design standards (consider vector concerns) • Clean out sediment from trench drains, curb inlets, and pipes
Twice annually (end of wet season and prior to beginning of wet season)	• Remove weeds • Replant/stabilize exposed soil areas • Maintain check dams at specified intervals
At least annually (prior to beginning of wet season)	• Remove sediment and debris from drains, inlets, flow spreaders, check dams, and pipes • Remove and replace dead plants • Cut back grass and prune overgrowth 1-2 times a year • Replace splash blocks or inlet gravel/rock • Rake, till, or amend planting media to restore infiltration rate, if needed • Clean underdrain pipe (if applicable) and outlet if infiltration is poor and/or infiltration restoration activities are performed, such as amending planting media • If flow channelization occurs, regrade and replant the swale • Mowing at PDX (if required) shall be scheduled at night when the runways are closed within relevant areas of the primary zone. Mowing activities in other areas of the primary and intermediate zones may be conducted during daylight hours.

Other Key Information

This fact sheet shall be used in conjunction with the BMP selection and design information presented in Chapter 6 of the DSM.

FS7-VEGETATED FILTER STRIP

BMP SELECTION AND PLANNING

Photo Credit: Washington Department of Transportation, Aviation Stormwater Design Manual

Table 1: Filter Strip Overview

BMP Functions	*Primary* • Water Quality Treatment • Volume Reduction *Secondary* • Peak Flow Control • LID/GI
Targeted Pollutants	*Primary* • TSS • Oil and Grease *Secondary* • Metals • Organics
Pretreatment	• Not required • May be used as pretreatment for other BMPs
Typical Wildlife Risk	Low
Cost	$
O&M Level of Effort	Low
Tributary Area	≤2 acres
Relative Footprint	Medium-Large

Functional Description

Vegetated filter strips (filter strips) are gently sloped linear vegetated facilities that treat sheet flow runoff from adjacent impervious areas (Figure 1). They are flow-based BMPs that can be designed to filter out sediment and associated pollutants in the vegetation and soil, and may provide volume reduction through infiltration into underlying soils (depending on the soil conditions, slope, and strip length).

In addition to providing primary treatment for water quality, filter strips may also be used as pretreatment for infiltration BMPs, bioretention areas, or media filtration. Filter strips are not effective as the primary BMP for reducing peak runoff discharges, but can be effective at reducing annual runoff volumes via infiltration.

If filter strips are to be used at PDX, their design and placement shall be coordinated with the requirements and guidance in the PDX WHMP. Additional considerations for siting and design of filter strips to manage wildlife risk are provided in the following subsections of this fact sheet.

Site Suitability and Limitations

Siting is critical for hazardous wildlife attractant management. In addition, there are other factors that should be assessed when evaluating if a location is suitable for a filter strip. Table 2 summarizes the various factors and considerations.

Table 2: Site Suitability Considerations for Vegetated Filter Strips	
Soil Characteristics	• Can be constructed on any NRCS HSG • If the contributing drainage area has a lateral slope >5% or is within 200 feet of a hazardous slope or landslide area, a geotechnical investigation is required • A geotechnical evaluation shall be conducted if the filter strip will be installed above a retaining wall and the soils are especially erodible or permeable
Groundwater	Seasonal high groundwater table shall be >2 feet below the lowest point of the filter strip
Wildlife Considerations	• Use of filter strips at PDX within the primary or intermediate zones requires approval by the Port Wildlife Manager • Comply with FAA Advisory Circulars and PDX WHMP requirements for siting and design criteria
Tributary Area and Land Use	• <2 acres. Filter strips are not suitable for treating large impervious areas that can generate high-velocity runoff and concentrated flows • Filter strips are not suitable for tributary areas with steep slopes. The maximum lateral slope (in the direction of flow) for the contributing drainage area shall not exceed 5% and the maximum longitudinal slope (perpendicular to the flow direction) shall not exceed 2%.

Footprint Considerations

Filter strips are particularly well suited for providing treatment to linear tributary areas and could be implemented by the Port along runways, taxiways, roads, and walkways, and may also be used to treat runoff from roof downspouts, and small parking lots. Filter strips can also be easily integrated into roadside vegetated buffers.

The filter strip shall have a width equivalent to the tributary area width, and have a length designed to provide adequate flow residence time given the design flow and filter strip slope. For large impervious areas, the maximum flow path across the contributing impervious area shall not exceed 150 feet.

Wildlife Attractant Considerations

Vegetated filter strips do not contain ponded water when designed appropriately, but do include vegetation. Thus they are considered a low concern for wildlife. As such, repellent vegetation may need to be considered in the design when these facilities are proposed for an airport site. Refer to the Stormwater Management standard for Hazardous Wildlife Attractants in Chapter 4 of the DSM for more information.

General O&M Considerations

Normal O&M requirements for filter strips mainly consist of vegetation management (e.g., mowing) and removing accumulated trash, debris, and sediment. Signs of erosion and channelization should be inspected after major storms. Clearing of debris should be scheduled when it affects functionality. Major maintenance, which mainly consists of replacing or adding vegetation, should be needed infrequently. More detailed O&M requirements are summarized in the following section on BMP Design and Implementation.

Cost Considerations

Major cost components for BMP installation include site preparation (clearing, grubbing, preserving topsoil and amending the topsoil with planting media), purchasing planting media, purchasing and planting vegetation (seed, sod, or low-growing herbaceous perennials/shrubs), and installing the flow spreader device.

BMP DESIGN AND IMPLEMENTATION

Overview of Design Criteria

Table 3 summarizes minimum design criteria for vegetated filter strips. More detailed design and information is provided in the sections that follow.

Table 3: Minimum Design Criteria for Vegetated Filter Strips

Design Parameter	Unit	Design Criteria
Water quality design flow rate	cfs	See Chapter 4 of DSM
Filter strip longitudinal slope	%	4 maximum
Filter strip lateral slope (direction of flow)	%	1 minimum 15 maximum
Minimum design flow depth	in	1
Design flow velocity	ft/sec	<1
Minimum residence time	min	10
Minimum width	ft	Equal to width of tributary drainage area
Minimum length (in flow direction)	ft	15, minimum if designed as primary treatment BMP 4, minimum if designed as a pretreatment BMP

Considerations for Locating On-line with Runoff Conveyance

Vegetated filter strips are designed to treat sheet flow runoff from adjacent areas and are by definition on-line BMPs.

Major BMP Components

Filter Strip Geometry

- The top and toe of the slope shall be as flat as possible to encourage sheet flow and prevent erosion.
- Filter strips shall be free of gullies or rills.

Vegetation and Growing Medium

Vegetation that is tolerant of high flow rates, can withstand both wet and dry periods, and can prevent erosion is recommended for filter strips. The target vegetation density is a minimum of 90 percent coverage after one year.

- Native vegetation shall be used whenever feasible.
- Vegetation shall be appropriate for the amount of sunlight at the site (for example, select shade-tolerant plants for use under tree canopies and in areas shaded by buildings or other structures).
- The designer may wish to consider planting filter strips at a time of year when the grass can be established with minimal irrigation (e.g., spring). However, supplemental irrigation may need to be provided until grasses are established. The designer may wish to consider selecting grasses that thrive under normal rainfall conditions and are drought tolerant, so that long-term irrigation during dry periods is not needed. Note that seeds may attract wildlife – see Special Wildlife Considerations.
- Filter strip native soils shall be amended with 2 inches of organic matter (e.g., compost or shredded hardwood mulch), incorporated into the native soils to a depth of 6 inches. If onsite topsoils already contain 1-5 percent organic matter, amending the soils with additional organic matter is not required. Alternatively, the designer may wish to consider using an engineered media mix, which could enhance the treatment performance of the filter strip. The engineered media results in a final texture consistent with a sandy loam and has the following composition: 80 to 88 percent sand, 8 to 12 percent soil fines (in the form of topsoil), and 1 to 5 percent organics (aged compost or hardwood mulch) by volume. If compost is used as the source of organic matter, it shall be tested and determined to meet US Composting Council specifications. It is further recommended that the compost is certified by the US Composting Council's Seal of Testing assurance program. In addition, the phosphorus index (P-index) of the engineered media shall be monitored and controlled to minimize phosphorus export from the BMP.

Energy Dissipation Structures

The designer may wish to consider the use of flow spreading devices such a grade board, trench, or a level spreader placed between the impervious drainage area and the filter strip, which will promote shallow, evenly-distributed sheet flow to the filter strip. Gravel, sand, or washed crushed rock may be used for the trench material. The trench shall be at least 6 inches deep and 12 inches wide. The trench shall be positioned at least one inch below the tributary area surface. The top of the lever spreader or trench must be at an appropriate height to provide sheet flow directly to the filter strip without scour. If trenches are used adjacent to runways at PDX, the aggregate material shall be outside the runway shoulder and shall meet ODOT specifications for shoulder aggregate material.

In addition to managing inflow velocities, energy dissipators such as check dams or rip rap may provide additional energy dissipation for long slopes or treatment areas with steep drops.

Pretreatment Requirements

Vegetated filter strips typically do not require pretreatment. These facilities are used as pretreatment for other BMPs and/or drain highly impervious areas, so should not require additional settling of sediment.

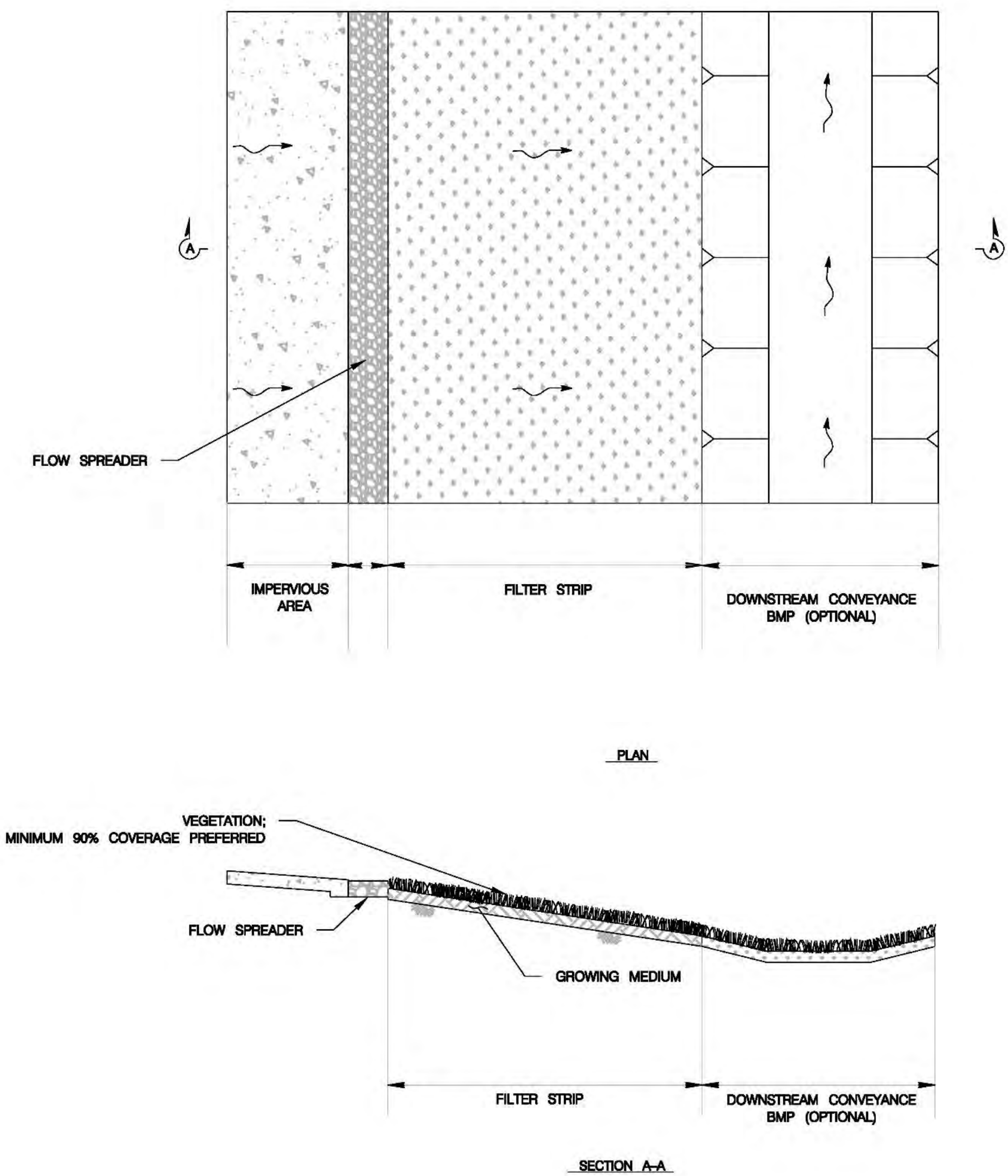


Figure 1: Vegetated Filter Strip Schematic Plan and Section View

Special Wildlife Considerations

- For filter strips at PDX in the primary or intermediate zones, the tall fescue seed mix approved for use in these zones shall be used, or refer to the PDX WHMP Appendix J (List of Approved PDX Plants).
- Properly designed filter strips shall not have standing water for more than 24 hours (for the water quality storm), which promotes growth of emergent vegetation and may attract hazardous wildlife.
- Timing for seed planting (such as broadcast seeding and hydroseeding) is important and must be coordinated with the Port. Seed planting can become a significant wildlife attractant if new growth develops during periods when hazardous migratory birds can be present

Considerations for Future Expansion

As vegetated filter strips are designed to treat sheet flow from relatively small and immediately adjacent drainage areas, expanding the filter strip to accommodate future development is likely not applicable.

BMP POST-DESIGN AND IMPLEMENTATION

Construction Considerations

- The top of the filter strip shall be installed 2 to 5 inches below the source area to prevent accumulation of sediment and vegetation along the margins and to allow water to freely enter the BMP.
- Avoid soil compaction during construction.
- Grade vegetated filter strips to attain uniform lateral slopes.
- The vegetated filter strip shall not be put into operation until areas of exposed soil in the contributing drainage area have been sufficiently stabilized and the vegetation has been established. Erosion and sediment control measures shall remain in place until this time as soil deposition can inhibit the growth of vegetation and reduce effectiveness of water quality treatment.
- The use of treated wood or galvanized metal anywhere inside the facility is prohibited.

O&M Considerations

Final construction shall allow for maintenance access to the flow spreader at the upper edge of the filter strip and for mowing equipment. In general, maintenance activities focus on vegetation control, erosion prevention and control, and removal of accumulated sediment. Table 4 summarizes common filter strip O&M activities.

Table 4: Maintenance Activities and Frequency	
Schedule	**Activity**
As needed (frequently)	• Perform periodic inspections and remove trash and debris • Remove contamination visible from floatables (i.e., oil and grease) • Irrigate newly planted vegetation as recommended by the landscape professional (plants should not require long-term irrigation) • Mow grass filter strips to maintain a 2 to 4 inch height or as compatible with Port wildlife and maintenance requirements
As needed (within 48 hours after storms >1")	• Remove excess sediment if it exceeds 2 inches or covers vegetation • Inspect the flow spreader for accumulated sediment • Inspect for pools of standing water
Twice annually or as needed (end of wet season and prior to beginning of wet season)	• Inspect for erosion • Inspect for damage to vegetation, thin vegetation, or replant as needed • Remove noxious weeds
At least annually	• Fill ruts or rills with crushed gravel • Clean and reset flow spreaders as needed to restore original function • Regrade if ruts and rills exceed 3 inches in depth

Other Key Information

This fact sheet shall be used in conjunction with the BMP selection and design information presented in Chapter 6 of the DSM.

FS8-MEDIA FILTER

BMP SELECTION AND PLANNING

Photo Credit: CASQA Stormwater BMP Handbook

Table 1: Media Filter Overview	
BMP Functions	*Primary:* • Water Quality Treatment *Secondary:* • *Peak Flow Control*
Targeted Pollutants	*Primary:* • TSS • Metals • Organics • Bacteria • Oil and Grease *Secondary:* • Nutrients
Pretreatment	Required, except for roof runoff which does not require pretreatment
Typical Wildlife Risk	Low
Cost	$$
O&M Level of Effort	Low
Tributary Area	Varies (see Table 2)
Relative Footprint	Small-Medium

Functional Description

Typically, a media filter consists of a constructed media bed containing engineered media that is either mixed or layered. Several design variations can be achieved by adding an underdrain embedded in a drainage layer or a controlled outlet, a sedimentation forebay, vegetation, a liner, an impermeable containment structure (vault), and/or ponding storage above the media. Media filters can be implemented as surface or subsurface features and influent flows may be introduced over the surface of the bed or internally within the media via a perforated pipe network or perimeter trench (Figure 1). They can be designed to allow for other uses in addition to stormwater control such as walkways, or implemented as aesthetically pleasing landscape features. Well known design variations include the Austin sand filter, the Washington D.C. sand filter, and the Delaware sand filter. Primary differences lie in the location (above/below ground), space requirements, surface areas, and quantity of treated runoff.

Media filters treat stormwater runoff through a variety of physical and chemical unit treatment processes including sedimentation, entrapment, straining, and sorption. Additional treatment through biological processes can be achieved if vegetated and/or as bacteria grows in the media over time. The primary function of a media filter is to provide water quality treatment. However, additional benefits include some flow attenuation and control of peak runoff rates (depending on the amount of storage that is available above and in the pore space of the media bed). In most systems, water that percolates through the media is collected by a slotted or perforated underdrain at the bottom of the basin and conveyed downstream towards the discharge point. High flows in excess of the design volume and flow rate spill out over the top of the media via the available bypass mechanism which may consist of an overflow spillway, overflow outlet structure or simple dispersion over adjoining areas. Depending on the design, media filters typically provide good treatment for sediment and sediment bound pollutants, but engineered media may be used to target specific pollutant types.

Media filters are versatile and can be lined and used when other BMPs, such as infiltration practices, are not feasible. For media filters that are unlined, and have the potential to infiltrate, refer to the Infiltration Trench Fact Sheet for UIC considerations.

If media filters are to be used at PDX, their design and placement shall be coordinated with the requirements and guidance in the PDX WHMP.

Site Suitability and Limitations

Media filters can be used in a wide range of sites if properly designed. Table 2 summarizes the various site suitability considerations for media filters.

Footprint Considerations

The surface area required for media filters as a percentage of tributary impervious area varies depending on:

- Site conditions (i.e., soil characteristics and slopes),
- Presence or absence of upstream detention,
- Infiltration capacity of native soils (if designed for infiltration),
- Filtration rate of the engineered media (if not outlet controlled),
- The flow characteristics of underdrains and outlet structures (if outlet controlled), and
- The available storage within and on top of the media filter.

Table 2: Site Suitability Considerations for Media Filters	
Soil Characteristics and Infiltration Concerns	• If designed for infiltration, limitations of infiltration trenches apply (see FS5-Infiltration Trench fact sheet) • If lined or enclosed in impermeable enclosure, can be installed in areas with any HSG
Groundwater	• The seasonal high groundwater table shall be ≥5 feet lower than the bottom of the media filter if the system is designed for infiltration (without underdrains) • The seasonal high groundwater table shall be ≥3 feet lower than the bottom of the media filter if the system is not designed for infiltration (with underdrains) • There are no constraints for lined or concrete facilities, however checking for buoyancy during construction is recommended
Wildlife Considerations	Comply with FAA Advisory Circulars and PDX WHMP requirements for siting and design criteria.
Tributary Area and Land Use	Recommended tributary area limitations are as follows: • <10 acres for surface media filter • <2 acres for perimeter media filter • <1 acre for underground media filter • The Port may propose media filters for larger drainage areas, to function as a regional BMP • The site slope shall be less than 15%
Contamination Concerns	• Not appropriate if hazardous chemicals/materials are stored within the drainage area unless adequate source controls can be implemented • Not appropriate in areas with contaminated soil

Typically, the surface area required treatment is 2 to 5 percent of the tributary drainage area. Media filters are not bound by length-to-width ratio requirements and can therefore assume various geometries as long as other design requirements are met. This makes them suitable for narrow or linear site areas as well as irregularly shaped areas.

General O&M Considerations

General O&M requirements are related to maintaining the structural integrity and the treatment performance of the media filter. Without proper maintenance, media filters lose their filtration and/or infiltration capacity from clogging, and the sorption sites within the media eventually become exhausted. Rill and gully erosion on the media bed, deterioration of berms/liners/containment enclosures, and structural damage to inlet and outlet structures are likely to occur overtime. Regular inspections are needed to identify maintenance tasks and verify that the media filter is functioning properly. Regular maintenance consists of cleaning clogged components such as inlet and outlet structures, removing trash and debris, and repairing minor erosion of the media bed. Major maintenance should be infrequent and consists of removal of accumulated sediment and top layer of media bed, replacement of media bed, major structural repairs to the media bed and berms to reverse effects of erosion, and inlet/outlet structure repairs or replacement. More detailed O&M requirements are summarized in the Design and Implementation section.

Cost Considerations

Major capital cost components include:

- Site preparation (clearing vegetation, protection of the infiltration area (if unlined)
- Excavation and grading
- Structural components (inlet and outlet structures)
- Media bed components/layers (engineered media, under drain pipes (if included), drain rock, liner (if included), and impermeable enclosure (if included)).

Factors that may increase design and construction costs include:

- Unknown site conditions, such as the composition of subsurface materials (which can increase excavation costs)
- Unknown underground utility conflicts (which may require relocation or changes in geometry)
- Site pollutant loads (which may require pretreatment and removal of fine sediment), size of tributary area
- Site imperviousness and watershed response characteristics (which may require detention for peak shaving).

Typical maintenance cost components include vegetation management, sediment removal, media replacement and structural repair of inlet/outlet structures and media bed.

BMP DESIGN AND IMPLEMENTATION

Overview of Design Criteria

Table 3 summarizes the minimum design criteria for media filters. More detailed design information is provided in the sections that follow.

Table 3: Minimum Design Criteria for Media Filters		
Design Parameter	**Unit**	**Design Criteria**
Water quality volume	cu-ft	See Chapter 4 of the DSM
Design infiltration rate[1]	in/hr	• ≥0.5 for unlined systems (for full infiltration of the water quality volume) • <0.5 (underdrain needed) • Not limiting for lined or enclosed media filter
Design filtration rate (for systems with underdrains)	in/hr	1
Media contact time	minutes	• Varies depending on media composition and target pollutants. General recommendations based on composition can be obtained from the literature[2]. The designer should perform a media flow through test if media contact times are not cited in literature.
Pore space of engineered media	%	20-30

Table 3: Minimum Design Criteria for Media Filters

Design Parameter	Unit	Design Criteria
Pore space of drain rock	%	30-40
Ponding depth above media bed	feet	≤3
Media layer thickness	feet	>2 and 3 preferred (if not outlet controlled) <2 (if horizontal flow or outlet controlled)
Media hydraulic conductivity	in/hr	Varies (if outlet controlled) >1 (if not outlet controlled)
Drain rock layer depth	in	Varies with underdrain size >12
Underdrain geometry	in	>6-inch diameter or equivalent; 0.5% slope >4-inch diameter or equivalent; 1% slope
Pretreatment	—	As needed to reduce sediment loads and maintain long-term infiltration capacity

[1] *If media filter is unlined, the design soil infiltration rate shall be based on the infiltration capacity of the underlying soil. Site-specific infiltration testing shall be conducted and the design infiltration rate based on the results of the tests.*

[2] *Pitt, R. and S.E. Clark, 2010. Evaluation of Biofiltration Media for Engineered Natural Treatment Systems. May 10, 2010.*

Soils Suitability

Unless the BMP is designed for infiltration, soil suitability is a not critical component of media filter design and implementation since media filters can be lined or contained in structural enclosures and can use imported engineered media rather than native onsite soils. As long as the soils have the bearing capacity to support the media filter and buoyancy requirements in saturated soils are met during and after construction, soil suitability impacts are minimal for enclosed media filters.

Media filters designed for full infiltration (i.e., without underdrains) have similar soil suitability requirements to infiltration trenches and shall not be installed in contaminated soils, saturated soils, soils with design infiltration rate less than 0.5 in/hr (minimum design infiltration rate) or near steep slopes (>15 percent). If installing a media filter above native soil with a design infiltration rate less than 0.5 in/hr the media filter shall have an underdrain. If the media filter with an underdrain is unlined, the media filter may achieve partial infiltration depending on the position of the underdrain and the actual design infiltration rate.

Groundwater Considerations

Media filters designed for full infiltration of the water quality volume (without underdrains or liners and unenclosed in vaults) shall have at least 5 feet clearance between the bottom of the facility and the seasonal high groundwater table to ensure that groundwater intrusion does not cause the media to remain wet during dry conditions. Unlined media filters with underdrains shall have at least 3 feet clearance between the bottom of the facility and the seasonally high groundwater table. Lined and enclosed media filters do not have groundwater level restrictions as long as buoyance is taken into consideration during and after construction.

Considerations for Locating On-line with Runoff Conveyance

Media filters are generally recommended to be designed as off-line facilities, as clogging or scouring of the facility could be exacerbated by passing higher flows (and sediment loads) above the water quality volume through the facility.

Major BMP Components

Optional Sedimentation Forebay

A built-in sedimentation forebay may be provided for pretreatment removal of coarse sediment to protect the media bed from accelerated clogging. The recommended volume of the sedimentation forebay is 20 to 25 percent of the total volume of the facility if no additional pretreatment is provided.

Media Bed

For highly constrained sites, the media bed can be installed in an underground vault or completely below the surface. Media filters typically contain two layers of media, an engineered mix for water quality treatment and a gravel layer that sits beneath the engineered mix for drainage. Engineered media mixes with multiple constituents are more likely to achieve a greater degree of removal and exhibit desirable hydraulic properties that minimize clogging and improve contact time. The following media shall be installed in the media bed (in order from surface - engineered mix, to bottom layer - gravel layer):

- Engineered mix shall consist of a custom blend of one or more of the following constituents depending on the target pollutants and the desired hydraulic properties of the media:
  - Washed medium to fine grain sand (effective grain diameter 0.2 to 0.35 mm with very few fines). Sand helps control the hydraulic conductivity, removes particulate pollutants via straining, filtration and shallow sedimentation, and also may remove pollutants by sorption as a secondary mechanism. Concrete grade sand is appropriate. Rhyolite sand, a naturally occurring mineral used as top dressing on golf courses, is an effective and reliable substitute for concrete sand due to its favorable physical properties (e.g., durable, light weight, low angularity, consistent gradation). Sand may be amended with calcite or iron filings to enhance phosphorus removal. Sand may also be coated with iron or manganese oxides to remove phosphate, bacteria, arsenic, and other metals.
  - Perlite, which is a naturally occurring material sources from volcanic ash. Perlite is effective at removing TSS, oil, and grease.
  - Granular activated carbon, which is manufactured through the combustion of organic materials. Granular activated carbon is effective at removing organic pollutants, metals, and petroleum hydrocarbons.
  - Chitosan, a product made from the shells of crabs, shrimp and other crustaceans (e.g., oysters), is a natural coagulant that has been shown to effectively remove metals from runoff.

- o The designer may wish to consider crushed oyster shells in their raw form as an alternative media amendment to raise the water hardness and pH to improve dissolved metals removal (such as copper). However, because the use of raw oyster shells as a media filter component has not been thoroughly tested (i.e., no specific guidance is available on the quantity to use, cost or performance), oyster shells shall only be used for pretreatment or as polishing treatment for a media filter.
- o Compost which has been shown to effectively remove soluble metals, TSS, oil and grease. To minimize nutrient export, it is recommended that compost is aged at least 6 months and mixed with other granular media such that the total *organic content does not exceed 1-5% of the media by volume. See Chapter 6 of the DSM for more information on media specifications.*
- o Zeolite, a naturally occurring mineral, is effective at removing metals and ammonia, especially ionic forms of copper.

- The gravel layer is typically at least 12 inches of washed aggregate. The aggregate shall be 0.75 to 3-inch round or crushed rock. The void space in the aggregates shall be between 30 to 40 percent.
- A two-inch transition gradation layer (i.e., layer of choke stone) is recommended between the media layer and the gravel backfill layer.
- For media filters designed for infiltration, a third media layer is typically 6 to 12 inches of clean sand to encourage infiltration and prevent compaction of native soils due to aggregate placed on top.

Inlet and Outlet Structures

An inlet structure with adequate energy dissipation is recommended. For irregularly shaped media filters or media filters with length to width ratios greater than 2:1, a flow spreader shall be provided for a minimum of 20 percent of the filter perimeter, preferably along the longer edge of the media filter. Outlet-controlled media filters are preferred since they offer more precise control of the contact time and more uniformly utilize the entire media bed. Under outlet control, the media bed flow-through rate is controlled by the outlet rather than the hydraulic conductivity of the media. A perforated riser or an orifice plate is recommend for outlet control and an overflow outlet shall be provided to bypass flow in excess of the design treatment flow rate. In the absence of outlet control, an underdrain pipe to connect the outlet structure is recommended for media filters that are not designed to infiltrate the entire water quality volume.

Underdrains

For media filters that are not designed to infiltrate the entire water quality volume, an underdrain is required:

- Underdrain pipes and connectors shall be at least 4 inches or greater in diameter. Underdrain systems that are not circular shall provide an equivalent open area that is equal or greater than the open area of an equivalent length of 4-inch diameter perforated pipe.

- Slotted pipe is preferred to perforated pipe since it is less prone to clogging and slots sizes can be reduced while maintaining the effective open area ratio. If perforated pipe is used, round perforations shall be at least 0.5-inch in diameter.
- Underdrain pipes shall be placed with a minimum slope of 0.5 percent.
- The invert of the underdrain pipe shall be above the seasonal high groundwater level.
- Underdrains shall be installed with vented clean out risers at the terminal ends of each pipe.
- Underdrains can be installed in a variety of configurations including a central underdrain with or without lateral collection pipes.
- At least 8 inches of gravel backfill shall be maintained over all underdrain piping, and at least 6 inches shall be maintained on both sides and beneath the pipe to prevent damage by heavy equipment during maintenance. Either drain rock or gravel backfill may be used between pipes.

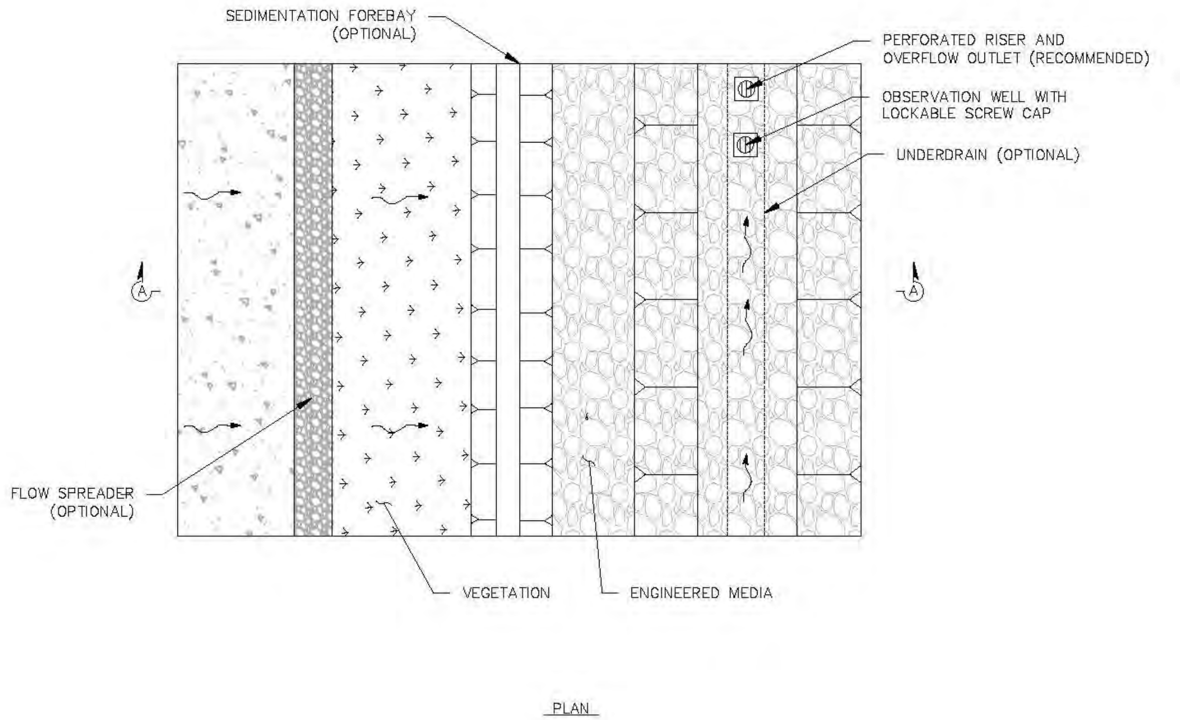
Observation Wells

An observation well shall be installed at the downgradient end of the media filter (or multiple wells may be installed depending on the surface area of the media bed) to check water levels, drawdown time, sediment accumulation, and to facilitate water quality monitoring.

- The observation well shall be constructed using perforated PVC pipe (4 to 6 inches in diameter) that is flush to the ground surface elevation. The top of the well shall be capped with a lockable screw cap.

Pretreatment Requirements

Pretreatment shall be required to remove coarse sediment upstream of the media filter to prevent accelerated clogging and increased maintenance requirements. Pretreatment may be accomplished with either a built-in sediment forebay or a separate sediment-reducing BMP installed upstream of the media filter. Potential pretreatment BMPs include grassy swales, vegetated filter strips, and proprietary filtration and sediment removal devices. If the media filter is solely treating roof runoff, pretreatment is not required, however, the inlet of the media filter shall be protected with a screen to keep out trash and debris.



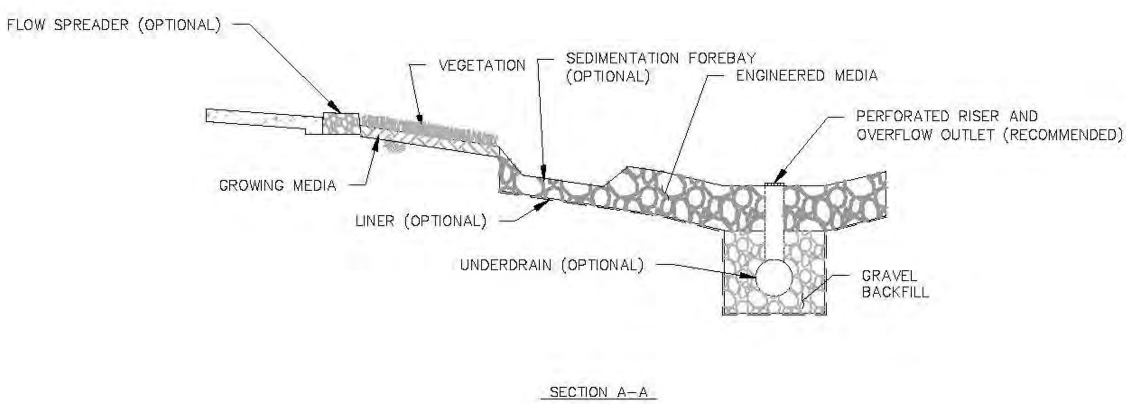


Figure 1: Media Filter Schematic Plan and Section Views

Considerations for Future Expansion

Media filters shall be designed for full build-out of the tributary drainage area when installed. Generally no modifications can be made to accommodate phased development when the media filter is designed to treat the relatively small tributary areas in Table 2. However, if the media filter is designed as a regional facility, baffles or berms could be installed in the BMP so that only a small area of the BMP is being frequently utilized until a larger treatment area is routed to it. This design option could reduce the maintenance costs if there is a long delay between development phases.

Wildlife Safety Considerations

If implemented as subsurface features or aboveground treatment facilities with no significant surface ponding, media filters are less likely to attract hazardous wildlife. Carefully selected vegetation can help maintain the infiltration rate of a media filter. If a media filter is vegetated, the vegetation selection shall be consistent with the Port's WHMP to reduce wildlife hazard. All proposed BMPs that fall within the primary or intermediate zones shall be reviewed by Port wildlife staff. Vegetated media filters are not allowed in the PDX primary zone and vegetated should be limited in the intermediate zone. Only linear narrow media filters are allowed in the primary zone.

Media filters with pretreatment chambers that are designed to hold water for up to 48 hours between storms shall be designed with wildlife exclusion devices to reduce the potential for attracting hazardous wildlife.

BMP POST-DESIGN AND IMPLEMENTATION

Construction Considerations

If the media filter is designed for infiltration, the construction considerations of infiltration trenches apply (refer to Infiltration Trench Fact Sheet). The following additional considerations apply:

- Treated wood or galvanized metals shall not be used anywhere inside the media filter footprint.
- If constructing a mixed filter bed media filter, all materials shall be thoroughly mixed, preferably off site. A grain size analysis of the media is recommended prior to installation.
- Rinsing of the media prior to installation can help remove fines and extend the life of the media bed. Once installed, rinsing the media with clean water is recommended to facilitate settling of the media bed. All effluent from rinsing activities shall be captured and properly disposed.

O&M Considerations

Maintenance access should be constructed near the outlet of the media bed for removal of accumulated sediment and debris. The access road must be able to support heavy equipment such as a vacuum sweeper, vactor truck, dump truck, or track hoe. To prevent damage and compaction, access must be able to accommodate a track hoe working at “arm’s length”. For media filters designed to infiltrate, vehicle traffic is prohibited within 10 feet of the facility.

Table 3 summarizes common media filter O&M activities.

Table 3: Maintenance Activities and Frequency

Schedule	Activity
As needed (frequently)	• Perform periodic inspections and remove noxious weeds, trash and debris • Remove accumulated sediment if depth exceeds 0.5 inches or excessive ponding is observed (e.g., surface ponding exceeding 4 hours in duration after the storm event)
As needed (within 48 hours after storms >1")	• Check observation wells to ensure proper media bed function • Check pretreatment BMPs and remove sediment if needed • Clean out accumulated sediment as needed • Check inlet/outlet structures for obstructions and repair minor structural damage
At least annually (prior to beginning of wet season)	• Clean and reset flow spreaders if needed • Repair minor rill/gully erosion of media bed • Restore media to design depth if needed • Remove top 2-3 inches of filter media as needed to alleviate ponding • Remove grass and excessive weed growth • Cleanout underdrain, inlet and outlet pipes • Remove sediment from pretreatment BMPs as needed

Other Key Information

This fact sheet shall be used in conjunction with the BMP selection and design information presented in Chapter 6 of the DSM.

FS9-UNDERGROUND STORMWATER CONTROL FACILITIES

BMP SELECTION AND PLANNING

Photo Credit: Capitol Region Watershed District

Table 1: USCF Overview	
BMP Functions (Depends on USCF Type)	*Primary:* • Peak Flow Control • Water Quality Treatment • Volume Reduction
Targeted Pollutants	*Primary:* • Sediment • Nutrients • Metals • Bacteria • Oil & Grease • Organics
Pretreatment	Required for infiltrating facilities
Typical Wildlife Risk	Not applicable
Cost	$$$
O&M Level of Effort	Medium
Tributary Area	≤25 acres
Relative Footprint	Low surface area requirements

Functional Description

Underground stormwater control facilities (USCFs) are structures placed underground that can be designed to provide key stormwater management functions including peak flow control, water quality treatment, and/or volume reduction. These control facilities can be made from a variety of materials (e.g., steel, concrete, HDPE) and can either be designed to either prevent infiltration to underlying soils via a closed structure bottom or added liner or provide infiltration via an open-bottom or perforations in the structure. Figure 1 provides an example schematic of an USCF constructed using a network of connected pipe. Various other configurations and proprietary designs are possible including cast-in-place and pre-fabricated vaults, modular chambers, and lattice structures.

There are numerous pros and cons to USCFs that can vary in importance depending on site requirements and resources. For the Port, an advantage to a USCF compared with surface stormwater controls is that an USCF is unlikely to attract wildlife due to the lack of vegetation and the belowground location of the water surface. Another advantage is that USCFs can be used in places where open space is limited. Placement of USCFs may be under parking or roadway areas or under areas where green space is preferentially dedicated to a purpose other than stormwater management.

Potential disadvantages of USCFs in comparison to other BMPs are that maintenance needs may be more labor intensive, and the lack of surface visibility creates additional risk that maintenance needs may not be completed in a timely manner. Additionally, due to underground siting where vegetation growth is absent, water quality treatment provided by USCFs are predominately though physical processes (e.g., sedimentation), without additional biological processes that are available from vegetation (e.g., filtering, uptake), which may result in less effective treatment. However, if infiltration is available for a site, a USCF could be designed to infiltrate and remove a large volume of stormwater runoff and its corresponding pollutants.

USCF Storage Compartments

USCFs are typically designed to meet stormwater management objectives through the use of storage compartments with functional design volumes. At least one of these three storage compartments is included in a given USCF:

Detention Storage (known as “live storage”) – storage used to temporarily detain a volume of stormwater runoff through outlet control to reduce peak flow release rates from the site.

Infiltration Storage – storage located below the outlet invert used to reduce the volume of stormwater runoff and corresponding pollutants released from the site through controlled infiltration into underlying, permeable materials.

Permanent Pool (known as “dead storage”) – storage used to hold a fixed volume of water below the outlet invert to improve settling of stormwater runoff pollutants.

USCF Types

Other BMP manuals use a variety of names for underground structures that use at least one of the storage compartments discussed above for stormwater management. This fact sheet streamlines the naming conventions by defining the USCF by the function of the storage compartment, including:

Detention USCF (e.g., Detention Vault, Detention Tank, Underground Detention, Structural Detention) – provides detention storage; has a closed or lined bottom

Infiltration USCF (e.g., Infiltration Vault, Infiltration Tank, Infiltration Chambers) – provides infiltration storage; has an open bottom or perforations in structure

Wet USCF (e.g., Wet Vault, Wet Tank) – provides permanent pool storage; has a closed or lined bottom

The storage within a USCF may be designed to provide a single function (e.g., just detention or just infiltration), or it may provide a combination of these functions with different functions for the bottom and top compartments of the USCF. The two common combination USCF types (bottom function/top function) include:

- Infiltration/Detention USCF; has an open bottom or perforations in structure
- Wet/Detention USCF; has a closed or lined bottom

While generally one USCF (whether single or combination function) is installed to serve a site, a train of USCFs could be used where each USCF has a separate stormwater management function.

Site Suitability and Limitations

Table 2 summarizes the various factors and considerations for site suitability for a USCF. Installation of the USCF assumes gravity flow.

Table 2: Site Suitability Considerations for USCF	
Soil Considerations and Infiltration Concerns	• Can be constructed on any NRCS HSG • Infiltration USCFs shall be located on HSG A and B soils • USCFs shall be placed on stable soils with suitable bedding and backfill • Geotechnical analysis verifying stability of the USCF is recommended to evaluate, when applicable: 1) subgrade saturation or head loading on the permeable layer; 2) seepage issues to downstream properties; 3) placement in fill slopes (≥25%); and, 4) setback requirements from slopes and foundations • H-20 live loads shall be accommodated for tanks and vaults under parking and roadways areas.[1]
Groundwater	• ≥ 5 feet separation from the seasonal high groundwater table and the bottom for infiltrating USCFs • Wet or Detention USCFs may be placed in groundwater if properly sealed and ballast material or anchoring are provided
Tributary Area and Land Use	The maximum contributing drainage area to be served by a single underground detention vault or tank is 25 acres
Contamination Concerns	• Infiltration USCFs are not appropriate in areas with contaminated soil or groundwater • Infiltration USCFs are not appropriate if hazardous chemicals/materials are stored within the drainage area unless adequate source controls can be implemented • A liner shall be used for Wet or Detention USCFs if soil or groundwater contamination is a concern

[1]*For live load requirements refer to AASHTO Standard Specifications for Highway Bridges, 17th Edition, 2002.*

Footprint Considerations

The footprint of the USCF depends primarily on the tributary area treated, whether the USCF allows for infiltration, and the site depth and/or width limitations. A low-profile, non-infiltrating USCF can required a large amount of space for runoff management needs whereas a deep, infiltrating USCF will likely require less space. USCFs require land areas similar to centralized BMPs with significant storage volumes, such as extended dry detention basins, but are appropriate for areas where aboveground space is limited. Typically USCFs require about one to five percent of the contributing drainage area.

Wildlife Attractant Considerations

Due to USCFs being located underground without an open water surface or vegetation, they pose little attraction to hazardous wildlife.

General O&M Considerations

Primary O&M considerations include routine inspection for sediment and debris accumulation in pretreatment areas and the USCF and periodic removal of these solids either manually or using appropriate maintenance equipment (e.g., a vactor truck). An appropriate amount of cleanout risers with integrated ladder rungs and locking lids must be provided in the design of USCFs to facilitate inspection and solids removal. More detailed O&M requirements are summarized in the BMP Design and Implementation section.

Cost Considerations

Major costs for USCF include:

- Excavation and associated hauling and disposal costs
- USCF structure materials for storage and treatment needs
- Bedding and backfill materials
- Outlet structure with weir and orifice components
- Cleanout risers and access manholes

Unknown site conditions, such as the composition of subsurface materials (which can increase excavation costs and affect infiltration rates), groundwater levels (which could cause structural site instability due to saturation) and unknown underground utility locations (which could require the USCF or the utility line to be relocated) are factors that may increase construction costs.

The cost of regular maintenance and cleaning of USCFs may be significant. Costs for in-house cleaning may be reasonable with access to proper equipment, such as a vactor truck with adequate hosing length to remove accumulated sediment. Cleaning by a private cleaning service company could be more expensive if the USCF requires confined space entry.

BMP DESIGN AND IMPLEMENTATION

Overview of Design Criteria

Design requirements vary based on the stormwater management functions of the USCFs. Table 3 summarizes some design criteria for various USCF types and structural materials. More detailed design and information is provided in the sections that follow.

Table 3: Minimum Design Criteria for USCFs

Design Parameter	Unit	Design Criteria
Water quality volume	cu-ft	See Chapter 4 of the DSM
Minimum design infiltration rate (for infiltrating USCF)	in/hr	0.5
Drawdown time for WQ volume (detention USCF)	hr	36-48 (minimum-maximum)
Drawdown time for WQ volume (above permanent pool for Wet USCF)	hr	• 12-48 (minimum-maximum) • Also refer to Chapter 6 of the DSM for a discussion on sizing BMPs with a permanent wet pool
Minimum cleanout riser diameter (All USCFs)	ft	2 (3 ft preferred)
Minimum sediment storage[1] (Wet/Detention USCF)	ft	0.5
Minimum pipe diameter, vault or tank depth	ft	3
Minimum freeboard from grate/manhole cover	ft	1
Maximum USCF depth	ft	20

Required if pretreatment is not provided

Setbacks

USCFs shall be set back 5 feet from property lines and a recommended 200 feet from the top of steep slope or landslide area. When required, a geotechnical analysis shall be completed to identify appropriate setback requirements from building foundations or if the USCFs will be placed within 200 feet of a steep slope or landslide area.

Considerations for Locating On-line with Runoff Conveyance

USCFs can be designed as on-line, flow-through systems that can handle the entire range of expected design storm events (e.g., up to and including the 100-year flood control event) or as off-line systems that receive a calculated design flow rate or volume. For a given site, USCFs can meet the primary stormwater management objectives as stand-alone BMPs or they can supplement other site stormwater controls and objectives. For example, a USCF could be used to meter flows to a sub-surface flow wetland.

Major BMP Components

Structural Materials

The USCF can be constructed with a variety of materials and the USCF structure can be configured to be watertight or allow for infiltration. Materials for the USCF are not limited to:

- Reinforced concrete (precast or cast-in-place) vaults; constructed with an open bottom (Infiltration USCF) or closed bottom (Wet, Detention USCF)
- Metal (aluminum, steel, corrugated) pipes; perforated (Infiltration USCF) or non-perforated (Wet, Detention USCF)
- HDPE pipes; perforated (Infiltration USCF) or non-perforated (Wet, Detention USCF)
- Proprietary fiberglass tanks (e.g., Darco, Xerxes®); typically Wet and/or Detention USCF
- Proprietary plastic arch chambers (e.g., CULTEC Contactor® or Recharger®, CONTECH ChamberMaxx®, Stormtech®, StormChamber®); open bottom (Infiltration USCF) or lined with plastic or clay (Wet, Detention USCF)
- Modular lattice structures (e.g., Atlantis Flo-Tank®, Invisible Structures Rainstore[3])

Reinforced concrete shall have a minimum compressive strength of 3,300 psi. Vaults that will be cast-in-place shall be designed by a licensed structural civil engineer. For metal pipes or other components such as fittings, the metal shall not be galvanized (coated with zinc to prevent rusting) in order to prevent leaching of zinc.

Pollutant Outflow Prevention

Design techniques to minimize oil and sediment in outflow include:

- Oil retention baffles, or other techniques such as a downturned elbow at the outlet, can be incorporated into USCFs to hold back oil and grease from outflows. Cleanout risers shall be provided to remove accumulated oil behind oil retention components.
- The bottom of the USCF can be designed with a longitudinal slope or a “v” shaped cross-section to facilitate sediment removal.

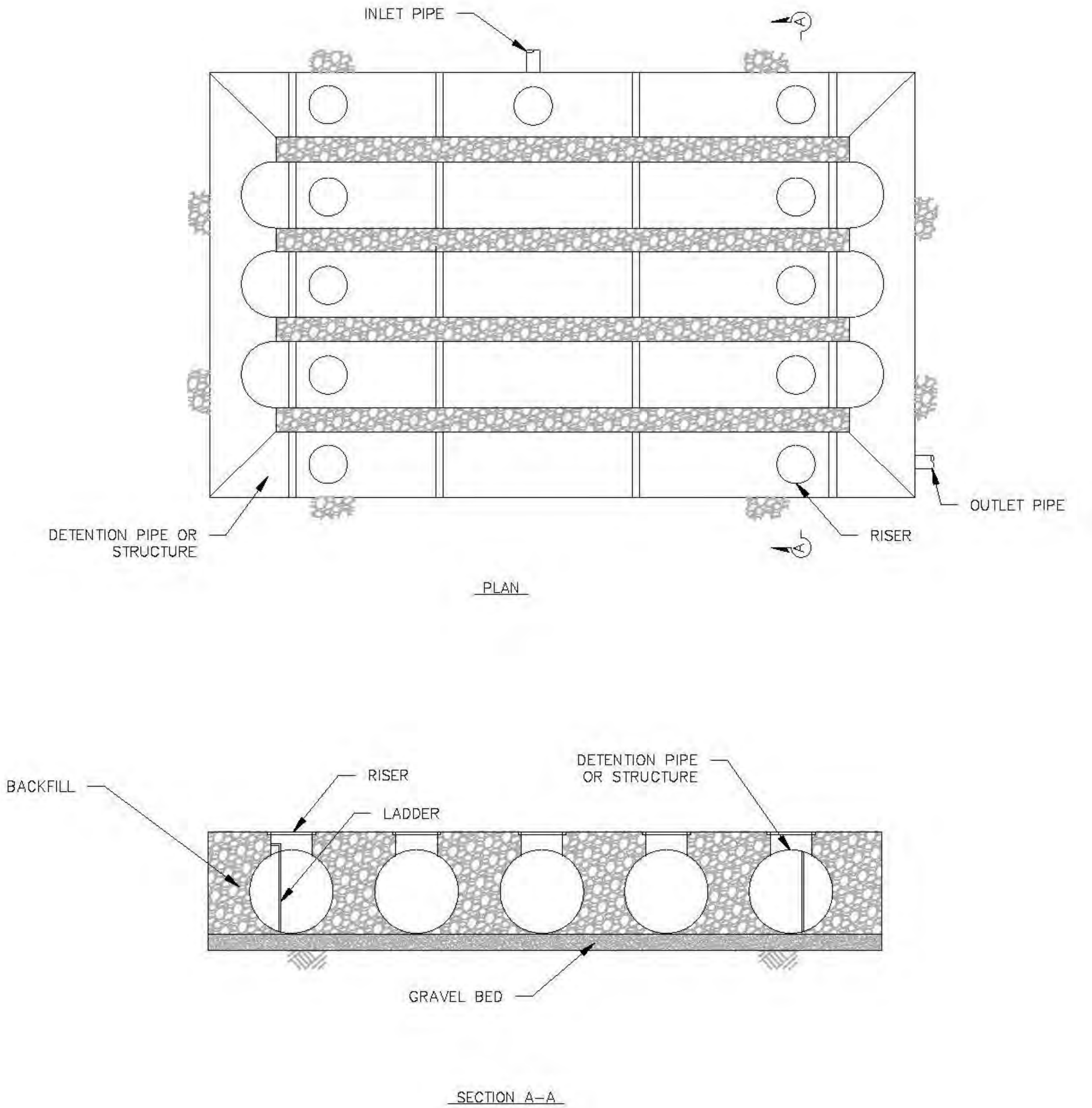


Figure 1: USCF Schematic Plan and Section Views

Pretreatment Requirements

Pretreatment for tributary areas is required for USCFs that allow for infiltration. Pretreatment could be in the form of aboveground surface BMPs, such as vegetated swales, or below ground BMPs, such as hydrodynamic separators. Infiltrating USCFs shall have a functioning and well-maintained pretreatment to minimize clogging from sediment, trash, and/or debris loading to the USCF, thereby maximizing the longevity of the infiltration system.

Non-infiltrating USCFs do not require pretreatment. In-lieu of pretreatment, additional storage volume shall be incorporated below the outlet invert of the structure to account for sediment accumulation.

Considerations for Future Expansion

Because the maximum tributary area draining to a single USCF shall be less than or equal to 25 acres, the entire drainage area should be developed before the USCF becomes operational. All runoff into the USCF should be blocked until the site is stabilized to preserve the sediment storage capacity. The capacity of the USCF determines the tributary area that can be served by the facility. If additional capacity is needed beyond the capacity of a single USCF, two or more vaults and tanks may be installed in parallel.

BMP POST-DESIGN AND IMPLEMENTATION

Construction Considerations

For Infiltration USCFs, soil compaction shall be avoided to the extent practicable during construction to maximize infiltration rates. In general, due to the typically large size of USCFs, careful construction with proper bedding and backfill is required to stabilize the structure and minimize geotechnical hazards. For USCFs using proprietary structure materials, construction installations shall be completed per the manufacturer’s specifications.

USCF plans and construction shall ensure that access via maintained paths is provided to safely enter and inspect the USCFs cleanouts, manholes and outlet structures. For sites where influent and/or effluent monitoring is required, sampling manholes shall also be included upstream and/or downstream of the USCF with adequate inspection access.

O&M Considerations

Proper O&M is necessary for USCFs to continue to function as designed over time. Weir and orifice structures and monitoring equipment shall be located in an accessible manhole. Maintenance access shall be wide and supportive enough for typical maintenance equipment. Maintenance routes shall not exceed 10 percent in slope. Table 4 summarizes common USCF O&M activities.

Table 4: Maintenance Activities and Frequency	
Schedule	**Activity**
Semi-annually	• Check for and remove sediment, trash, debris and oil accumulation from pretreatment and USCF • Check inlet and outlet configurations for obstructions

Other Key Information

This fact sheet shall be used in conjunction with the BMP selection and design information presented in Chapter 6 of the DSM.

FS10-PERVIOUS PAVEMENT

BMP SELECTION AND PLANNING

Photo Credit: Portland Stormwater Management Manual

Table 1: Pervious Pavement Overview	
BMP Functions	*Primary:* • Volume Reduction • Peak Flow Control • LID/GI *Secondary:* • Water Quality Treatment
Targeted Pollutants	*Primary:* • TSS • Metals • Organics • Bacteria • Oil and Grease *Secondary:* • Nutrients
Pretreatment	Not required
Typical Wildlife Risk	Not applicable
Cost	$$
O&M Level of Effort	Low
Tributary Area	• Own footprint or • ≤3 times the pervious pavement footprint if designed to receive run-on
Relative Footprint	Large

Functional Description

Pervious pavements are designed to infiltrate stormwater runoff from rain that falls directly on its surface and potentially adjacent impervious areas. For the purposes of this factsheet, pervious pavements are classified into two main categories: (1) pour-in-place pervious concrete and asphalt and (2) modular pervious paver units or blocks (Figure 1). Pour-in-place pervious asphalt and concrete are poured onsite and allowed to cure in place. Modular pervious pavers vary in composition and design and can be customized for specific sites and infiltrating capacity, including (but not limited to) interlocking concrete pavers, grass pavers, and gravel pavers. Pervious pavement applications are designed to infiltrate stormwater while providing a stable load-bearing surface without increasing the amount of effective impervious cover within a project site.

Pervious pavements treat stormwater runoff through a variety of physical and chemical unit treatment processes including shallow sedimentation, entrapment, straining and sorption. Where site conditions allow, the subsurface layers can be configured to allow water to infiltrate into the underlying native soil. If site soils are not conducive for infiltration, the water that percolates beneath the surface is routed to a downstream stormwater conveyance system via an underdrain. In both cases, the initial percolation of runoff through the surface and subsurface layers of the pervious pavement increases the time of concentration of the drainage area, provides some treatment of pollutants, and decreases the peak flows. Therefore when designed with adequate storage in the pore spaces of the surface and subsurface layers, pervious pavement can provide peak flow control benefits for small storms. Pervious pavements designed for infiltration in permeable native soils can also provide significant volume reduction benefits with the associated pollutant load reduction.

If an underdrain is required and the pavement is used in a high use area, an enhanced design is required. Enhanced pervious pavements include a media filtration layer consisting of sand or an engineered media mix. Basic pervious pavements that do not include a media filtration layer can be applied to non-pollutant generating surfaces, such as pedestrian paths, courtyards, raised traffic islands, and sidewalks with or without an underdrain. Enhanced pervious pavement can be implemented by the Port as treatment facilities for direct runoff (runoff from rain incident on the pavement itself and immediately adjacent impervious surfaces). Additional considerations for siting and design of these BMPs are provided in the following subsections of this fact sheet.

Site Suitability and Limitations

Table 2 summarizes the various site suitability considerations for pervious pavements.

Pervious pavement shall not be located in certain operational areas surrounding the airport due to loading and structural capacity of the systems. In general, the areas where pervious pavements are recommended include parking and light to medium traffic areas. Pervious paver systems are capable of supporting higher traffic loads and volumes, but should be used in lower speed areas. No pervious pavement installations shall be used in areas with tight turning radii, which can cause unraveling and loss of integrity of permeable pavement.

Pervious pavement shall not be placed on areas of recent fill or compacted fill. Grade adjustments requiring fill should be performed using the stone subbase material. Areas of historical fill (>5 years) may be considered for pervious pavement.

Traction sands should not be applied to pervious pavements due to the risk of clogging. Traction sands are typically not needed for pervious pavement because they provider more friction and tend to accumulate less snow and ice than conventional pavements.

Table 2: Site Suitability Considerations for Pervious Pavement	
Soil Characteristics and Infiltration Concerns	• Pervious pavements shall not be constructed over recent fill or compacted fill • Do not locate where infiltrated water may affect the stability of downgradient structures, slopes and embankments • Use where slopes exceed 5% requires a geotechnical investigation • Locations with NRCS HSG A and B preferred. May be placed on HSG C or D soils with additional infiltration testing • An underdrain is required for HSG C and D soils • A raised underdrain may be used for C and D soils to provide ‘partial’ infiltration
Groundwater	• ≥ 5 feet separation between the seasonal high groundwater table and bottom of aggregate layer • ≥ 3 feet separation between the seasonal high groundwater table and bottom of aggregate layer if an underdrain is used
Tributary Area and Land Use	• Limit to own footprint, roof runoff and runoff from adjacent impervious surfaces • Roofs and adjacent impervious surfaces served shall not exceed 3 times pervious pavement footprint (limit of 2 times footprint recommended) • Vegetated areas shall drain away from pervious pavement • Shall not be used at PDX in runway safety areas, taxiway safety areas, or the clearway
Contamination Concerns	• Not appropriate if hazardous chemicals/materials are stored within the drainage area unless adequate source controls can be implemented • Pervious pavement shall be lined or avoided in areas where soils or groundwater might be contaminated

Footprint Considerations

Pervious pavements shall be designed to only receive direct runoff and runoff from adjacent paved areas and roofs. Vegetated areas shall not be allowed to drain onto pervious pavement. Installation of French drains to route sediment laden runoff from adjacent areas away from pervious pavements is recommended to lengthen their useful life and minimize maintenance costs. Berming the drainage area to the French drain could also be effective, but is not recommended in areas where heavy truck traffic is expected.

Wildlife Attractant Considerations

When properly designed and maintained, pervious pavements do not result in significant ponding above the surface and are not likely to attract hazardous wildlife.

General O&M Considerations

General O&M requirements are related to maintaining the infiltration capacity of pervious pavements. Regular maintenance consists of cleaning out clogged surfaces using vacuum-assisted sweepers or pressure washers, removal of moss and vegetation to prevent structural damage from plant roots, and clearing trash and debris. Major maintenance (replacing/repairing pavement or paver blocks) should be needed infrequently. More detailed O&M requirements are summarized in the following section on BMP Design and Implementation.

Cost Considerations

Unknown site conditions, such as underground utility conflicts (which may affect pavement placement), site soil infiltration capacity, reusability of site soils for media mixes, and site slopes are factors that may influence construction costs. Other factors that may influence cost include design decisions such as type of pervious pavement system selected, inclusion or exclusion of media filtration layers, underdrains, and controlled outlet structures.

BMP DESIGN AND IMPLEMENTATION

Overview of Design Criteria

Table 3 summarizes the minimum design criteria for pervious pavement. For enhanced pervious pavement, see Media Filter Fact Sheet for additional information related to the design of the media filtration layers of the pervious pavement system. More detailed design information is provided in the sections that follow.

Table 3: Minimum Design Criteria for Pervious Pavement

Design Parameter	Unit	Design Criteria
Water quality volume	cu-ft	See Chapter 4 of the DSM
Design infiltration rate	in/hr	• ≥0.5 (without underdrains) • An appropriate safety factor shall be applied to the field-measured short-term infiltration rate to obtain the design infiltration rate (see Chapter 6 of the DSM).
Drawdown time for design WQ volume	hours	≤ 30 (subsurface media and gravel layers shall fully drain in no more than 30 hours)
Pore space of media filtration layer	%	20-30
Pore space of aggregate layer	%	30-40
Maximum slope	%	• 6 for pervious asphalt/concrete • 10 for pervious pavers • 5-10 slopes must address under-pavement water retention
Minimum aggregate layer (reservoir layer) depth	in	>12
Underdrain geometry	in	• >6-inch diameter or equivalent; 0.5% slope • >4-inch diameter or equivalent; 1% slope
Other	—	French drains and other diversion structures shall be used for diverting runoff generated from pervious open space areas away from pervious pavement

Groundwater Considerations

Pervious pavements designed to completely infiltrate the water quality volume shall be designed with the bottom of the system at least 5 feet above the seasonal high groundwater table unless is it possible to incorporate a groundwater bypass mechanism into the pervious pavement system. This is to ensure that groundwater does not cause the pavement to remain wet during dry conditions and potentially attract wildlife and compromise the integrity of the pavement over time. The groundwater separation for systems with underdrains shall be 3 feet.

Considerations for Locating On-line with Runoff Conveyance

Pervious pavements are recommended for treating the areas solely contained within their own footprint, roof runoff and directly adjacent areas, which makes them on-line facilities.

Major BMP Components

Diversion Structures

Pervious pavement is vulnerable to clogging from fine sediment loadings in runoff from adjacent surfaces which can be managed by diversion.

- Appropriate site grading shall be employed to the extent practicable to prevent runoff from off-site or adjacent surfaces.
- Diversion structures, such as French drains, may be incorporated to avoid introducing runoff from off-site or adjacent areas to the pervious pavement system.
- The designer may wish to consider hydraulically isolating the facility from off-site areas by edge drains, turnpikes, and tapered bumps.

Surface or Wearing Layer

The choice of either poured-in-place pervious asphalt\concrete or modular paver systems should be carefully considered based on the type of traffic (pedestrian or vehicular) that the space is designed for. The minimum depth requirements for the surface/wearing layer depend on the type and application and are summarized in Table 4.

Table 4: Pervious Pavement Surface Layer Depth Requirements

Application	Concrete (inches)	Asphalt (inches)	Pavers (inches)
Pedestrian Only	4	2.5	2.375
Private Street, Parking Lot, or Fire Lane	4	3	3.125
Public Street	7	6	3.125

Additional design specifications are provided in the following subsections below.

- *Pervious Asphalt* – the surface layer of pervious asphalt is composed of open-graded coarse aggregate that is cemented together by asphalt cement.
  - ODOT has approved a pervious asphalt mix for use on its public highways, referred to as the ODOT open-graded 0.5-inch or 0.75-inch asphalt mix design (ODOT 2008 Standard Specifications 00745 has more information about open-graded mixes).
  - Void space in properly installed pervious asphalt shall have at least 15 percent void space.
- *Pervious Concrete* - Pervious concrete is a uniform open-textured pervious paving surface typically consisting of Portland cement, fly ash, locally available open-graded coarse aggregate, admixtures, fibers, and potable water.
  - Void space in properly installed pervious concrete must have at least 15 percent void space and the gradation shall be AASHTO Grading No. 67 (0.75 inch and lower).
  - The depth of the layer may increase from the minimum required depth (4 or 7 inches) depending on the bearing strength and pavement design requirements.
  - Pervious concrete must be 2400 to 2500 psi in 28 days.
- *Pervious Pavers* - Numerous pervious paver systems are commercially available that can be tailored to the specific site and application. Brand names and specifications must be submitted with permit applications.
  - Open surface spaces between pavers can be from 0.5 to 1 inch.
  - Edge restraints for pavers must be permanent (cast-in-place or pre-cast concrete curbs) that are a minimum of 6 inches wide and 12 inches deep.

Bedding and Choker Course Layers

Beneath the surface/wearing layer is the bedding and choker course layers (also known as the stabilizing course) consisting of smaller sized aggregate (e.g., ASTM D422 No. 8) which provides a level surface for installing the permeable pavement and also acts as a filter to trap particles and help prevent the aggregate layer beneath it from clogging. The bedding course layer is typically about 1.5 to 3 inches deep and may be underlain by a choker course layer or geotextile fabric to prevent the smaller sized aggregate from migrating into the larger aggregate base layer. For an enhanced treatment design, a media filtration layer can be installed between the bedding and choker course layers. See the Media Filter Fact Sheet for a list of media types that can be blended together for the media filtration layer.

Aggregate Layer (Reservoir Layer)

The aggregate layer is installed just below the choker course and provides the bulk of the runoff storage capacity for the pervious pavement system. The aggregate layer shall be designed to function as a structural support layer as well as a reservoir layer for storing water. The aggregate layer provides a stable base for the pervious pavement surface with a high degree of permeability that temporarily stores and disperses water before allowing it to infiltrate into the underlying soil. The reservoir layer typically consists of washed, coarse, open-graded AASHTO

No. 57 aggregate without any fine sands. If no infiltration is allowed, an impermeable liner shall be placed under the aggregate layer. The reservoir layer shall be level and have zero slopes.

- The aggregate material is composed of washed crushed 0.75 to 2-inch or No. 57 rock.
- Void space within the aggregate base layer is typically between 20 to 40 percent.
- A minimum base layer depth of 12 inches is recommended.

Underdrains

For pervious pavement installations that are not designed to infiltrate the entire water quality volume, an underdrain shall be installed with the following characteristics:

- All underdrain pipes and connectors shall be at least 4 inches or greater in diameter. Underdrain systems that are not circular shall provide an equivalent open area that is equal to or greater than the open area of an equivalent length of 4-inch diameter perforated pipe.
- Slotted pipe is preferred to perforated pipe since it is less prone to clogging and slots sizes can be reduced while maintaining the effective open area ratio. If perforated pipe is used, round perforations must be at least 0.5-inch in diameter.
- The underdrain pipe shall be placed with a minimum slope of 0.5 percent.
- The invert of the underdrain pipe shall be above the seasonal high groundwater table elevation.
- Underdrains shall be installed with vented clean out risers at the terminal ends of each pipe.
- Underdrains can be installed in a variety of configurations including a central underdrain with or without lateral collection pipes.
- At least 6 inches of gravel backfill shall be maintained over all underdrain piping, and at least 6 inches must be maintained on both sides and beneath the pipe to prevent damage by heavy equipment during maintenance. Either drain rock or gravel backfill may be used between pipes.

Geotextile Separation Fabric or Choke Stone

A separation layer is needed to provide a pervious barrier to prevent fine soil particles from migrating up into the aggregate layer from the native soils, which may be a woven geotextile fabric or choke stone.

- Choke stone may be used in lieu of a geotextile to separate media layers and is preferred over geotextile.
- The geotextile shall extend along the bottom and sides of the pavement structure.
- If the long-term underlying infiltration rate is greater than 2.4 inches per hour, a treatment media filtration base layer shall be incorporated below the geotextile/choke

stone layer. See the Media Filter Fact Sheet for a list of media types that can be blended together for the media filtration layer.

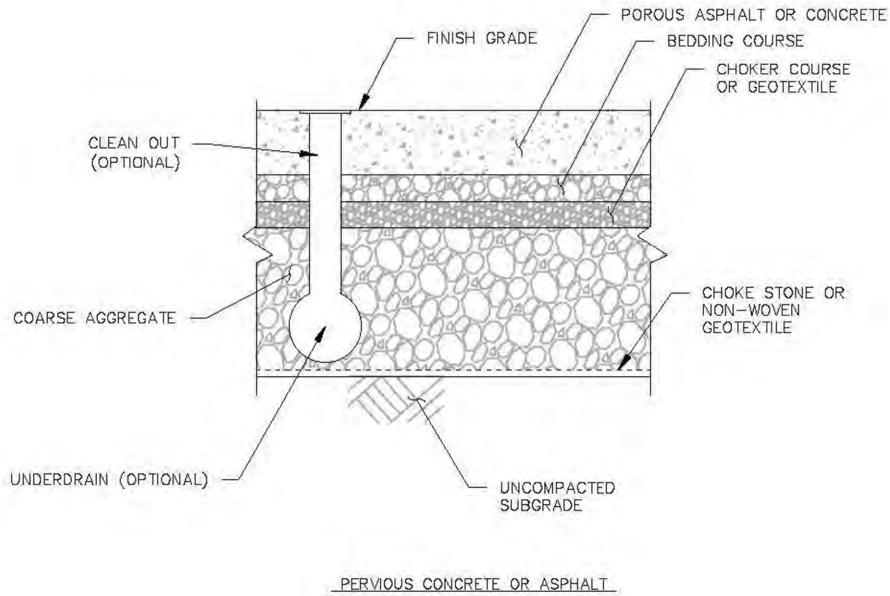
Subgrade

The subgrade layer represents the native soils underneath the aggregate and separation layers.

- Pervious pavements shall not be constructed on recent fill soils.
- The subgrade layer shall be scarified or tilled to a depth of 3 to 4 inches prior to placing the aggregate material. The subgrade layer shall be leveled and lightly compacted using a plate compactor with a slight grade away from any foundations. While compaction is required to minimize rutting and ensure structural stability for public roadways, private streets, parking lots, and fire lanes, it will reduce the permeability of soils and shall be kept at whatever minimum will maintain structural integrity.
- If the subgrade is overly compacted, till the soil down to 2 feet below the proposed bottom of the facility to maintain permeability.

Pretreatment Requirements

Pervious pavement installations do not require pretreatment, but the design shall avoid run-on from adjacent pervious open space areas.



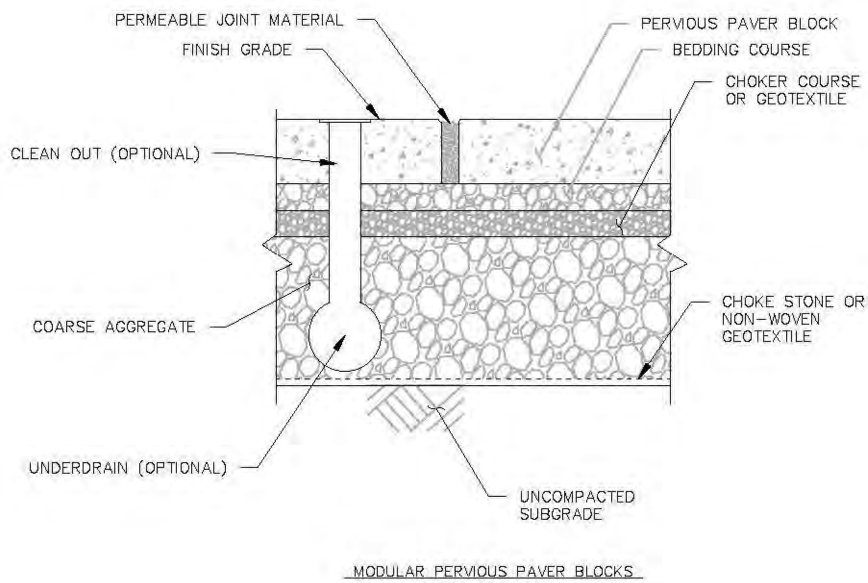


Figure 1: Pervious Pavement Schematic Plan and Section Views

Considerations for Future Expansion

If pervious pavement is designed to treat areas within its own footprint, additional pervious pavement would be added as a replacement for any additional planned impervious area. If pervious pavement is designed to treat run-on from a directly adjacent tributary area, the tributary area should be fully developed and stabilized before it is allowed to discharge to the facility to minimize the potential for clogging the facility and reducing its infiltration capacity. To avoid tracking soil on to the pervious pavement surface during construction activities, construction vehicles should not be allowed unless the surface is fully covered or otherwise protected.

BMP POST-DESIGN AND IMPLEMENTATION

Construction Considerations

Protection of the subgrade shall be established during construction to prevent over-compaction. Traffic over the proposed pavement area shall be prohibited until construction is complete. The geotextile separation fabric (if used instead of choking stone) shall be extended over the edges of the proposed pervious pavement area during construction to prevent siltation of the area. For enhanced pervious pavement, see the Media Filter Fact Sheet for additional construction considerations. An observation well shall be installed to facilitate water quality monitoring and visual maintenance inspections.

O&M Considerations

Pervious pavements do not require separate maintenance access for regular or routine maintenance. Table 5 summarizes common pervious pavement O&M activities. For enhanced pervious pavement, additional maintenance requirements from the Media Filter Fact Sheet should be considered.

Table 5: Maintenance Activities and Frequency

Schedule	Activity
As needed (frequently)	• Perform periodic scheduled inspections to identify problems and maintenance needs such as the required frequency for manual litter removal • Sweep leaf litter and trash or debris using a mechanical sweeper (i.e., regenerative air or vacuum-assisted sweeper) 3-4 times per year to prevent clogging • Manually remove weeds from pervious pavers; do not use herbicides
As needed (infrequently)	• Repair cracked or moving edge restraints • Repair cracked or settled pavement • Remove any potentially large root systems that could cause damage • If the infiltration capacity is significantly reduced (based on visual observations), reestablish the infiltration capacity by removing sediment deposited in the upper layers of the system with a vactor truck excavating down to clogged layer and cleaning or replacing clogged layer

Table 5: Maintenance Activities and Frequency	
Schedule	**Activity**
As needed (within 48 hours after storms >1")	• Inspect pervious pavement surface to identify problems and maintenance needs • Check observation wells to ensure proper drainage • Sweep leaf litter and trash or debris to prevent clogging as needed
At least annually (prior to beginning of wet season)	• Power wash asphalt or concrete pavement surfaces; do not use surfactants • Check for any needed structural repairs and repair or replace aggregate base, sand, or surface layer components • Fill in interstitial gaps between pavers with gravel/sand fill • Remove moss and vegetation in pavement or non-vegetated pavers

Other Key Information

This fact sheet shall be used in conjunction with the BMP selection and design information presented in Chapter 6 of the DSM.

Refer to the Portland Bureau of Transportation (2013) to coordinate pavement design requirements.

FS11-BUILDING BMPS

BMP SELECTION AND PLANNING

Photo Credit: Portland BES Stormwater Management Manual

Table 1: Building BMPs	
BMP Functions	*Primary:* • LID/GI • Varies *Secondary:* • Varies
Targeted Pollutants	Varies (see text)
Pretreatment	Not required for roof runoff
Typical Wildlife Risk	• Planter Box Filters: Low • Green Roofs: Low • Cisterns: Not applicable • Dry Wells: Not applicable
Cost	• Planter Box Filters: $$$ • Green Roofs: $$$$ • Cisterns: $$$ • Dry Wells: $$$
O&M Level of Effort	• Planter Box Filters: Medium • Green Roofs: High • Cisterns: High • Dry Wells: Low
Tributary Area	Varies (see text)
Relative Footprint	Varies (see text)

Functional Description

For the purposes of this fact sheet, BMPs that treat rain falling on roofs or runoff from building roofs are classified as building BMPs. While a number of proprietary and non-proprietary BMPs meet this definition, the focus of this fact sheet is limited to (1) green roofs, (2) planter box filters, (3) cisterns, and (4) dry wells (Figure 1 through Figure 4). A brief description of each of the BMPs included in the building BMP category follows.

Green Roofs *(also known as ecoroofs, roof gardens, or vegetated roof covers)* are roofing systems that consist of vegetation planted in growing media installed over a drainage layer and water proof membrane on the roof of a building or other roofed structure. Rainfall that normally runs off a roof is captured and detained in the growing media and drainage layer, allowing for subsequent evapotranspiration or slow release to downstream conveyance systems. This essentially reduces the effective imperviousness of the building or structure and provides volume and peak flow reduction benefits. Roof runoff is relatively clean compared to runoff from other onsite surfaces; therefore, the treatment performance of green roofs is not comparable to other BMPs. There are two main types of green roofs: Extensive and intensive. Extensive green roofs are lighter designs (4 to 6 inches of soil and 20 to 30 pounds per square foot) aimed at minimizing additional structural support needs. Intensive green roofs are heavier designs with increased soil depth to support a variety of grasses, shrubs, and trees. The treatment processes in green roofs include shallow sedimentation, entrapment, straining and sorption depending on the depth and composition of the growing media and drainage layers.

Planter Box Filters (planter boxes) are distributed bioretention-type treatment controls that are either contained in closed bottom enclosures or open-bottomed enclosures over native soils to capture stormwater runoff primarily from roofs and nearby adjacent surfaces. Planter box filters are typically installed around the perimeter of a building and typically consist of an underdrain embedded in gravel/drain rock underneath a boundary layer of geotextile fabric (or a choking layer) on top of which is installed growing media with vegetation. Planter box filters support a variety of physical, biological, and chemical unit treatment processes similar to green roofs and bioretention areas.

Cisterns are typically used for rainwater harvesting and range in size from 100 gallons to over 10,000 gallons. They are typically larger than rain barrels and made of more durable materials such as concrete, plastic, polyethylene, or metal. The size of the cistern needed and the volume reduction capacity for a project depends largely on the size of the rooftop drainage area, the demand for nonpotable use, and the space available. Rainwater can be used for both indoor nonpotable uses and for outdoor irrigation. All cisterns require plumbing approval from the City of Portland's Bureau of Development Services. Cisterns can be either installed above or below ground or on rooftops. The primary benefit provided by cisterns is volume and peak flow reduction.

Dry Wells are vertical, perforated underground structures (typically made of concrete or plastic) that capture and hold stormwater for infiltration into surrounding native soils. The primary benefit provided by dry wells is volume and peak flow reduction; dry wells provide little to no treatment of incoming flows prior to infiltrating into site soils. Dry wells are classified as "Class V Injection Wells" under the federal UIC Program. UICs must be registered with the Oregon DEQ and classified as exempt, authorized by rule, or authorized by permit to be used as stormwater BMPs. To protect groundwater, the UIC program requires stormwater to be pretreated for pollutants of concern prior to discharging to UICs. Dry wells are prohibited from use within the Columbia South Shore and Cascade Station/Portland International Center Plans Districts. DEQ has set minimum criteria for UICs, which can be found on the DEQ website at http://www.deq.state.or.us/wq/uic/akuthorization.htm. As described in Chapter 4 of the DSM, the Port has a policy that does not allow the creation of new UICs, unless no other options are feasible and a variance is requested.

Some building BMPs such as green roofs and planter boxes, because they contain vegetation, have the potential to attract hazardous wildlife at PDX if not managed properly. If these BMPs are to be used at PDX, their design and placement shall be coordinated with the requirements and guidance in the PDX WHMP. Additional considerations to manage wildlife risk are provided in the following subsections of this fact sheet.

Site Suitability and Limitations

Table 2: Site Suitability Considerations for Building BMPs	
Soil Considerations and Infiltration Concerns	**Green Roofs** • Not applicable – no specific concerns exist beyond what would otherwise be expected for a typical roof with no green roof installed **Planter Box Filters** • Can be constructed on any NRCS Hydrologic Soil Group • Do not locate or allow infiltration where infiltrated water may affect the stability of downgradient structures, slopes, and embankments **Cisterns** • Can be constructed on any NRCS Hydrologic Soil Group • Can be designed to overflow into perforated underdrains for infiltration into adjacent native soils where infiltrated water will not affect stability of structures; otherwise overflow to surface or piped conveyance system • Level slope required for aboveground cistern foundation **Dry Wells** • Dry wells shall only be used in native soils with an infiltration rate ≥0.5 in/hr • Do not locate or allow infiltration where infiltrated water may affect the stability of downgradient structures, slopes, and embankments • A geotechnical report is required for areas with slopes greater than 15%
Groundwater	**Green Roofs** • Not applicable – no specific concerns exist beyond what would otherwise be expected for a typical roof with no green roof installed **Planter Box Filters** • ≥ 5 feet separation between bottom and seasonal high groundwater table if designed for infiltration • ≥ 3 feet separation between bottom and seasonal high groundwater if designed with underdrains **Cisterns** • Shallow groundwater area installations shall account for buoyancy during and after construction. **Dry Wells** • ≥ 5 feet separation between bottom of dry well and groundwater table
Tributary Area and Land Use	**Green Roofs** • Limited to own footprint **Planter Box Filters** • <15,000 square feet recommended **Cisterns** • No tributary area limitations apply if properly designed **Dry Wells** • No tributary area limitations apply if properly designed and maintained
Contamination Concerns	**Green Roofs, Cisterns** • None **Planter Box Filters** • Not appropriate in areas with contaminated soil or groundwater if designed for infiltration. Not appropriate if hazardous chemicals/materials are stored within the drainage area unless adequate source controls can be implemented **Dry Wells** • Not appropriate in areas with contaminated soil or groundwater

Footprint Considerations

Planter Box Filters can be incorporated into the existing landscape and sized appropriately to control runoff. Proper siting is controlled by the locations of roof drains and downstream conveyance system components. They can be built in any area around the edge of a building or building driveways and sidewalks as long as there is enough relief for any included underdrains and overflow pipes to connect to the downstream stormwater conveyance system. The footprint to tributary area ratio for planter boxes depends on the site conditions and the design of the planter box (typically 5 percent).

Cisterns can be sized as needed based on the available budget, space, and the demand for harvested rainwater. Cisterns can range in size and footprint, can be creatively located (e.g., underground, on rooftops, or flush with the side of a building) to conserve space. The footprint to the tributary area ratio varies widely based on site conditions and design goals.

Dry Wells installed vertically have very limited surface footprint requirements. The volume of storage needed and the amount of excavation depends on the minimum diameter for the dry wells (28 inches), the infiltration capacity of onsite soils, and the size of the tributary area. The surface footprint to tributary area ratio for a dry well is typically limited to the diameter of the access cover and is therefore very small.

Wildlife Attractant Considerations

Planter box filters may pond surface water and also contain vegetation. Therefore they are considered a low concern for hazardous wildlife because they are distributed facilities with a relatively small footprint. Green roofs, which are vegetated although they do not pond water, are also considered to be a low concern for attracting hazardous wildlife. Cisterns and dry wells are not considered to have a risk of attracting hazardous wildlife because they do not pond water or contain vegetation.

General O&M Considerations

General O&M requirements are related to maintaining the flow and infiltration capacity of the building BMPs and maintaining an adequate cover of vegetation to minimize erosion and promote water quality treatment, where appropriate. Regular maintenance consists of clearing sediment, trash and debris, mowing (if required), pruning and replacing plants as needed to cover denuded areas, and performing periodic inspections to ensure the BMP is functioning properly. Major maintenance should be needed infrequently. More detailed O&M requirements are summarized in the following sections on BMP Design and Implementation.

Cost Considerations

Major capital cost components for building BMPs include site preparation (waterproofing, clearing vegetation, excavation and grading), piping/plumbing, and structural components (enclosures, structural support, inlet/outlet structures, manholes, etc.). Specific major cost components vary by building BMP type.

- Green roofs require plants, soil, moisture barriers, and substantial structural support.

- Cisterns, depending on their size and location, may require additional plumbing, overflow and bypass systems, and a sturdy foundation sized to support the weight of the cistern filled to capacity.
- Dry wells may require plumbing, an overflow system, and substantial excavation.
- Planter box filters may require substantial excavation, plants, growing media, and plumbing.

Unknown site conditions, such as the composition of subsurface materials (which can increase excavation costs), and unknown underground utility locations (which may require relocation) are factors that may increase construction costs. Also, phasing of construction to minimize impacts to building access may be a relevant cost consideration in some cases.

BMP DESIGN AND IMPLEMENTATION

Overview of Design Criteria

Tables 3a-3d summarize minimum design criteria for building BMPs. More detailed design and information is provided in the sections that follow.

Table 3a: Minimum Design Criteria for Green Roofs		
Design Parameter	**Unit**	**Design Criteria**
Water quality volume	cu-ft	See Chapter 4 of the DSM
Soil Depth	in	≥3 inches (extensive green roofs) ≥6 inches (intensive green roofs)
Saturated soil weight	pound per square foot	10 - 35 (extensive green roofs) 60 – 200 (intensive green roofs)
Minimum/Maximum slope	%	0 - 25

Table 3b: Minimum Design Criteria for Planter Box Filters		
Design Parameter	**Unit**	**Design Criteria**
Water quality volume Water quality flow	cu-ft cfs	• See Chapter 4 of the DSM • May be designed as volume-based, flow-based or a combination • No minimum required for opportunistic implementation
Drawdown time	hr	≤12, free water in planting media must drain within 24 hours
Ponding Depth	in	≤12 inches, ≤ 6 inches preferred
Underdrain geometry	in	• ≥4-inch diameter or equivalent; ≥0.5% slope • Raised underdrain may be used to provide 'partial' infiltration
Soil depth	in	≥24 minimum, ≥ 36 inches preferred and required if trees planted
Stabilized mulch depth	in	≥2 minimum, 3 inches preferred
Freeboard	in	2 inches between water surface elevation and overflow elevation

Table 3c: Minimum Design Criteria for Cisterns		
Design Parameter	**Unit**	**Design Criteria**
Water quality design volume	cu-ft	• See Chapter 4 of the DSM • Designer shall perform a water balance to ensure the cistern sizing is adequate to meet the water demand • No minimum required for opportunistic implementation
Minimum/Maximum slope	%	Any as long as foundation is leveled
Optional first flush bypass	gal/sq ft	0.0125 – 0.05 gallons per square foot of roof area depending on expected roof pollutant loading

Table 3d: Minimum Design Criteria for Dry Wells		
Design Parameter	**Unit**	**Design Criteria**
Water quality design volume	cu-ft	• See Chapter 4 of the DSM • No minimum required for opportunistic implementation
Design filtration rate	in/hr	2
Minimum diameter	in	28
Recommended depth	ft	5-20
Minimum draw down time	hr	72 after inflows have stopped

Soils Suitability

Soil suitability is not an important consideration for some building BMPs such as green roofs, and closed-bottom planter boxes. The soil suitability considerations for the remaining building BMPs are discussed below.

Planter box filters (open-bottom)

Installed only on unsaturated soils with design infiltration rates on the order of 0.5 in/hr or greater, if designed for infiltration (otherwise underdrains shall be used). Partial infiltration may be implemented with a raised underdrain where underlying soil infiltration rate is less than 0.5 in/hr.

Cisterns (underground)

Installed in unsaturated soils, high groundwater area installations shall account for buoyancy during and after construction.

Dry Wells

Installed only in unsaturated soils with design infiltration capacities of 0.5 in/hr or greater.

Considerations for Locating On-line with Runoff Conveyance

Green roofs capture and treat runoff from rainfall that is directly incident on their own footprint and are therefore on-line by default. Planter box filters treat roof runoff and can be made off-line by installing an overflow roof drain system for conveying high flows directly to the downstream stormwater conveyance system. Cisterns shall be installed in an off-line configuration allowing bypass to downstream conveyance when full. Dry wells shall similarly be installed in an off-line configuration for the same reasons.

Major BMP Components

Green Roofs

- Soil used in the green roof shall be rapidly draining, not too heavy when saturated, and contain the appropriate nutrients to be an adequate growing medium for plants. A mix of ¼ topsoil, ¼ compost, and ½ pumice perlite may be an appropriate soil blend, other components may include digested fiber, shale, and coir. Clay soils shall be avoided.
- It is recommended that the vegetation covers a minimum of 80 percent of the planted roof surface within two years of installation. Plants selected shall be low maintenance and able to cope with the extreme weather conditions of a rooftop. Plants may be selected from “Green Roof Plants” by Snodgrass & Snodgrass, the 2008 City of Portland BES Ecoroof Plant Report, and/or another equivalent source.
- Irrigation systems are encouraged to help establish plants and maintain the system through periods of extended drought.
- Waterproof membranes prevent roof runoff from penetrating and damaging the underlying roofing materials. There are many different types of membranes on the market.
- Root barriers may be needed to prevent plant roots from damaging the water proofing material and the underlying roof.
- A drainage layer is recommended to move excess runoff from the roof. The drainage layer may consist of gravel or several available plastic alternatives.
- Ballast rock may be placed around the perimeter of the roof and over flow structures to provide maintenance access.
- Structural supports shall be sufficient to support the weight of the soil, water, and vegetation. This component can be an especially challenging consideration for retrofit projects. A licensed structural engineer shall be consulted to verify support requirements.

Planter Box Filters

- Enclosure/container walls shall be made of concrete, brick, stone, or other durable material.
- Splash blocks or other erosion protection materials shall be installed under downspout or pipe inflows. Woody plants shall not be located near these inflows.
- Impermeable liners used in flow-through facilities shall be made of 30 mil PVC or an equivalent material.

- Drain rock used in planter boxes shall have a diameter of ¾ - 1½ inches. Drain rock and soil layers must be separated by geotextile fabric or a 3-inch choking layer.
- Underdrains shall be at least 4 inches in diameter. They shall be made of slotted PVC or corrugated HDPE. Pipes shall have a slope of at least 0.5 percent and shall be installed at least 6 inches above the bottom of the planter box enclosure/container. If raised underdrains are used to promote infiltration, install additional drain rock below underdrain.
- Rigid observation/cleanout pipes shall be connected to the underdrain at every lateral connector pipe (typically spaced at 10 feet apart). The tops of the pipes shall extend at least 6 inches above the top of the planter mulch and be covered with lockable screw caps.
- Vegetation shall be drought and flood tolerant. The recommended vegetation density is a minimum of 70 percent coverage after 2 years.
- The imported planting media shall be a minimum of 18 inches deep. Imported planting media shall be composed of 80 to 88 percent sand (e.g., meeting ASTM C33 specifications), 8 to 12 percent soil fines (in the form of topsoil) and 1 to 5 percent organic matter (aged compost or shredded hardwood bark mulch) by volume. If compost is used as the source of organic matter, it shall be tested and determined to meet US Composting Council specifications. It is further recommended that the compost is certified by the US Composting Council's Seal of Testing assurance program. The P-index of the engineered media shall be monitored and controlled to minimize phosphorus export from the BMP.
- Mulch (2 to 3 inch layer) is recommended for all planters on the planting media surface.

Dry Wells

- Dry well structure is typically a 5 to 20-foot depth precast concrete or high density plastic structure that is buried in the ground.
- Drain rock is recommended to fill in and around the dry well structure.
- Geotextile fabric shall be placed above the drain rock and along the sides of the dry well to prevent fine sediment particles from clogging the structure.
- Upstream diversion shall be included to bypass excess flows and prevent dry well overflow during exceptionally large storm events that exceed the dry well's design capacity.

Cisterns

- Cisterns are made of a wide variety of materials. Aboveground cisterns are typically made of plastic or metal and below ground cisterns are typically made of reinforced fiberglass. All cisterns shall include a label stating that the water is not potable.
- Additional plumbing may be needed to connect roof downspouts to the cistern, as well as to plumb the cistern drain and overflow. Plumbing shall also include maintenance clean outs.

- The foundation must be flat and robust enough to support the maximum weight of the cistern to avoid shifting as the cistern fills. Aboveground cisterns are often anchored to the foundation and strapped to the side of the building to prevent tipping. It is also common practice to strap below ground cisterns to their foundation to prevent shifting and counteract buoyancy especially in areas where the groundwater may seasonally rise above the bottom of the cistern.
- Optional components:
  - Gutter screens are encouraged to reduce gutter and cistern inlet clogging from leaf litter and other organic debris.
  - A roof washer or first flush diverter is highly recommended to allow any built up debris, animal waste, or other pollutants that may have deposited on the roof top between storms, to bypass the cistern. After a pre-determined volume has passed, then clean water will be directed towards the cistern.
  - Inlet screens are recommended to reduce coarse material and organic debris deposition in the cistern.
  - Filtration systems are only required if rain water is to be used for indoor or potable purposes. Potable treatment systems typically include, at a minimum, advanced filtration, with a five micron or less cartridge followed by a three micron or less activated charcoal filter, followed by disinfection by chemical treatment, ozonation, or UV treatment.

Pretreatment Requirements

Pretreatment is not applicable for green roofs, and not required for planter boxes and cisterns. Dry well inlets shall have screens to keep out trash and debris. Additional pretreatment is not required for dry wells solely treating roof runoff. Full treatment by another BMP considered to be acceptable for primary treatment is required if the dry well is located in soil with an infiltration rate that exceeds 2.4 in/hr.

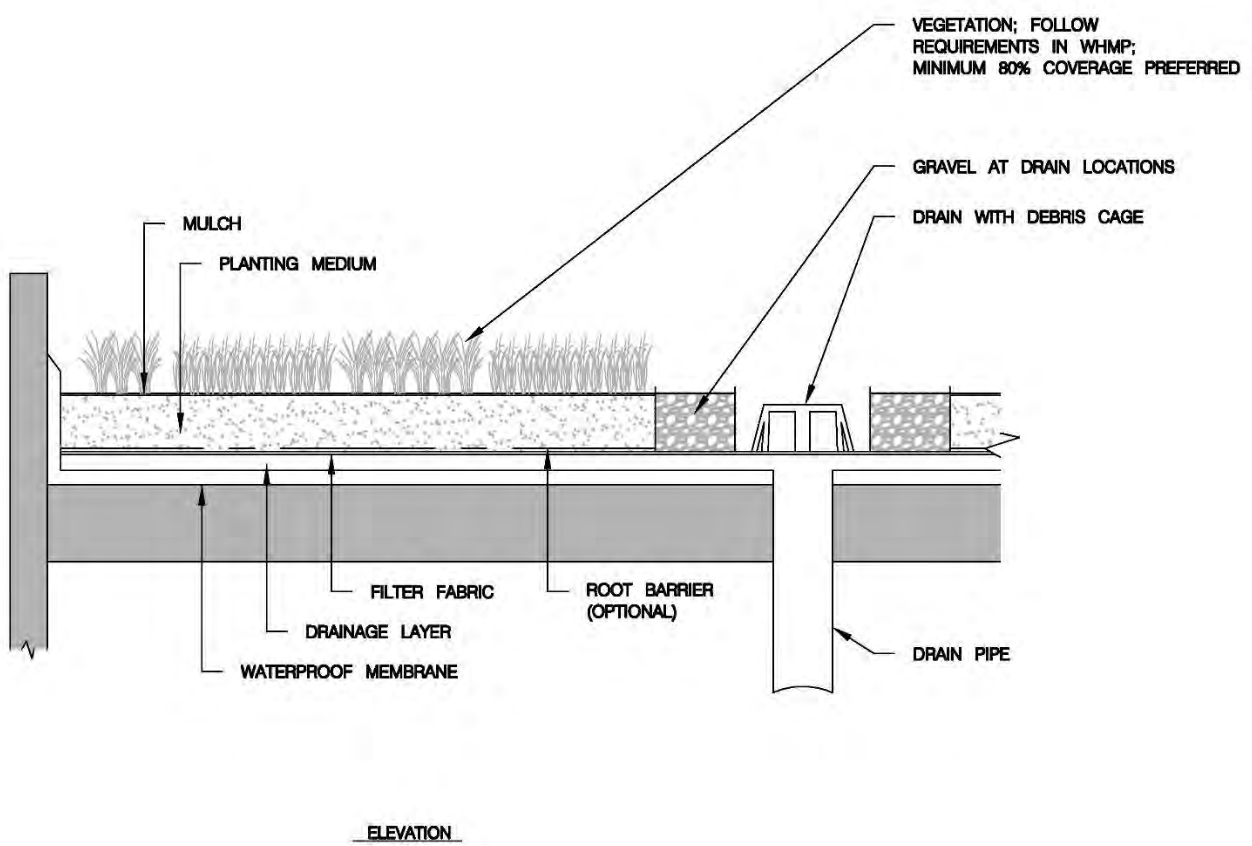


Figure 1a: Building BMPs Schematic (Green Roof)

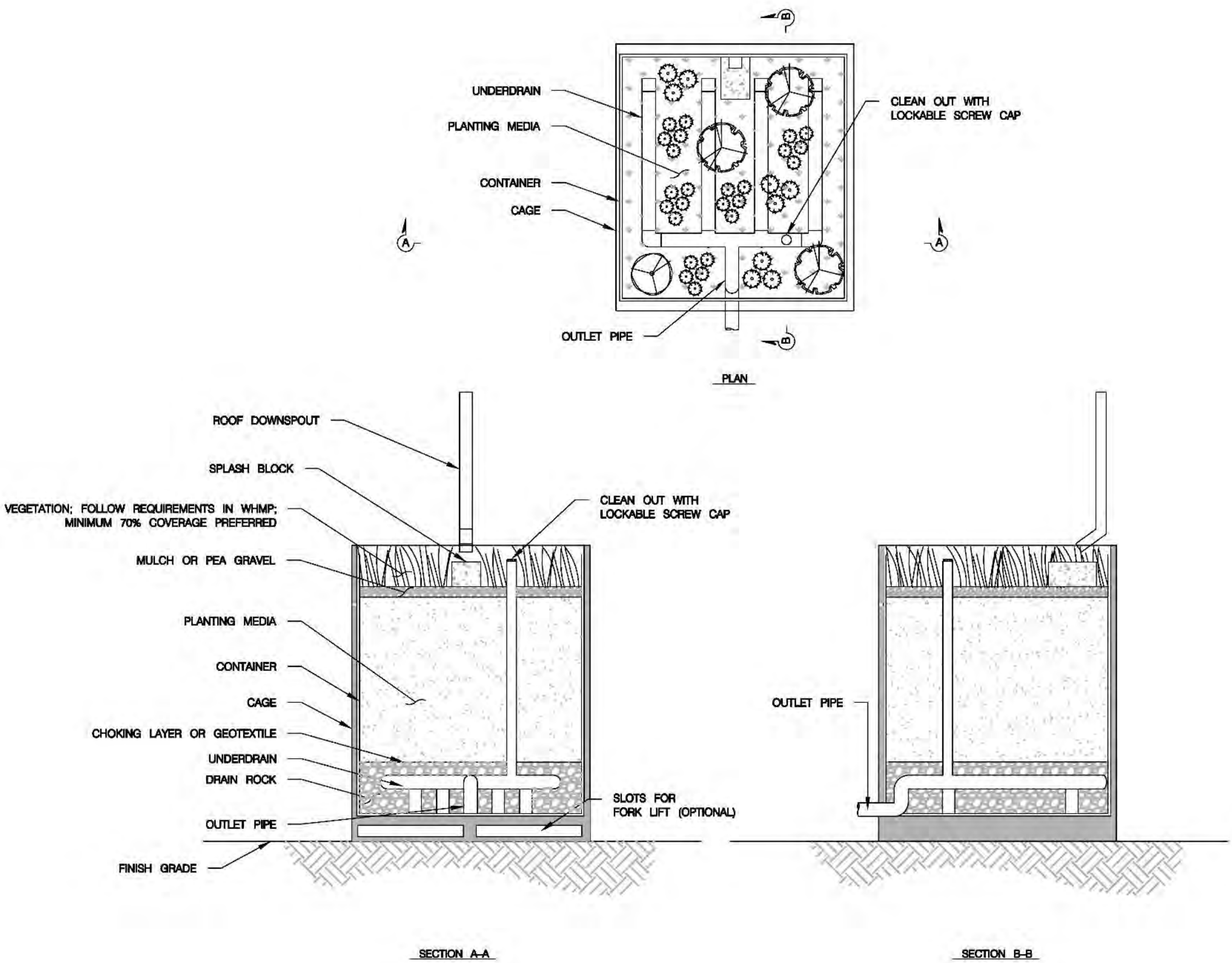


Figure 1b: Building BMPs Schematic Plan and Section Views (Planter Box Filter)

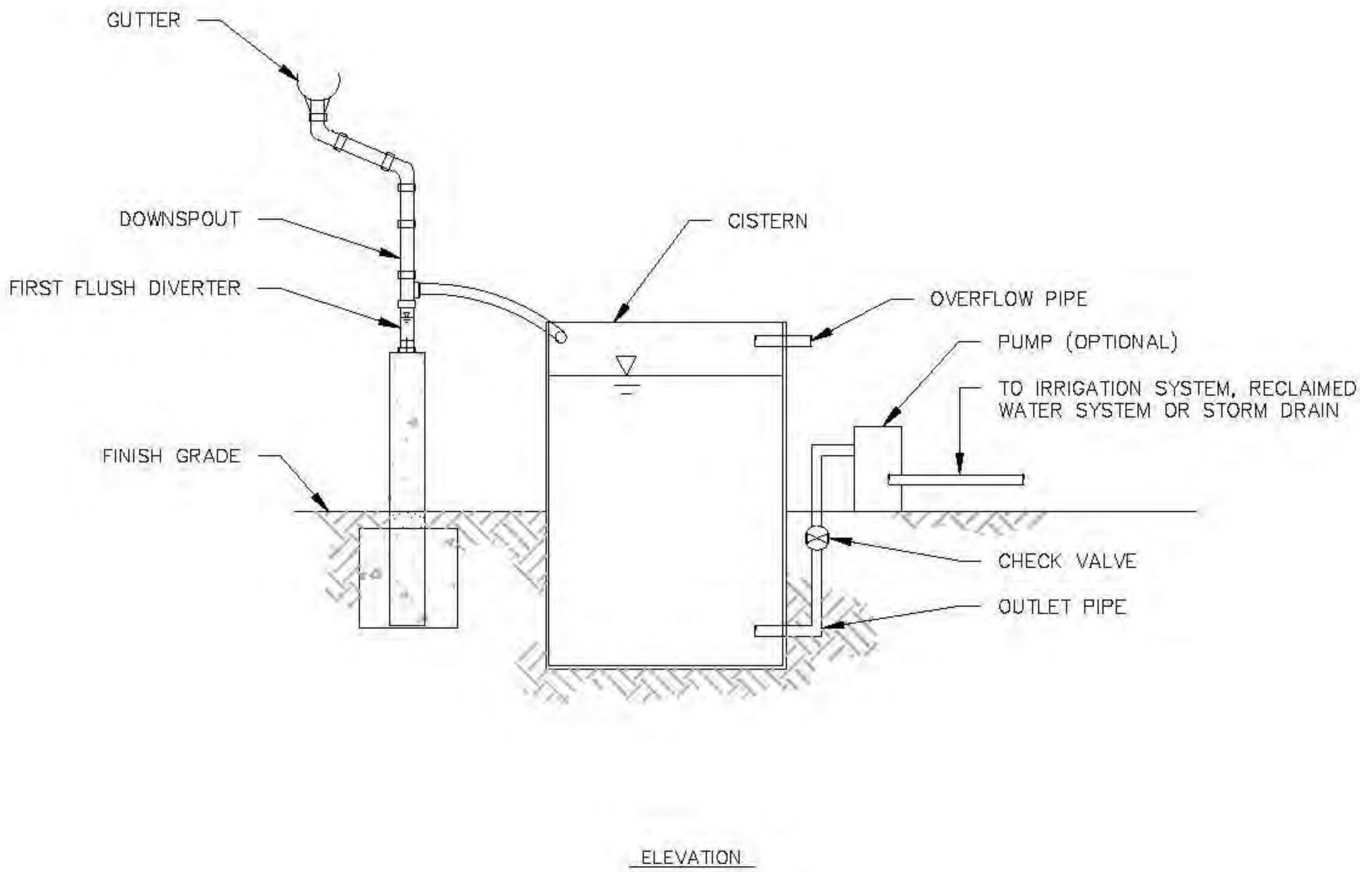


Figure 1c: Building BMPs Schematic (Cistern)

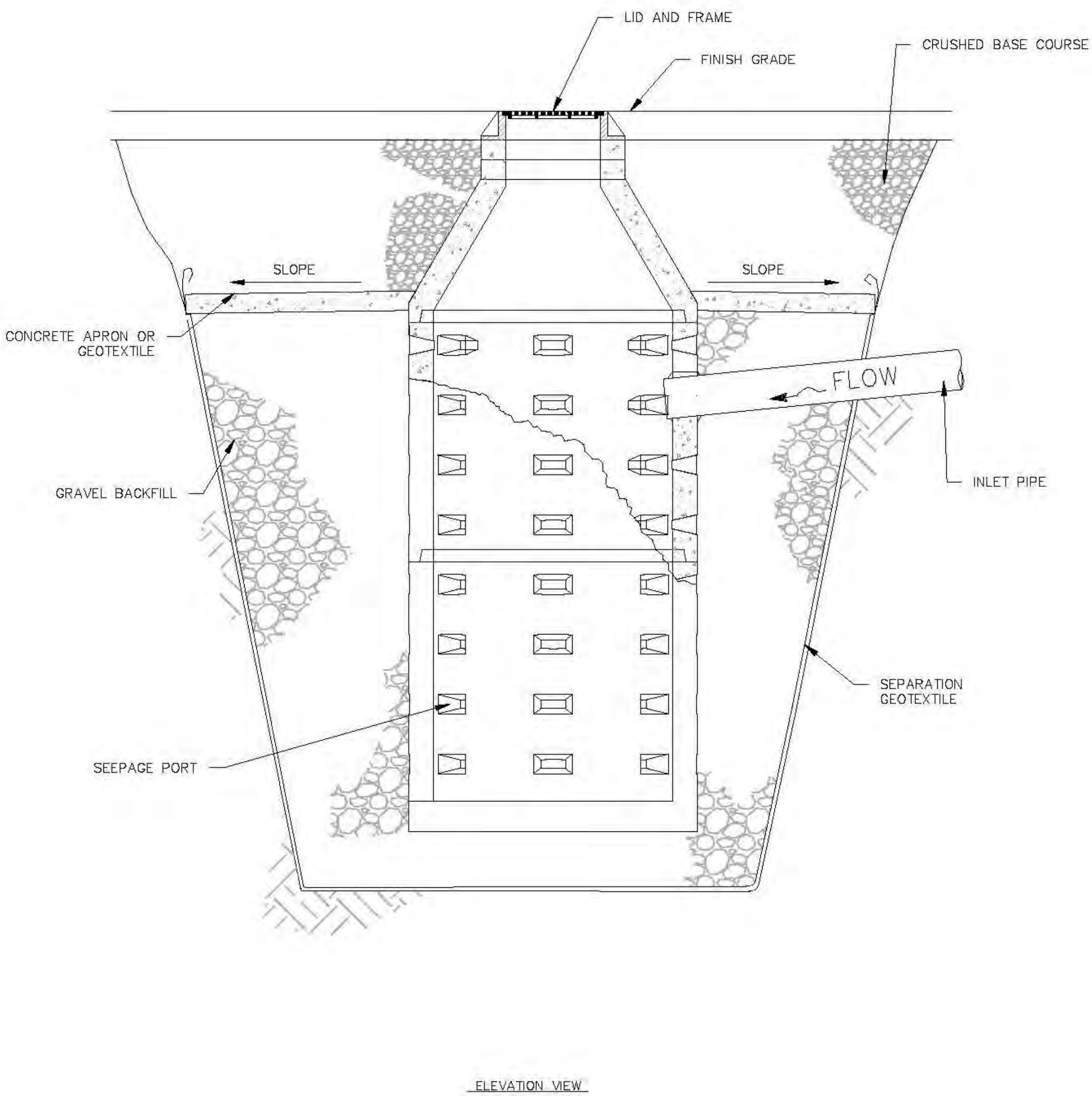


Figure 1d: Building BMPs Schematic (Dry Well)

Special Wildlife Considerations

Using building BMPs that have vegetation at PDX in the primary or intermediate zones requires approval by the Port Wildlife Manager and vegetation selection shall be consistent with the Port's Wildlife Hazard Management Plan. All building BMPs must comply with FAA Advisory Circulars and with the Port's Wildlife Hazard Management Plan. Additional considerations organized by BMP type are presented below.

Green Roofs

- Allowed in primary zone, however only sedums and succulents can be planted.
- Allowed in intermediate zone, however vegetation must be approved by Port wildlife management staff.

Planter Box Filters

- Not allowed in the primary zone but allowed intermediate zone. The BMP must be a flow-through planter designed to drain completely to sub-surface storage or to downstream conveyance system after storm events.

Cisterns

- Covered cisterns or subsurface installations are allowed in all areas in compliance with all other restrictions.

Dry Wells

- Allowed accept for in the Columbia South Shore and Cascade Station/PIC Plan Districts (due to groundwater protection requirements).

Considerations for Future Expansion

As the tributary drainage area to distributed facilities is small, the entire drainage area should be developed and stabilized before the BMP is put into operation as heavy sediment loading will damage the BMP. Thus, new distributed facilities should be sized and designed for areas of expansion. For a green roof, the roof area designed for treatment should be determined initially and therefore there would be no future expansion considerations for a green roof.

BMP POST-DESIGN AND IMPLEMENTATION

Construction Considerations

- Building BMPs must consider monitoring needs and incorporate features that facilitate monitoring of inflows and outflows as needed.
- Galvanized metal or treated wood shall not be used as components of building BMPs.
- Planter box filters constructed next to a building shall install waterproofing between the Planter box and the building to protect the building's foundation.
- The City of Portland Water Bureau's Water Quality Inspections group requires all cisterns connected to plumbing to have a reduced pressure type of back flow assembly. If a cistern is to be located in a sloped area, the foundation area must be leveled prior to installation.

O&M Requirements

Table 4 summarizes common building BMP O&M activities. Adequate access must be provided to safely enter and inspect any Building BMP facility via maintained paths, gates, ladders and covers. Access must allow for visual inspections of the inlet and outlet pipes in addition to access to the bottom of the unit. If cistern is underground, ensure that manhole is accessible, operational, and secure. Maintenance access to dry wells shall also be provided; observation wells may be installed to facilitate maintenance access.

Table 4: Maintenance Activities and Frequency

Schedule	Activity
As needed (frequently)	• For all building BMPs, perform periodic scheduled inspections to identify maintenance needs • For all building BMPs remove trash and debris • For all vegetated building BMPs maintain vegetation, remove fallen leaves, and dead plants • For cisterns, planter boxes and green roofs, replace broken screens, spigots, valves and sensors
As needed (within 48 hours after storms >1")	**Green Roofs** • Inspect roofs for erosion and damage to vegetation. **Planter Box Filters** • Inspect flow entrances for erosion, ponding areas, and overflow pipes. **Cisterns** • Remove trash, debris, and sediment accumulation near the inlet and outlets. • Drain first flush device (if applicable). **Dry Wells** • Inspect dry well structure for debris and sediment deposition as well as any signs of clogging.

Table 4: Maintenance Activities and Frequency	
Schedule	**Activity**
At least annually (prior to beginning of wet season)	**Green Roofs** • Inspect water proofing and drainage system to make sure water is draining as intended. • Remove dead vegetation if it exceeds 10% of the vegetated roof area. • Re-vegetate denuded, barren or eroded areas. **Planter Box Filters** • Inspect flow entrances, ponding areas, and overflow pipes. Replace soil, plants, and/or mulch in eroded patches. If erosion occurs identify the source and implement additional energy dissipation. • Replace mulch annually in places where heavy metal loading is a concern. **Cisterns** • Check cistern stability, straps and anchors (if applicable). • Stabilize and repair any erosion or scouring from drain or overflow **Dry Wells** • Repair inlet pipes and overflow outlets (if included). • Repair clogs by removing sediment or replacing geotextile fabric and gravel lens around the dry well as needed.

Other Key Information

This fact sheet shall be used in conjunction with the BMP selection and design information presented in Chapter 6 of the DSM.

FS12-CARTRIDGE FILTER

BMP SELECTION AND PLANNING

Photo Credit: Contech Engineered Solutions

Table 1: Cartridge Filter Overview	
BMP Functions	*Primary:* • Water Quality Treatment
Targeted Pollutants	*Primary:* • Sediment • Sediment-Bound Pollutants • Nutrients • Soluble Metals *Secondary:* • Trash and Debris • Oils and Grease
Pretreatment	Required when TSS, hydrocarbons, and/or debris are expected
Typical Wildlife Risk	Low
Cost	$$
O&M Level of Effort	High
Tributary Area	Varies
Relative Footprint	Small-Large

Functional Description

Cartridge filters typically consist of a series of vertical filters within a vault, manhole, curb inlet or catch basin that treat stormwater through filtration and sedimentation. Vaults may be divided into multiple compartments with the first bay providing pre-settlement for coarse sediment removal and the next bay housing the filter cartridges and providing filtration.

When a cartridge filter system is housed in a vault or manhole, stormwater enters the structure through an inlet pipe (or multiple inlet pipes) where it passes through an energy dissipator (if so equipped) to reduce re-suspension of pollutants due to turbulence. After entering the filtration compartment, the stormwater percolates through the filter cartridges. The treated stormwater exits the filtration compartment to an outlet sump (if so equipped) and is discharged through the outlet pipe (see Figure 1).

Flow entering the unit is typically controlled via weir walls, check valves, or an orifice. The maximum flow rate through each cartridge is adjustable through use of calibrated restrictor discs located at the base of each cartridge. Typically, a float valve releases the filtered water at the designed flow rate. Sometimes units are equipped with an internal overflow bypass. Units designed to be off-line do not require an internal overflow bypass because only the water quality design flow rate is diverted to the unit.

Flow through the system will decrease as more particulates are trapped in the porous structure of the filter media inside the cartridges. As the flow through the cartridges becomes restricted replacement of the filter media will be required.

Cartridge filters are typically proprietary devices that are customizable based on model configuration and filtration media. Size can range from small off-the-shelf units to large units assembled from modular pre-cast components. The capacity and performance of a cartridge filter is variable but is primarily influenced by the type of media contained in the cartridge and the targeted pollutants. The selection of cartridge filter media must be appropriate for the pollutants expected on-site. Table 2 lists types of media available and corresponding targeted pollutants. The listed pollutants are sometimes available in a blend such as ZPG which is a Zeolite, Perlite, and Granular Activated Carbon blend.

Table 2: Filtration Media and Corresponding Targeted Pollutants

Filtration Media	Targeted Pollutants
Perlite	• Sediment • Oil
Zeolite	Metals
Perlite with Activated Alumina	• Suspended Solids • Total Phosphorous
Compost	• Sediment • Total Nutrients • Soluble Metals • Oil • Complex Metals • Soluble Metals • Anthropogenic Organic Contaminants
Granular Activated Carbon	Organic Compounds

Cartridge filters are used as stand alone treatment facilities. Pretreatment is required when TSS, hydrocarbons, and/or debris could cause failure due to clogging. When TSS loadings or debris are expected, either a sedimentation manhole or hydrodynamic separator shall be selected for pretreatment. If hydrocarbon loadings exist, an oil/water separator shall be chosen.

Cartridge filters are typically designed so high flow rates are bypassed internally. For situations where influent and/or effluent monitoring may be required, sampling manholes shall be included upstream and/or downstream of the cartridge filter.

Site Suitability and Limitations

Table 3 summarizes the various factors and considerations that shall be assessed when evaluating if a location is suitable for cartridge filters.

Table 3: Site Suitability Considerations for Cartridge Filters	
Soil Characteristics and Infiltration Concerns	Generally appropriate for any hydrologic soil group (A, B, C, D)
Groundwater	Consider buoyancy issues in areas of high groundwater
Wildlife Considerations	N/A
Tributary Area and Land Use	• Varies based on site conditions • Multiple facilities can be placed in series or parallel to treat large tributary areas, if needed. Large facilities can be designed using modular structural components
Head Loss	Consult manufacturer's requirements for vertical drop across the structure

Footprint Considerations

The area required for cartridge filters depends on the model selected and if multiple units are to be installed in series or parallel to treat a larger tributary impervious area. An off-line unit may require a larger footprint than an on-line unit because of the diversion structure requirement. These units are placed underground; therefore, the only surface area consideration is that of the unit unless pretreatment is needed. If needed, space requirements for the pretreatment unit must be considered.

Wildlife Attractant Considerations

As underground, enclosed treatment facilities, cartridge filters do not attract hazardous wildlife.

General O&M Requirements

General O&M requirements are related to periodic inspection of the cartridge filter to check for excessive quantities of sediment, trash, or debris as well as filter cartridge condition. Regular maintenance consists of removing any trash, debris, oil, and sediment; cleaning clogged components; and repairing or replacing cartridges or filter media. Major maintenance (repairing or replacing inlet or outlet piping, re-grouting pipes at the vault wall, repairing cracks in the structure) should be needed infrequently. More detailed O&M requirements are summarized in the Design and Implementation section.

This section will also include a discussion of the O&M requirements relative to the requirements for other the BMPs for which fact sheets will be developed. Waiting on completion of O&M Level of Effort Appendix.

Cost Considerations

Major capital costs include site preparation (excavation and grading, protection of the installation area, labor), structural components (cartridge filter, vaults, inlet and outlet structures), optional or supplementary design features (see list of typical BMP components in the BMP Design and Implementation section of this document), engineering and design, surveying, geotechnical analysis. There is some economy of scale when purchasing a large facility. The cost for a unit that can process double the flow rate of a smaller unit will be less than the cost of purchasing two smaller units.

Unknown site conditions, such as the composition of subsurface materials (which can increase excavation costs) and unknown underground utility locations are factors that may increase construction costs.

New cartridges can be ordered and at times delivered by the manufacturer. Replacing the media and/or cartridges can be a significant expense depending on the size of the facility and shall be considered when evaluating life cycle cost. Cartridge replacement can be approximately 6-8 percent of the total capital costs (cartridge filter, structure cleaning, and installation), but can vary greatly depending on manufacturer and other site specific circumstances. Frequency of media replacement varies based on type of media used, pollutants of concern, and pollutant load. Typically, cartridges will not need replacing more than once a year, and this is viewed as a worst-case scenario. Pretreatment such as an upstream sedimentation manhole or hydrodynamic separator can reduce the frequency of media replacement. Costs for the pretreatment system shall be compared on a life-cycle basis to the reduced costs in media replacement.

Typical maintenance cost components include regular maintenance and cleaning, replacement and disposal of filter media and/or cartridges, and removal and disposal of accumulated sediment. Some operational costs may be associated with sampling and monitoring of performance. Additional O&M costs may be incurred depending on site conditions due to traffic control during inspections and maintenance if the cartridge filter is located near a runway, taxiway, or road, or if a confined space permit is required for entry into the unit. In-house cleaning may be relatively inexpensive with access to the right equipment such as a sump vacuum or vactor truck. Calling in a private cleaning service company is more expensive, especially if entry into a confined space is required.

BMP DESIGN AND IMPLEMENTATION

Overview of Design Criteria

In order for a cartridge filter to be approved for use, it must meet criteria included in Chapter 4 of the DSM. Under special circumstances, the Port may approve facilities that do not meet these criteria.

Table 4 summarizes the minimum design criteria for cartridge filters. More detailed design information is provided in the sections that follow.

Table 4: Minimum Design Criteria for Cartridge Filters		
Design Parameter	**Unit**	**Design Criteria**
Water Quality Design Flow Rate	cfs	See Chapter 4 of the DSM
Pretreatment	—	Required if high TSS or petroleum hydrocarbon loading is expected
Structure Lid Load Rating	—	HS-20[1]

[1]At a minimum, structures located within Safety Areas of PDX must be able to withstand a minimum load of 100 kips. Coordinate with the Port to verify loading criteria. See DSM Chapter 5.

Considerations for Locating On-line with Runoff Conveyance

An on-line BMP provides treatment while processing the entire range of flows from a drainage area. This configuration can be used when peak flows will not damage the facility and water quality treatment objectives can be met at the expected range of flow rates. When locating the structure on-line, design the high flow bypass to the conveyance flow rate. Sediment and sediment-bound pollutants are at risk of re-suspension if the unit is located on-line and receives high flows. If locating the device off-line, a flow splitter, pumping system, or other diversion structure may be used to divert the incremental portion of flows that equal the water quality flow from the primary conveyance to the cartridge filter facility.

Pretreatment Requirements

Cartridge filters shall include pretreatment facilities if high sediment or petroleum hydrocarbon loading that could cause failure or clogging is expected. If TSS loading is expected, use either a sedimentation manhole or a hydrodynamic separator as the pretreatment facility. If high petroleum hydrocarbons exist, select an oil/water separator as the pretreatment facility.

Major BMP Components

Housing Structure

The structure that houses the system is either a vault, manhole, catch basin, or curb inlet.

- Manholes and vaults are typically precast concrete structures ranging in size from 48 inches to 96 inches in diameter for a manhole and up to 10 feet by 24 feet for vaults depending on the application and manufacturer.
- A vault may optionally be metal (corrosivity shall be considered in the design and the design life of the metal tank must be assessed).
- Facilities designed especially for sites with large flows may require vaults assembled on-site from precast components.
- Catch basin chambers may be steel, concrete, or plastic.

Inlet and Outlet Pipes

Inlet and outlet pipes direct stormwater through the structure for treatment.

- Not all variations of cartridge filters have inlet pipes (catch basins and curb inlets will have grated openings).
- Some curb inlet models provide multiple inlet grates depending on peak flow rates.
- Some vaults accommodate multiple inlet pipes.

Flow Spreader

The facility may be equipped with a flow spreader to evenly distribute flow along the width of the unit.

Energy Dissipator

Certain models may include an energy dissipator. This reduces turbulence in the flow to minimize re-suspension of previously captured pollutants.

Cartridge Filters (Media Filters)

The facility contains replaceable media filled cartridges that trap particulates and absorb materials such as dissolved metals, hydrocarbons, and nutrients in polluted stormwater runoff.

- Examples of media types and their targeted pollutants are listed in Table 1.
- Each model is designed with the number of cartridges required to meet the water quality design flow rate and the maximum flow rate through each cartridge can be adjusted.

Baffle Walls

An optional baffle insert can be installed in the cartridge bay to trap oils and other pollutants on the water surface.

Weir Walls

This component is utilized in certain models to allow stormwater overflow to bypass the cartridge bay and leave accumulated pollutants undisturbed.

Outlet and Inlet Sumps

If so equipped, the inlet sump provides an area for heavier solids to settle and collect. The outlet sump discharges the treated stormwater from the facility.

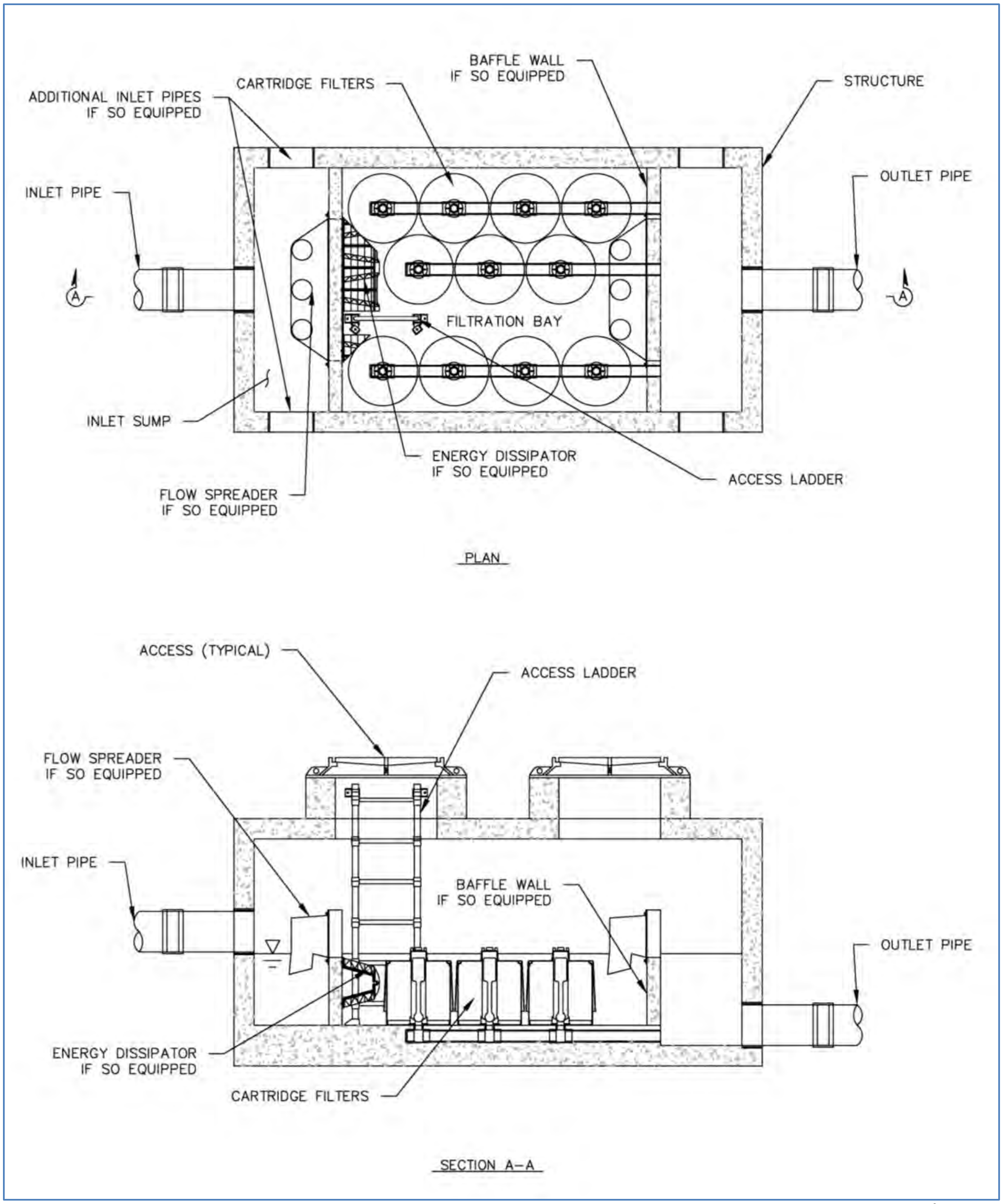


Figure 1: Cartridge Filter Schematic Plan and Section View (Not to Scale)[1]

[1] Adapted with permission from *Contech Engineered Solutions,* by MJW, 2013. Retrieved from http://www.conteches.com/Products/Stormwater-Management/Treatment/Stormwater_Management-StormFilter.aspx

Considerations for Future Expansion

If future development is anticipated within the drainage basin, cartridge filters shall be sited to accommodate installation of future additional cartridge filters based on available information of the future development footprint. Additionally, if the facility is located off-line, strategic placement of the flow-splitter in relation to the proposed development may decrease costs of expansion if significant increases in inflows are anticipated.

Maintenance Access

Adequate access must be provided to safely enter and inspect the facility via maintained paths, gates, ladders and covers. Access to each compartment of the cartridge filter is required. Access must allow for visual inspections of the inlet, cartridges, and outlet, in addition to access to the bottom of the unit.

BMP POST-DESIGN AND IMPLEMENTATION

Construction Considerations

The drainage area shall be stabilized before BMP construction begins. Alternatively, a diversion berm can be placed around the BMP footprint to protect it from sediment loading.

If the cartridge filter is installed prior to overall project completion, use the required erosion and sediment control BMPs to prevent sediment from entering the device. Do not use the cartridge filter to collect sediment during construction activities without Port approval. If sediment enters the facility during the construction phase, clean the facility prior to use.

O&M Requirements

Proper O&M is necessary for cartridge filters to continue to function as designed over time. Sediment can be removed with a sump vacuum or vactor truck or a professional cleaning service can be hired. The removed sediment must be disposed of in accordance with regulatory protocols. Sediment and water disposal must comply with all applicable waste disposal regulations.

The media in the filters must be replaced when it becomes clogged, typically about once every year, depending on the rate of pollutant accumulation. Initially, replacement shall be per manufacturer's recommendations; however, during the first recommended media replacement, an inspection of the media will indicate if the recommended replacement frequency is sufficient. Replacement frequency shall be adjusted according to observations of the condition of the media.

Operations and maintenance must follow the manufacturer's instructions for proprietary devices. O&M requirements shall be provided to the Port by the designer/manufacturer and shall consider additional O&M measures that may be necessary based on site specific conditions. Design of the facility shall assume that O&M recommendations will be implemented.

Table 5 summarizes common cartridge filter O&M activities. Table 6 provides maintenance considerations for cartridge filters.

Table 5: Maintenance Activities and Frequency

Typical Schedule	Activity
As Needed (per manufacturer's recommendation and as determined by inspection)	Perform periodic inspections to check if excessive quantities of sediments, trash, or debris have accumulated
At Least Annually or as Needed Based on Inspection	• Replace media in media filters/cartridges or replace cartridges • Clean facility with use of a sump vacuum or vactor truck to remove sediment when depth in bottom of unit exceeds 6 inches in depth • Remove any trash and debris

Table 6: Maintenance Considerations for Cartridge Filters

Component	Issue Requiring Maintenance	Recommendation for Maintenance
Effluent	Inspection of discharge water shows obvious signs of poor water quality	Clean the unit and replace media or cartridges
Sediment	Sediment depth in bottom of unit exceeds 6 inches in depth	Remove sediment deposits in structure bottom that would impede flow through the unit and reduce efficiency
Trash and Debris	Trash and debris accumulates in unit, or pipe inlet/outlet, floatables and nonfloatables	Remove trash and debris from unit and inlet/outlet piping
Pipes	Inlet/outlet pipes are damaged or broken and in need of repair	Replace or repair pipe
Access Cover	Access cover will not open or is corroded or deformed	Replace or repair cover so that it meets design specifications and is structurally sound
Structure Top/Frame	Structure top slab has holes larger than 2 square inches or cracks wider than ¼ inch	Repair top slab so it is free of holes and cracks
	Structure frame is not sitting flush on top of structure slab (gap wider than ¾ inch) or frame not securely attached	Securely attach the frame so it sits flush on the riser rings or top slab
Structure Walls/ Bottom	Inspector judges structure is unsound	Replace or repair to meet design standards
	Grout fillet is separated or cracked wider than ½ inch and longer than 1 foot at the joint of an inlet/outlet pipe or there is evidence of soil particles entering through cracks	Re-grout pipe and secure at the vault wall
Baffles	Baffles are corroding, cracking, warping, and/or showing signs of failure as judged by inspector	Replace baffles or repair to meet specifications
Access Ladder	Ladder is corroded or deteriorated, is not functioning properly, is not securely attached to the structure, is missing rungs, is cracked, or misaligned	Replace ladder or repair to meet specifications so it is safe to use as determined by an inspector

Other Key Information

This fact sheet must be used in conjunction with the BMP selection and design information presented in Chapter 6 of the DSM.

FS13-OIL/WATER SEPARATOR

BMP SELECTION AND PLANNING

Photo Credit: Oldcastle Precast

Table 1: Oil/Water Separator Overview	
BMP Functions	*Primary:* • Petroleum Removal
Targeted Pollutants	*Primary:* • Oil and Grease • Other Petroleum Products (Gasoline, Diesel) • Sediment • Sediment-Bound Pollutants
Pretreatment	Not Required
Typical Wildlife Risk	Low
Cost	$$
O&M Level of Effort	High
Tributary Area	Small
Relative Footprint	Small

Functional Description

Oil/water separators are tanks that separate oil and sediment from stormwater (see Figure 1). Oil/water separators target petroleum hydrocarbons which include oil and grease and polycyclic aromatic hydrocarbons (sometimes called polynuclear aromatic hydrocarbons or PAHs).These are compounds used in or created as a byproduct of many industrial processes. These constituents typically originate from automotive/jet fuel sources, including leakages, spills, or improper disposal. Some hydrocarbons are toxic to aquatic organisms and may present bioaccumulation risks. Many produce sheens on stormwater, even at low concentrations.

There are two primary types of oil/water separators - the American Petroleum Institute (API) or baffle type and the coalescing plate (CP) type. Both types use gravity as a separation mechanism. Both generally consist of three compartments: forebay, oil separation bay, and afterbay. Both API and CP separators are typically proprietary devices.

API-type separators are designed with baffles separating each compartment. Oil floats to the surface of the water where the baffle prevents it from exiting the separator. In addition, baffles installed at the bottom of the unit trap materials that settle out of the water. Certain models include a sediment weir to trap sediment. If so equipped, floating skimmers remove the oil from the surface. Mechanical skimmers are another option. A spill control separator consists of a vault or manhole structure with an outlet that draws from the bottom of the structure for temporarily capturing small quantities of oil.

Stormwater enters the forebay where sediment is collected and turbulence is reduced prior to the oil separation bay. The separation bay traps the oil that floats to the surface and collects additional sediment. The afterbay discharges the treated stormwater exiting the facility back into the conveyance system.

Similar to API-type units, CP units include multiple compartments including a forebay, oil separation bay, and afterbay. The forebay collects sediment and reduces turbulence prior to stormwater entering the oil separation bay. The separation bay is comprised of a series of plates that are typically angled between 45 to 60 degrees or are corrugated. Rising oil contacts the underside of the plate and accumulates on the surface of the plate, coalescing into larger masses. Once the accumulation of oil is large enough, the oil mass slides up the plate to the edge where it breaks free from the plate and rises to the surface. Other coalescing media are also available but are less common than coalescing plates. These alternative coalescing technologies include a mesh of plastic strands or bundled plastic tubes.

Coalescing of the oil increases treatment efficiency and reduces the size of the unit from that of a baffle-type separator. The horizontal projection of the plates determines oil removal capabilities of the device. The size of the unit is based on the area of the plates which are designed based on the influent concentration, specified oil droplet size, and design flow. CP units are more effective than API units for areas with high concentrations of oil such as fueling yards and heavy equipment repair yards. CP separators may be more appropriate for sites constrained by space limitations.

Oil/water separators shall be located where high concentrations of oil and grease are expected such as (1) retail fuel facilities, (2) high volume roads, (3) petroleum-related industrial facilities, (4) high-use parking, (5) vehicle washdown facilities, (6) vehicle/heavy equipment repair and fueling yards, and (7) ramps where aircraft fueling takes place. Oil/water separators are less effective in situations where dissolved or emulsified oils or detergents are present (such as where de-icing chemicals are used or car wash facilities). For situations where emulsified oils are expected, filtration may be an effective alternative to the use of an oil/water separator. API oil/water separators are designed to remove oil droplets 150 microns in diameter and larger. CP oil/water separators are designed to remove oil droplets as small as 20 microns in diameter. For situations where influent and/or effluent monitoring may be required, sampling manholes shall be included upstream and/or downstream of the oil/water separator.

The oil/water separator tank is most commonly an underground concrete vault, but a manhole or steel, polymer, or fiberglass tank may be used as well. Oil/water separators are designed to remove products that separate from water due to differences in density. Oil/water separators are implemented as the first BMP in a treatment train. When used as the first BMP in a treatment train, they both reduce discharge of petroleum products to the environment and protect downstream BMPs such as infiltration trenches from damage.

Oil/water separator units can be custom designed, especially if there is a need to process higher flow rates, but the most cost-effective solution is usually an off-the-shelf unit. Selection of the proper device will follow design guidance provided by the selected manufacturer. In most circumstances, oil/water separators are installed underground; however, certain applications require an aboveground configuration.

Site Suitability and Limitations

Table 2 summarizes the various factors and considerations that shall be assessed when evaluating if a location is suitable for oil/water separators.

Table 2: Site Suitability Considerations for Oil/Water Separators	
Soil Characteristics and Infiltration Concerns	Generally appropriate for any hydrologic soil group (A, B, C, D)
Groundwater	Consider buoyancy issues in areas of high groundwater
Wildlife Considerations	N/A
Tributary Area and Land Use	• Varies based on site conditions, but generally smaller than surface BMPs such as vegetated swales • Multiple facilities can be placed in series or parallel to treat large tributary areas, if needed

Footprint Considerations

The area required for an oil/water separator depends on the model selected and if multiple units are to be installed in series or parallel to treat a larger tributary impervious area. An off-line unit may require a larger footprint than an on-line unit. These units are placed underground; therefore, the only surface area consideration is that of the unit.. Generally, the area required to install an oil/water separator is relatively small.

Footprint considerations shall include the area needed for the oil/water separator unit as well as the surface area of any downstream BMP such as a vegetated swale or infiltration trench.

Wildlife Attractant Considerations

As underground, enclosed treatment facilities, oil/water separators do not attract hazardous wildlife.

General O&M Requirements

General O&M requirements are related to periodic inspection of the separator to check for accumulated oil and solids. Regular maintenance consists of removing accumulated oil and sediment, cleaning of coalescing plates and berms, cleaning clogged components, and repairing or replacing baffles or coalescing plates. Major maintenance (repairing or replacing inlet or outlet piping, re-grouting pipes at the vault wall, repairing cracks in the structure) should be needed infrequently. More detailed O&M requirements are summarized in the Design and Implementation section.

This section will also include a discussion of the O&M requirements relative to the requirements for other BMPs for which fact sheets will be developed. Waiting on completion of O&M Level of Effort Appendix.

Cost Considerations

Major capital costs include site preparation (excavation and grading, protection of the installation area, labor), structural components (CP pack, vault, inlet and outlet structures), optional or supplementary design features (see list of typical BMP components in the BMP Design and Implementation section of this document), engineering and design, surveying, and geotechnical analysis.

Unknown site conditions, such as the composition of subsurface materials (which can increase excavation costs) and unknown underground utility locations are factors that may increase construction costs.

Typical maintenance cost components include regular maintenance and cleaning and disposal of sediment and petroleum products. Some operational costs may be associated with sampling and monitoring of performance. Additional O&M costs might accrue depending on site conditions due to traffic control if the oil/water separator is located near a runway, taxiway, or road or if a confined space permit is required for entry into the unit. In-house cleaning might be relatively inexpensive with access to the right equipment such as a sump vacuum or vactor truck. Calling in a private cleaning service company is more expensive, especially if entry into a confined space is required.

BMP DESIGN AND IMPLEMENTATION

Overview of Design Criteria

In order to be approved for use, an oil/water separator must demonstrate adequate performance including the ability to achieve effluent efficiencies of 10 parts per million (ppm) or milligrams per liter (mg/L) for influent concentrations exceeding 50 ppm or mg/L.

Table 3 summarizes the minimum design criteria for API or baffle-type oil/water separator vaults.

Table 3: Minimum Design Criteria for API (Baffle Type) Separator Vaults

Design Parameter	Unit	Design Criteria
Water Depth	ft	3-8
Width of Vault	ft	6-20
Depth to Width Ratio	ft/ft	0.3-0.5
Minimum Length to Width Ratio	ft/ft	5:1
Forebay Length	ft	1/3-1/2 of unit length
Minimum Forebay Horizontal Area	ft^2	20 for every 10,000 of impervious drainage area
Minimum Afterbay Length	ft	8
Structure Lid Load Rating	—	HS-20[1]

[1]At a minimum, structures located within Safety Areas of PDX must be able to withstand a minimum load of 100 kips. Coordinate with the Port to verify loading criteria. See DSM Chapter 5.

Table 4 summarizes the minimum design criteria for CP separator vaults.

Table 4: Design Criteria for CP (Coalescing Plate) Separator Vaults[1]		
Design Parameter	**Unit**	**Design Criteria**
Forebay Length	ft	1/3-1/2 of unit length
Minimum Forebay Horizontal Area	ft^2	20 for every 10,000 of impervious drainage area
Minimum Afterbay Length	ft	8
Structure Lid Load Rating	--	HS-20[2]

[1]Geometry and dimensions of plates per manufacturer's specifications; vault size varies based on effectiveness of coalescing plate unit

[2]At a minimum, structures located within Safety Areas of PDX must be able to withstand a minimum load of 100 kips. Coordinate with the Port to verify loading criteria. See DSM Chapter 5.

Considerations for Locating On-line with Runoff Conveyance

An on-line BMP provides treatment while processing the entire range of flows from a drainage area. This configuration can be used when peak flows will not damage the facility and water quality treatment objectives can be met at the expected range of flow rates. If located at PDX, oil/water separators shall be located off-line from the primary conveyance system so that the flow rates to the separator can be limited to less than the maximum flow capacity of the unit. Surcharging of the oil/water separator can result in the discharge of accumulated oil and sediment, as well as decrease the treatment effectiveness of the unit. If locating the separator off-line, the flow diversion mechanism shall be designed to divert only flows that are equal to or less than the water quality design flow rate of the oil/water separator. It is preferable to locate oil/water separators off-line; however, at marine or industrial facilities, oil/water separators can be located on-line. If it is necessary to locate the separator on-line and peak flows have the potential to exceed the capacity of the oil/water separator, additional spill management measures may need to be incorporated to mitigate the potential discharge of petroleum products from the unit under high flow conditions. These actions shall be coordinated with the facility's SPCC plan.

Pretreatment Requirements

Pretreatment of stormwater runoff is not required for oil/water separators.

Major BMP Components

Housing Structure

The structure that houses the system is typically a precast concrete manhole or vault.

- A vault may optionally be metal (corrosivity shall be considered in the design and the design life of the metal tank must be assessed).
- The structure is typically divided into three compartments or bays: forebay, oil separation bay, and afterbay. The forebay controls turbulence and traps and collects debris, the oil separation bay captures and holds oil, and the afterbay provides an exit for treated stormwater.

Inlet and Outlet Pipes

Inlet and outlet pipes direct stormwater through the structure for treatment.

- Some structures accommodate multiple inlet pipes.

Oil Retaining Baffles

Baffles extend up from the bottom of the vault with an orifice at the bottom. The baffles impede oil flow out of the structure since oil is less dense than water and floats to the water surface in the oil separation bay.

- Some models offer baffles to trap solids and sludge.
- Baffles are always a component of API units and are optional in CP units.

Coalescing Plate Unit (Plate Pack)

This component is found only in CP oil/water separators.

- The plate pack is typically made of polypropylene, fiberglass, or stainless steel.
- The spacing between the plate pack and vault sidewalls must be packed with a lightweight removable material such as plastic or polyethylene foam to minimize short circuiting.
- The plates are equally spaced (typical spacing ranges from ¼ to 1 inch) and may be inclined or corrugated.

Ventilation Pipes

Ventilation pipes are at times provided in all four corners of vaults to allow for ventilation for maintenance personnel and to assure that pressure or vacuum does not occur within the vault due to fluctuations in the water surface elevation. Often this ventilation is provided by the holes in a standard manhole cover or the openings in a grate cover.

Sediment Weirs

Certain models of oil/water separators offer installation of a baffle or weir at the bottom of the structure to trap solids and sludge.

Absorbent Booms and/or Skimmers

Simple floating or more advanced mechanical skimmers can be installed to remove oil that accumulates on the surface of the water. These devices are typically only included if high volumes of oil are expected.

Shut-off Valve

Some oil/water separators are equipped with a shut-off valve. Shut-off valves can be used to control either water or oil discharge from the system.

Gravity Drain

A gravity drain can be installed for maintenance purposes if the grade allows.

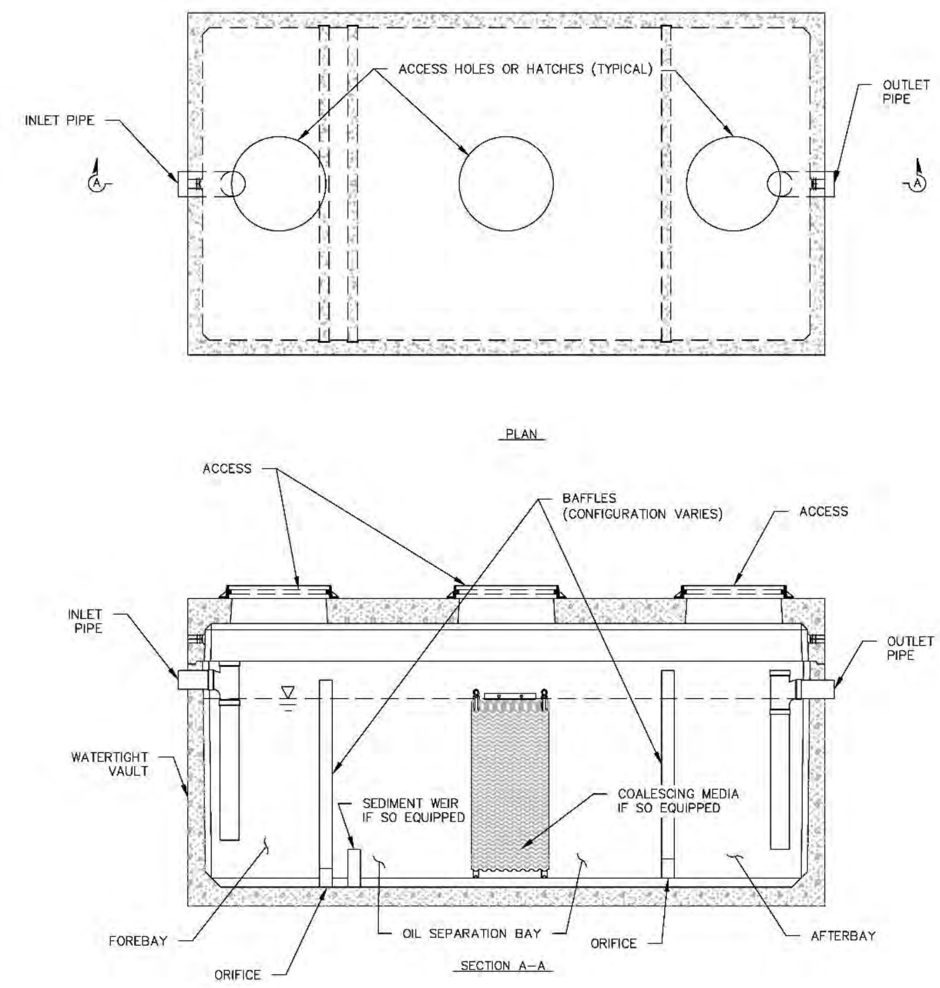


Figure 1: Oil/water Separator Schematic Plan and Section View (Not to Scale)[2]

[2] Adapted with permission from *Oldcastle Precast*, 2013. Retrieved from http://www.oldcastleprecast.com/plants/wilsonville/products/Documents/5e2c26ef-4ba4-478d-82fd-9cbcde37391f.pdf .

Considerations for Future Expansion

If future development is anticipated within the drainage basin, oil/water separators shall be sited to accommodate installation of future additional oil/water separators based on available information of the future development footprint. In general, due to the relatively small footprint of oil/water separators, future development may be addressed through installing additional units or extension of the existing facilities. Additionally, if the facility is located off-line, strategic placement of the flow-splitter in relation to the proposed development may decrease costs of relocation if significant increases in inflows are anticipated.

Maintenance Access

Adequate access must be provided to safely enter and inspect the facility via maintained paths, gates, ladders and covers. Access to each compartment of the separator is required. Access to the forebay and afterbay must allow for visual inspections of the inlet and outlet in addition to access to the bottom of the unit.

BMP POST-DESIGN AND IMPLEMENTATION

Construction Considerations

The drainage area shall be stabilized before the BMP construction begins. Alternatively, a diversion berm can be placed around the BMP footprint to protect it from sediment loading.

If the oil/water separator is installed prior to overall project completion, use the required erosion and sediment control BMPs to prevent sediment from entering the device. Do not use the separator to collect sediment during construction activities without Port approval. If sediment enters the facility during the construction phase, clean the separator prior to use.

O&M Requirements

Proper O&M is necessary for oil/water separators to continue to function as designed over time. Re-suspension of matter and flushing of oil limits efficiency of the device. Sediment can be removed with a sump vacuum or vactor truck or a professional cleaning service can be hired. The removed sediment must be disposed of in accordance with regulatory protocols. Oils that are free-floating can be pumped out or removed by use of absorbent pads. The pads float on top of the water and attract oil. Sediment, oil, and water disposal must comply with all applicable waste disposal regulations.

Operations and maintenance must follow the manufacturer’s instructions for proprietary devices. However, maintenance and cleaning frequency shall be adjusted if inspection of the facility reveals the unit needs maintenance more often. O&M requirements shall be provided to the Port by the designer/manufacturer and shall consider additional O&M measures that may be necessary based on site specific conditions. Design of the facility assumes that O&M recommendations will be implemented.

Table 5 summarizes common oil/water separator O&M activities. CP separators typically have more frequent and more labor intensive maintenance requirements than API separators. Tables 6 and 7 provide maintenance considerations for API and CP separators, respectively.

Table 5: Maintenance Activities and Frequency	
Typical Schedule	**Activity**
As Needed (per manufacturer's recommendation and as determined by inspection)	Perform periodic inspections to check if excessive quantities of solids or oil have accumulated
At Least Annually or as Needed Based on Inspection	• Clean coalescing plates • Clean facility with use of a sump vacuum or vactor truck to remove sediment when depth in bottom of unit exceeds 6 inches in depth • Extract oil accumulations that exceed 1 inch at the surface of water

Table 6: Maintenance Considerations for API (Baffle) Separators		
Component	**Issue Requiring Maintenance**	**Recommendation for Maintenance**
Effluent	Inspection of discharge water shows obvious signs of poor water quality	Clean the unit and remove oil and sediment
Sediment	Sediment depth in bottom of unit exceeds 6-inches in depth	Remove sediment deposits in structure bottom that would impede flow through the vault and reduce separation efficiency
Trash and Debris	Trash and debris accumulates in unit, or pipe inlet/outlet, floatables and non-floatables	Remove trash and debris from unit and inlet/outlet piping
Oil	Oil accumulation exceeds 1 inch at the surface of the water	Extract oil from unit by vactoring, carefully pumping, or through use of absorbent pads. Dispose according to state and local regulation
Pipes	Inlet/outlet pipes damaged or broken and in need of repair	Replace or repair pipe
Access Cover	Access cover will not open or is corroded or deformed	Replace or repair cover so that it meets design specifications and is structurally sound
Structure Top/Frame	Structure top slab has holes larger than 2 square inches or cracks wider than ¼ inch	Repair top slab so it is free of holes and cracks
	Structure frame is not sitting flush on top of the structure slab (gap wider than ¾ inch) or frame not securely attached	Securely attach the frame so it is sitting flush on the riser rings or top slab
Structure Walls/ Bottom	Inspector judges structure is unsound	Replace or repair to meet design standards
	Grout fillet is separated or cracked wider than ½ inch and longer than 1 foot at the joint of an inlet/outlet pipe or there is evidence of soil particles entering through cracks	Re-grout pipe and secure at the structure wall

Table 6: Maintenance Considerations for API (Baffle) Separators

Component	Issue Requiring Maintenance	Recommendation for Maintenance
Baffles	Baffles are corroding, cracking, warping, and/or showing signs of failure as judged by inspector	Replace baffles or repair to meet specifications
Access Ladder	Ladder is corroded or deteriorated, not functioning properly, not securely attached to the structure, missing rungs, cracked, or misaligned	Replace ladder or repair to meet specifications so it is safe to use as determined by an inspector

Table 7: Maintenance Considerations for CP Separators

Component	Issue Requiring Maintenance	Recommendation for Maintenance
Effluent	Inspection of discharge water shows obvious signs of poor water quality	Clean the unit and remove oil and sediment
Sediment	Sediment depth in bottom of unit exceeds 6 inches in depth and/or there is visible sediment on the plates	Remove sediment deposits in structure bottom and on plates that would impede flow through the vault and/or reduce separation efficiency
Trash and Debris	Trash and debris accumulates in vault, or pipe inlet/outlet, floatables and non-floatables	Remove trash and debris from vault and inlet/outlet piping
Oil	Oil accumulation exceeds 1 inch at the surface of the water	Extract oil from the unit by vactoring, carefully pumping, or through use of absorbent pads. Clean plates by rinsing and flushing. Dispose according to state and local regulation
Coalescing Plates	Plate media is broken, deformed, cracked and/or showing signs of failure	Replace a portion of the plate or the pack in its entirety depending on severity
Pipes	Inlet/outlet pipes damaged or broken and in need of repair	Replace or repair pipe
Access Cover	Access cover will not open or is corroded or deformed	Replace or repair cover so that it meets design specifications and is structurally sound
Structure Top/Frame	Structure top slab has holes larger than 2 square inches or cracks wider than ¼ inch	Repair top slab so it is free of holes and cracks
	Structure frame is not sitting flush on top of the structure slab (gap wider than ¾ inch) or frame not securely attached	Securely attach the frame so it is sitting flush on the riser rings or top slab
Structure Walls/ Bottom	Inspector judges structure is unsound	Replace or repair to meet design standards
	Grout fillet is separated or cracked wider than ½ inch and longer than 1 foot at the joint of an inlet/outlet pipe or there is evidence of soil particles entering through cracks	Re-grout pipe and secure at the structure wall
Baffles	Baffles are corroding, cracking, warping, and/or showing signs of failure as judged by inspector	Replace baffles or repair to meet specifications

Table 7: Maintenance Considerations for CP Separators		
Component	**Issue Requiring Maintenance**	**Recommendation for Maintenance**
Access Ladder	Ladder is corroded or deteriorated, not functioning properly, not securely attached to the structure, missing rungs, cracked, or misaligned	Replace ladder or repair to meet specifications so it is safe to use as determined by an inspector

Other Key Information

This fact sheet must be used in conjunction with the BMP selection and design information presented in Chapter 6 of the DSM.

FS14-HYDRODYNAMIC SEPARATOR

BMP SELECTION AND PLANNING

Photo Credit: Contech Engineered Solutions

Table 1: Hydrodynamic Separator Overview	
BMP Functions	*Primary:* • Water Quality Pretreatment
Targeted Pollutants	*Primary:* • Gross Solids (Coarse Sediment, Sediment-Bound Pollutants) • Trash and Debris *Secondary:* • Oils and Grease
Pretreatment	Not Required
Typical Wildlife Risk	Low
Cost	$
O&M Level of Effort	Low
Tributary Area	Varies
Relative Footprint	Small

Functional Description

Hydrodynamic separators are proprietary devices designed to provide pretreatment for other water quality treatment BMPs. Hydrodynamic separators are circular flow-through structures that do not require an outside power source and generally require less space than linear treatment measures, such as vegetated swales. Primary treatment mechanisms include entrapment of pollutants in screens, settling, and separation using centrifugal forces generated from forcing the flow into a circular motion. Depending on the design, indirect filtration of pollutants following centrifugal separation may also be a removal mechanism (see Figure 1).

Hydrodynamic separators can be designed to be either on-line or off-line; however, the primary purpose of hydrodynamic separators is pretreatment. Therefore, it is recommended to locate the system off-line from runoff conveyance and use a flow diversion structure to divert the water quality design flow to the unit. The general design can be modified for site constraints (i.e., insertion into manholes) and can be implemented by the Port where surface area is limited. Hydrodynamic separators shall not be selected for treating solids with poor settleability or dissolved pollutants. For situations where influent and/or effluent monitoring may be required, sampling manholes shall be included upstream and/or downstream of the hydrodynamic separator.

Site Suitability and Limitations

Table 2 summarizes the various factors and considerations that shall be assessed when evaluating if a location is suitable for hydrodynamic separators.

Table 2: Site Suitability Considerations for Hydrodynamic Separators

Soil Characteristics and Infiltration Concerns	Generally appropriate for any hydrologic soil group (A, B, C, D)
Groundwater	Consider buoyancy issues in areas of high groundwater
Wildlife Considerations	Comply with FAA Advisory Circulars and PDX Wildlife Hazard Management Plan requirements for siting and design criteria
Tributary Area and Land Use	• Varies based on site conditions • Multiple facilities can be placed in series or parallel to treat large tributary areas, if needed

Footprint Considerations

The area required for hydrodynamic separators depends on the model selected and if multiple units are to be installed in series or parallel to treat a larger tributary impervious area. An off-line unit may require a larger footprint than an on-line unit due to the requirement for a diversion structure. Hydrodynamic separators are placed underground; therefore, the only surface area consideration is that of the unit. Generally, the area required to install a hydrodynamic separator is relatively small; however, some vault configurations can be as large as 21 feet in one dimension and cast-in-place models can be even larger.

Footprint considerations shall include the area needed for the hydrodynamic separators unit as well as the surface area of any downstream BMP such as a vegetated swale or infiltration trench.

Wildlife Attractant Considerations

As underground, enclosed treatment facilities, hydrodynamic separators do not attract hazardous wildlife.

General O&M Requirements

General O&M requirements are related to maintaining the pollutant removal capacity of the hydrodynamic separator. Regular maintenance consists of periodic inspections to check for and remove accumulated sediment, debris, and trash. Major maintenance (repairing or replacing inlet or outlet piping, re-grouting pipes at the vault wall, repairing cracks in the structure) should be needed infrequently. More detailed O&M requirements are summarized in the Design and Implementation section.

This section will also include a discussion of the O&M requirements relative to the requirements for other the BMPs for which fact sheets will be developed. Waiting on completion of O&M Level of Effort Appendix.

Cost Considerations

Major capital costs include site preparation (excavation and grading, protection of the installation area, labor), structural components (hydrodynamic separator, manhole structures, vaults, inlet and outlet structures), diversion structures, if used, optional or supplementary design features (see list of typical BMP components in the BMP Design and Implementation section of this document), engineering and design, surveying, and geotechnical analysis.

Unknown site conditions, such as the composition of subsurface materials (which can increase excavation costs) and unknown underground utility locations are factors that may increase construction costs.

Typical maintenance cost components include regular maintenance and cleaning, and disposal of removed sediment and debris. Some operational costs may be associated with sampling and monitoring of performance. Additional O&M costs may be incurred depending on site conditions due to traffic control if the hydrodynamic separator is located near a runway, taxiway, or road or if a confined space permit is required for entry into the unit. In-house cleaning may be relatively inexpensive with access to the right equipment such as a sump vacuum or vactor truck. Calling in a private cleaning service company is more expensive, especially if entry into a confined space is required.

BMP DESIGN AND IMPLEMENTATION

Overview of Design Criteria

In order for a hydrodynamic separator to be approved for use, it must meet the Water Quality-Capture and Treat SWM standard included in Chapter 4 of the DSM. Under special circumstances, the Port may approve facilities that do not meet these criteria.

Table 3 summarizes the minimum design criteria for hydrodynamic separators. More detailed design information is provided in the sections that follow.

Table 3: Minimum Design Criteria for Hydrodynamic Separators		
Design Parameter	**Unit**	**Design Criteria**
Structure Lid Load Rating	—	HS-20[1]

1At a minimum, structures located within Safety Areas of PDX must be able to withstand a minimum load of 100 kips. Coordinate with the Port to verify loading criteria. See DSM Chapter 5.

Considerations for Locating On-line with Runoff Conveyance

An on-line BMP provides treatment while processing the entire range of flows from a drainage area. This configuration can be used when peak flows will not damage the facility and water quality treatment objectives can be met at the expected range of flow rates. When locating the structure on-line, such as when installed as a manhole, design the high flow bypass structure to the runoff conveyance flow rate. When flows exceed the design flow rates; however, treatment effectiveness may diminish. In addition, sediment and sediment-bound pollutants are at risk of re-suspension if the unit is located on-line and receives high flows. If locating the device off-line, a flow splitter, pumping system, or other diversion structure may be used to divert the incremental portion of flows that equal the water quality flow from the primary conveyance to the hydrodynamic separator facility.

Pretreatment Requirements

Pretreatment of stormwater runoff is not required for hydrodynamic separators.

Major BMP Components

Housing Structure

The structure that houses the system is typically either a vault or manhole.

- Manholes and vaults are either precast or cast-in-place concrete structures. They range in size from 48 inches to 96 inches in diameter for a manhole and from 3 feet by 9 feet to 14 feet by 21 feet for precast vaults depending on the application and manufacturer.
- A vault may optionally be metal (corrosivity shall be considered in the design and the design life of the metal tank must be assessed).

Inlet and Outlet Pipes

Inlet and outlet pipes direct stormwater through the structure for treatment.

- Some vaults and manholes accommodate multiple inlet pipes.

Separation Cylinder or Swirl Chamber

Depending on the model, the hydrodynamic separator will be equipped with either a separation cylinder or swirl chamber.

- The separation cylinder and swirl chamber components achieve the same purpose, inducing a swirl motion or low velocity vortex to remove pollutants. Stormwater enters the cylinder or chamber where a swirling motion is induced that enhances gravitational separation.
- A swirl chamber is typical of vault-type hydrodynamic separators. The swirl chamber, along with flow controls, minimizes turbulence and provides storage of removed pollutants. Swirl chamber models pass removed pollutants to storage in a solids storage sump.

Solids Storage Sump

The removed sediments are collected and remain in the solids storage sump until maintenance requires it be removed.

- An isolated storage sump reduces scour potential.

Separation Screen

Models that include a separation screen typically offer various apertures.

- Floatables and debris larger than the screen aperture are trapped.
- Some manufacturers offer self cleaning screens where velocity from the swirling water shears debris off the screen.

Baffles

Hydrodynamic separators in a vault configuration may include a baffle wall to catch floatables.

- Sinking pollutants remain in the swirl chamber and floatables, such as oil or buoyant trash, are stopped by the baffle wall.
- Sometimes the baffle wall is in the form of a skirt rather than a wall. The skirt captures oil and buoyant trash in the chamber between the inlet invert and the bottom of the baffle.

Diversion/Bypass Weirs

A component in certain models, the diversion weir diverts flow into the separation/swirl chamber.

- When flows exceed that of the unit's design capacity, the weir bypasses the excess flow around the separation chamber.

Flow Control Wall

A component in certain models, the flow control wall is used to control low and high flows. The wall contains both a weir and an orifice.

- The orifice reduces flow velocity and turbulence and creates a backwater condition. It is typically sized to submerge the inlet pipe at 20 percent of the unit's treatment capacity.
- The weir is utilized as a high flow control mechanism. It is typically sized to pass the peak capacity minus the peak orifice flow when the water surface elevation is at the top of the weir.
- There is also a gap at the top of the flow control wall. When the system is operating under peak hydraulic capacity, water will flow through the orifice, over the weir, and through the gap at the top of the wall.

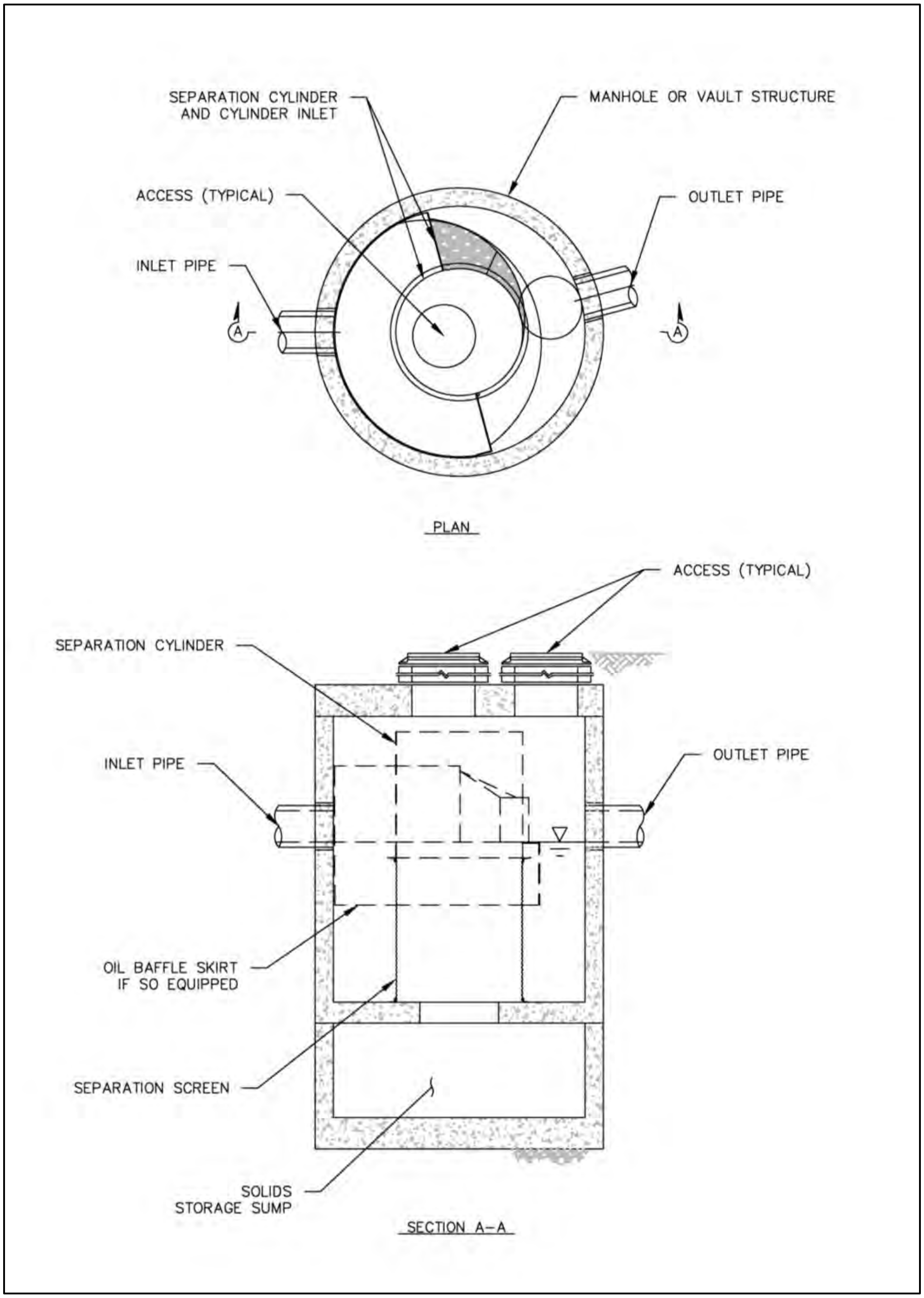


Figure 1: Hydrodynamic Separator Schematic Plan and Section View (Not to Scale)[3]

[3] Adapted with permission from *Contech Engineered Solutions*, 2013. Retrieved from http://www.conteches.com/Products/Stormwater-Management/Treatment/CDS.aspx

Considerations for Future Expansion

If future development is anticipated within the drainage basin, hydrodynamic separators shall be sited to accommodate installation of future additional hydrodynamic separators based on available information of the future development footprint. Additionally, if the facility is located off-line, strategic placement of the flow-splitter in relation to the proposed development may decrease costs of expansion if significant increases in inflows are anticipated.

Maintenance Access

Adequate access must be provided to safely enter and inspect the facility via maintained paths, gates, ladders and covers. Access to each compartment of the hydrodynamic separators is required. Access must allow for visual inspections of the inlet and outlet pipes in addition to access to each chamber and the bottom of the unit.

BMP POST-DESIGN AND IMPLEMENTATION

Construction Considerations

The drainage area shall be stabilized before BMP construction begins. Alternatively, a diversion berm can be placed around the BMP footprint to protect it from sediment loading.

If the hydrodynamic separator is installed prior to overall project completion, use the required erosion and sediment control BMPs to prevent sediment from entering the device. Do not use a hydrodynamic separator to collect sediment during construction activities without Port approval. If sediment enters the facility during the construction phase, clean the facility prior to use.

O&M Requirements

Proper O&M is necessary for hydrodynamic separators to continue to function as designed over time. Re-suspension of sediments and flushing of oil limits effectiveness of the device. Sediment can be removed with a sump vacuum or vactor truck or a professional cleaning service can be hired. The removed sediment must be disposed of in accordance with regulatory protocols. Sediment, oil, debris, and water disposal must comply with all applicable waste disposal regulations.

Operations and maintenance must follow the manufacturer's instructions for proprietary devices. However, maintenance and cleaning frequency shall be adjusted if inspection of the facility reveals that the unit needs maintenance more often. O&M requirements shall be provided to the Port by the designer/manufacturer and shall consider additional O&M measures that may be necessary based on site specific conditions. Design of the facility shall assume that O&M recommendations will be implemented.

Table 4 summarizes common hydrodynamic separator O&M activities. Table 5 provides maintenance considerations for hydrodynamic separators.

Table 4: Maintenance Activities and Frequency

Typical Schedule	Activity
As Needed (per manufacturer's recommendation and as determined by inspection)	Perform periodic inspections to check if excessive quantities of sediment, oil, trash, or floating debris have accumulated
At Least Annually or as Needed Based on Inspection	• Remove pollutants by vacuuming or using absorbent pads if facility is full (defined as ≤ 1 foot capacity remaining in the unit) • Clean facility with use of a sump vacuum or vactor truck to remove sediment when depth in bottom of unit exceeds 6 inches in depth • Remove sediment, oil, trash, or floating debris as needed

Table 5: Maintenance Considerations for Hydrodynamic Separators

Component	Issue Requiring Maintenance	Recommendation for Maintenance
Effluent	Inspection of discharge water shows obvious signs of poor water quality	Clean the unit and remove pollutants and sediment
Sediment	Sediment depth in bottom of unit exceeds 6 inches in depth	Remove sediment deposits in structure bottom that would impede flow through the unit and reduce efficiency
Trash and Debris	Trash and debris accumulates in unit, or pipe inlet/outlet, floatables and non-floatables	Remove trash and debris from unit and inlet/outlet piping
Pipes	Inlet/outlet pipes are damaged or broken and are in need of repair	Replace or repair pipe
Access Cover	Access cover will not open or is cracked, corroded, or deformed	Replace or repair cover so that it meets design specifications and is structurally sound
Structure Top/Frame	Structure top slab has holes larger than 2 square inches or cracks wider than ¼ inch	Repair top slab so it is free of holes and cracks
	Structure frame is not sitting flush on top of structure slab (gap wider than ¾ inch) or frame not securely attached	Securely attach the frame so it is sitting flush on the riser rings or top slab
Structure Walls/ Bottom	Inspector judges structure is unsound	Replace or repair to meet design standards
	Grout fillet is separated or cracked wider than ½ inch and longer than 1 foot at the joint of an inlet/outlet pipe or there is evidence of soil particles entering through cracks	Regrout pipe and secure at the structure wall

Table 5: Maintenance Considerations for Hydrodynamic Separators		
Component	**Issue Requiring Maintenance**	**Recommendation for Maintenance**
Baffles	Baffles are corroding, cracking, warping, and/or showing signs of failure as judged by inspector	Replace baffles or repair to meet specifications
Access Ladder	Ladder is corroded or deteriorated, is not functioning properly, is not securely attached to the structure, is missing rungs, cracked, or misaligned	Replace ladder or repair to meet specifications so it is safe to use as determined by an inspector

Other Key Information

This fact sheet shall be used in conjunction with the BMP selection and design information presented in Chapter 6 of the DSM.

7 REFERENCES

The references below are consistent with the content at the time of DSM development (corresponding to the dates described below). These references provide additional information that may be useful to the designer for the implementation and understanding of DSM requirements. Should any of the documents be updated at a later date, there may be discrepancies between DSM criteria and the updated manuals. Designers are responsible for complying with all applicable regulatory requirements at the time of project design (e.g., FAA, ODOT, AREMA, City, DEQ, as applicable to the project work), and as such, designers may need to comply with criteria in updated regulatory documents if they are more stringent than the DSM. In the case of updates to non-regulatory reference documents, designers shall continue to follow the criteria in the DSM, unless otherwise notified by the Port.

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2011b ODOT Water Resources Specialist Manual: ftp://ftp.odot.state.or.us/techserv/geo-environmental/environmental/procedural%20manuals/water_resources_manual/water_resources_manual.pdf

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8 GLOSSARY

Term	Definition for the Purposes of the DSM
Best management practice	For the purposes of the DSM, best management practices (BMPs) refer to post-construction stormwater management facilities that provide water quantity control, water quality treatment, or a combination of the two.
Biofiltration	Biofiltration is a water quality treatment mechanism that involves the use of vegetation and engineered soil media in place of typical filtration media options. Pollutants are removed through the combined effects of filtration, infiltration, and settling. For more information on biofiltration BMPs, refer to Chapter 6.
BMP fact sheets	BMP fact sheets contain design criteria unique to each type of BMP.
Building BMPs	Building BMPs are devices that are generally intended to provide volume reduction and water quality treatment for roof drainage. Building BMP options include green roofs, cisterns, roof downspout filters, flow-through planters, and dry wells. For more information on building BMPs, refer to Chapter 6.
Detention	Detention is a quantity control approach that involves the temporary storage of stormwater until it can be released at a controlled rate. Detention may also provide some water quality benefit through sedimentation, and may be combined with other water quality functions or infiltration. For more information on detention BMPs, refer to Chapter 6.
Disturbance area	The area where soil is exposed during construction of the development or redevelopment project.
Drainage system	Collection and conveyance infrastructure for stormwater runoff, including constructed channels, inlets, pipes, manholes, outfalls, pump stations, and other drainage features.
Environmental overlay zones	Pertain to City defined areas that have been inventoried and identified as having natural resource values. There are two overlay zones within the environmental overlay zone: the protection zone and the conservation zone. Resources within the Protection zone are considered very significant. Approval of development is atypical within the protection zone. Resources within the Conservation zone are considered significant and are protected while allowing environmentally sensitive urban development.
Erosion, Sediment, and Pollution Control Plan	The plan that details erosion and sediment control practices and implementation of the practices. The City calls this plan the “Erosion, Sediment and Pollutant Control Plan” (ESPCP) where DEQ calls this plan “Erosion and Sediment Control Plan” (ESCP). Sites that meet both applicability thresholds for the City and DEQ construction permit are encouraged to submit the same ESPCP to both agencies. In general the ESPCP should consist of narratives detailing the nature of the activity, activity schedule, site map, and drawings.

Term	Definition for the Purposes of the DSM
Filtration	Filtration is a water quality treatment mechanism that involves the use of various media, such as sand, perlite, zeolite, compost, and activated carbon to remove sediment and associated pollutants from stormwater that passes through the media. Some of these media types are also effective for removing dissolved pollutants. For more information on filtration BMPs, refer to Chapter 6.
Final design milestone	This milestone occurs at the completion of the project design, and requires the submittal, review, and coordination of final design documents (as defined within the scope), as well as the SWM Submittal. For more information, refer to Chapter 3.
Flood hazard area	These zones are defined in Title 33 of City Code and development within these areas is restricted per Title 24 of City Code. Flood Hazard Areas are detailed within Flood Insurance Rate Maps and within the "February 1996 Flood Inundation" areas.
Flow-based BMP	BMP that is designed to provide a water quality treatment capacity based on flow rate. For more information, see Chapters 4 and 6.
Green infrastructure	Green infrastructure is a Low-Impact Development (LID) practice that uses structural stormwater BMPs that mimic the natural processes of infiltration and evapotranspiration, or reuse stormwater, to manage stormwater runoff from a disturbed area.
Greenway overlay zones	Pertain to protected zones along the shoreline of the Willamette River. There are five types of greenway overlay zones, of which River Industrial is most likely to be encountered at Port facilities: River Natural – Intended to protect and conserve the land with scenic quality or valuable wildlife habitats. River Recreational – Encourages river-dependent and river related recreational uses. River General – Allows for development consistent with the base zoning. River Industrial – Promotes the development of river-dependent and river-related industries. River Water Quality – Protects water quality resources
Hazardous wildlife attractants	Stormwater facilities that have a tendency to attract wildlife that pose a strike risk to aircraft, of which a majority are birds. Such facilities may consist of open water or areas that provide food or shelter to wildlife.
Impervious Surface	The MS4 permit defines this term as "Any surface resulting from development activities that prevents the infiltration of water or results in more runoff than in the undeveloped condition. Common impervious surfaces include: building roofs, traditional concrete or asphalt paving on walkways, driveways, parking lots, gravel roads, and packed earthen materials." For consistency with the City SWMM, surfaces such as gravel roads and packed earthen materials will be considered impervious when the runoff coefficient is greater than 0.8, and otherwise will be considered to be pervious.

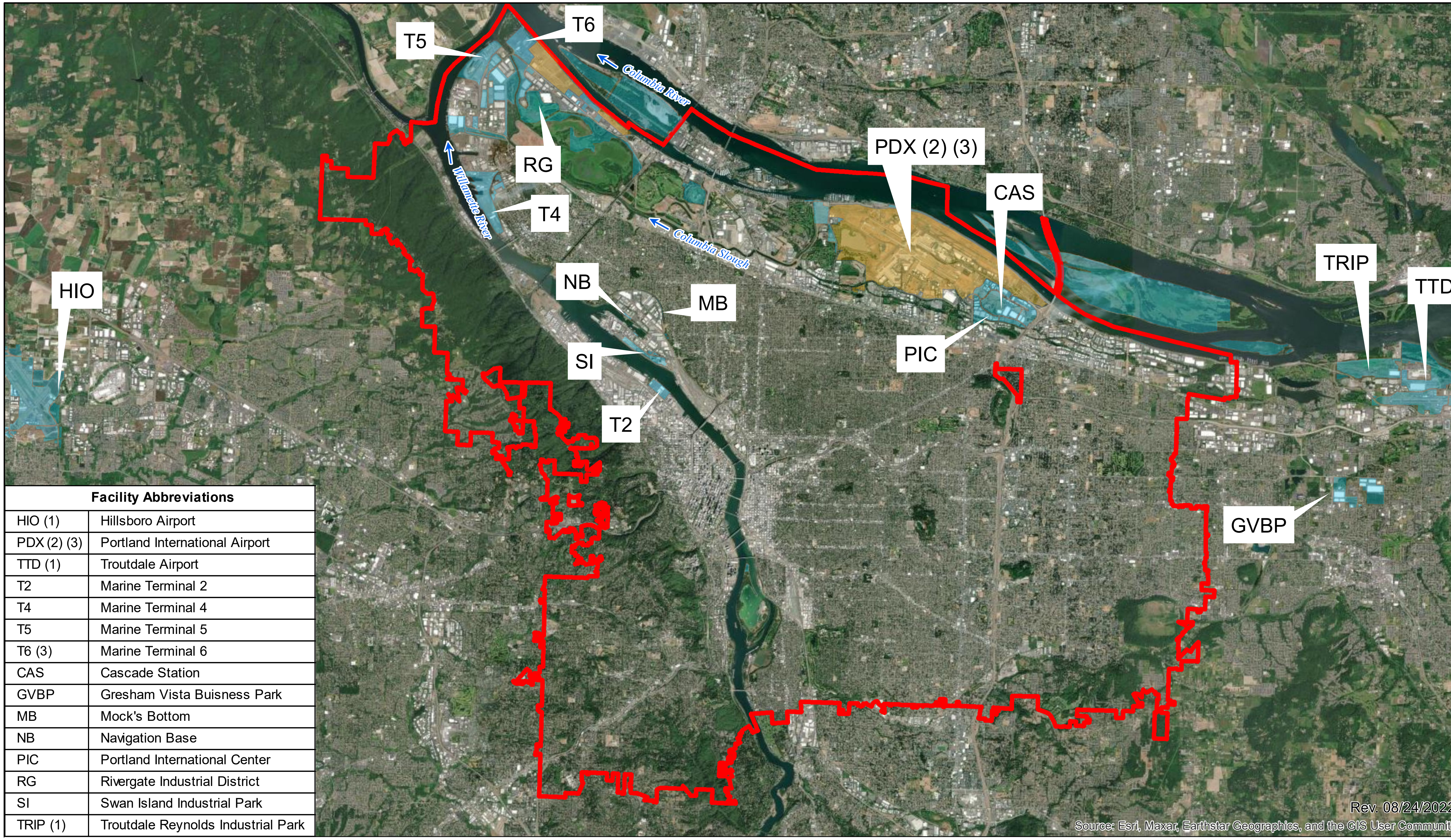
Term	Definition for the Purposes of the DSM
Infiltration Strategy	The design infiltration strategy is the selected strategy that allows for the use of infiltration to the maximum extent practicable on-site, taking into account site feasibility and implementation considerations. There are three strategies, Full Infiltration of the Water Quality Design Storm, Partial Infiltration of the Water Quality Design Storm, and No Reliance on Infiltration. See Chapter 4 and Table 4-1 for more information.
Larger Common Plan of Development	The United States Environmental Protection Agency (EPA) defines this term as “a contiguous area where multiple separate (development) activities may be taking place at different times… under one plan.”
LID Practices and Strategies	LID Strategies are the overarching approaches that cover multiple LID practices, these strategies are to minimize the disturbance of sensitive areas, minimize the impact of development and to manage runoff from disturbed areas. LID Practices are the approaches to accomplish the chosen LID Strategy, for example Green Infrastructure is an LID Practice that accomplishes the LID Strategy of managing runoff from disturbed areas.
Low-Impact Development	Low-Impact Development, as defined by the Environmental Protection Agency (EPA), is “an approach to land development (or re-development) that works with nature to manage stormwater as close to its source as possible,” and “employs principles such as preserving and recreating natural landscape features (and) minimizing effective imperviousness to create functional and appealing site drainage that treat(s) stormwater as a resource.”
Off-Line	If there is an upstream flow diversion and the BMP only receives stormwater less than or equal to the water quality design capacity, then the BMP is considered to be an “off-line” system.
Off-Site Mitigation	Additional measures required at a location other than the project site in order to comply with the SWM Standard.
On-Line	If the BMP is sited such that all of the runoff in the catchment area passes through the facility, the BMP is an “on-line” system. Runoff exceeding the water quality design capacity of the BMP is assumed to pass through the BMP untreated.
Pre-development conditions	Existing development conditions, immediately prior to the new or redevelopment project
Pretreatment	Treatment that occurs prior to draining to the primary BMP. Often targets removal of coarse sediment and gross solids.
Project Kickoff Meeting	Meeting with the Port that typically occurs at the start of the design project, where the Port will review project goals and objectives as identified in the project scope of work, as well as project schedule and milestones, logistics for coordination, Port information resources, and submittal requirements. As it relates to compliance with the DSM, the meeting provides an opportunity to discuss planning-level stormwater management considerations. See Chapter 3 for additional information.
Project Site	The site that is selected for land development and redevelopment activities including the functional project area, as well as areas used for stormwater management within the project limits of construction. The site also encompasses the full disturbance area, including areas that will ultimately be pervious and impervious.

Term	Definition for the Purposes of the DSM
Proprietary BMPs	Proprietary devices refer to a broad category of manufactured commercial products, some of which may employ patented innovative technologies. The proprietary devices included in this manual may be categorized as either separation devices or filtration devices. For more information on proprietary BMPs, refer to Chapter 6.
Redevelopment	The MS4 permit defines this term as "A project on a previously developed site that results in the addition or replacement of impervious surface." For purposes of the DSM, redevelopment will be defined as a previously developed site with existing impervious surface that is greater than or equal to 35% prior to addition or replacement.
Regulatory Coordination SWM Standards	Requirements identifying the need for designers to coordinate their design and SWM Strategy with key regulatory requirements. Although designers are responsible for designing to all applicable regulatory requirements, the requirements called out in these SWM Standards are those that may be especially pertinent to stormwater management at Port facilities.
Replacement	The MS4 permit defines this term as "the removal of an impervious surface that exposes soil followed by the placement of an impervious surface. Replacement does not include repair or maintenance activities" as long as those activities do not have "additional hydrologic impact results."
Retention	Retention is a quantity control approach that involves the permanent capture of stormwater runoff without an off-site discharge. Retention facilities are emptied by means of infiltration, evaporation, evapotranspiration, and/or capture and beneficial use. Retention facilities may provide some water quality benefit through reduction of runoff volume and pollutant load. Systems with permanent pools may also provide sedimentation and biological treatment. For more information on retention BMPs, refer to Chapter 6.
Runoff Control SWM Standards	Requirements for controlling the quality and quantity of post-construction stormwater runoff from applicable development and redevelopment projects. These requirements are largely driven by MS4 permit requirements for Post-Construction Site Runoff, which are aimed at minimizing the potential for impervious surfaces to impact receiving waters.
Separation	Separation is a water quality treatment mechanism that involves the use of gravity and centrifugal forces to physically remove coarse sediment, pollutants absorbed to sediment, and floatables (e.g., debris, oil, and grease) from stormwater runoff. Separation is a type of water quality treatment provided by some types of proprietary BMPs. For more information on separation BMPs, refer to Chapter 6.

Term	Definition for the Purposes of the DSM
Source Controls	Source controls provide a first line of defense by managing the pollutant at the source before it has the opportunity to mix with stormwater. These include operational and management strategies and procedures (e.g., spill response, pavement sweeping, etc.) and structural source controls (e.g., containment berms), Source controls are required and regulated through NPDES permits along with the City of Portland Source Control Manual (SCM) for certain activities and connections to sanitary. The Port may require additional source controls above and beyond regulations.
Stormwater Management Standard	Standards for managing the quantity and quality of post-construction stormwater runoff from new development and redevelopment sites at applicable Port facilities (Runoff Control SWM Standards), as well as standards for coordinating stormwater management with applicable water resource regulations (Regulatory Coordination SWM Standards)
Stormwater Management Submittal	The final stormwater management design document to be submitted to the Port that contains the final design contents as outlined within Chapter 3 and detailed in the "Stormwater Management Submittal Content List"
Treatment Trains	BMPs that are placed in series to target multiple pollutants, to separate the water quality and flow control functions, and/or to provide pretreatment which acts to protect and reduce maintenance for downstream BMPs.
Underground Injection Control Systems	Systems that allow for direct injection of stormwater into groundwater. See Appendix C for the regulatory context pertaining to UICs. See Chapter 4 SWM Standard for Infiltration for requirements related to the implementation of new UICs.
Variance Request	The means by which designers may communicate requests to deviate from the requirements of the DSM to the Port. There are five types of Variance Requests, as described in Chapter 3.
Volume-based BMP	BMP that is designed to provide a water quality treatment capacity based on volume. For more information, see Chapters 4 and 6.
Wellhead Protection Area	Columbia South Shore Well Field Wellhead Protection Area.

Figures

Figure 1-1: Port Facility Location Map
Figure 1-2: DSM Applicability Area at PDX
Figure 1-2A: DSM Applicability Area at PDX - West
Figure 1-2B: DSM Applicability Area at PDX - Central
Figure 1-2C: DSM Applicability Area at PDX - East
Figure 1-3: DSM Applicability Area at T6
Figure 2-1: Port Facility Drainage to Receiving Waters
Figure 4-1: Wellhead Protection Area
Figure 4-2: Hazardous Wildlife Attractant Zones
Figure 4-3: FEMA 100-Year Floodplain
Figure 4-4: February 1996 Flood Inundation Areas
Figure 4-5: Greenway Overlay Zones
Figure 4-6: Environmental Overlay Zones



Facility Abbreviations	
HIO (1)	Hillsboro Airport
PDX (2) (3)	Portland International Airport
TTD (1)	Troutdale Airport
T2	Marine Terminal 2
T4	Marine Terminal 4
T5	Marine Terminal 5
T6 (3)	Marine Terminal 6
CAS	Cascade Station
GVBP	Gresham Vista Buisness Park
MB	Mock's Bottom
NB	Navigation Base
PIC	Portland International Center
RG	Rivergate Industrial District
SI	Swan Island Industrial Park
TRIP (1)	Troutdale Reynolds Industrial Park

Legend

- Port Property - DSM applicable (3)
- Port Property - DSM not applicable
- City of Portland USB (4)

Notes:

(1) Facilities outside of Urban Services Boundary are outside of Portland Group MS4 permit jurisdiction.
(2) Air Cargo (Air Trans Center, PDX Cargo Center, North Cargo Complex) is not called out but is included within the PDX area.
(3) Refer to Figure 1-2 for details on Port of Portland Design Standards (DSM) applicable areas at PDX and Figure 1-3 for details on applicable areas at T6.
(4) Urban Services Boundary (USB). Copyright Oregon Metro www.oregonmetro.gov/rlis (9/30/2013).

Port of Portland
Stormwater Design Standards Manual
Figure 1-1: Port Facility Location Map

Figure 1-1

Port of Portland

Stormwater Design Standards Manual

Figure 1-2: DSM Applicability Area at PDX

Legend

- Extents for Figures 1-2A and 1-2C
- Extents for Figure 1-2B
- DSM (2)
- City SWMM (3)

Notes:

(1) This key map provides an overview of Design Standards Manual (DSM) applicability within Port-owned properties at PDX (shaded above). Please refer to Figures 1-2A, 1-2B, and 1-2C for further detail in areas of interest, based on figure extents noted above.

(2) The DSM is applicable to all airside areas (areas inside the AOA fence), including Air Cargo Facilities, the Oregon Air National Guard, as well as Port owned landside properties (areas outside the AOA fence) adjacent to the airfield.

(3) The DSM is not applicable to Port owned property in the Portland International Center (PIC) or Cascade Station (CAS), or the properties east of NE 33rd.

0 1,000 2,000

Feet

Figure 1-2

Legend

- Perimeter Fence
- DSM (1)
- City SWMM (2)

0 550 1,100 Feet

(1) The DSM is applicable to all airside areas (areas inside the AOA fence), including Air Cargo Facilities, the Oregon Air National Guard, as well as Port owned landside properties (areas outside the AOA fence) adjacent to the airfield.

(2) The DSM is not applicable to Port owned property in the Portland International Center (PIC) or Cascade Station (CAS), or the properties east of NE 33rd.

Port of Portland

Stormwater Design Standards Manual

Figure 1-2A: DSM Applicability Area at PDX - West

Figure 1-2A

Legend

Perimeter Fence

DSM (1)

City SWMM (2)

0 550 1,100

Feet

(1) The DSM is applicable to all airside areas (areas inside the AOA fence), including Air Cargo Facilities, the Oregon Air National Guard, as well as Port owned landside properties (areas outside the AOA fence) adjacent to the airfield.

(2) The DSM is not applicable to Port owned property in the Portland International Center (PIC) or Cascade Station (CAS), or the properties east of NE 33rd.

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Figure 1-2B: DSM Applicability Area at PDX - Central

Figure 1-2B

Legend

Perimeter Fence

DSM (1)

City SWMM (2)

0 550 1,100

Feet

(1) The DSM is applicable to all airside areas (areas inside the AOA fence), including Air Cargo Facilities, the Oregon Air National Guard, as well as Port owned landside properties (areas outside the AOA fence) adjacent to the airfield.

(2) The DSM is not applicable to Port owned property in the Portland International Center (PIC) or Cascade Station (CAS), or the properties east of NE 33rd.

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Figure 1-2C: DSM Applicability Area at PDX - East

Figure 1-2C

Legend

DSM

SWMM

Notes:

(1) The DSM is applicable to areas at T6 shown above in orange, which correspond to drainage basins C, D, F, G, H, I, J, K, L, M, O, and T. The City SWMM is applicable in the remaining areas (shown in blue).

0 625 1,250 Feet

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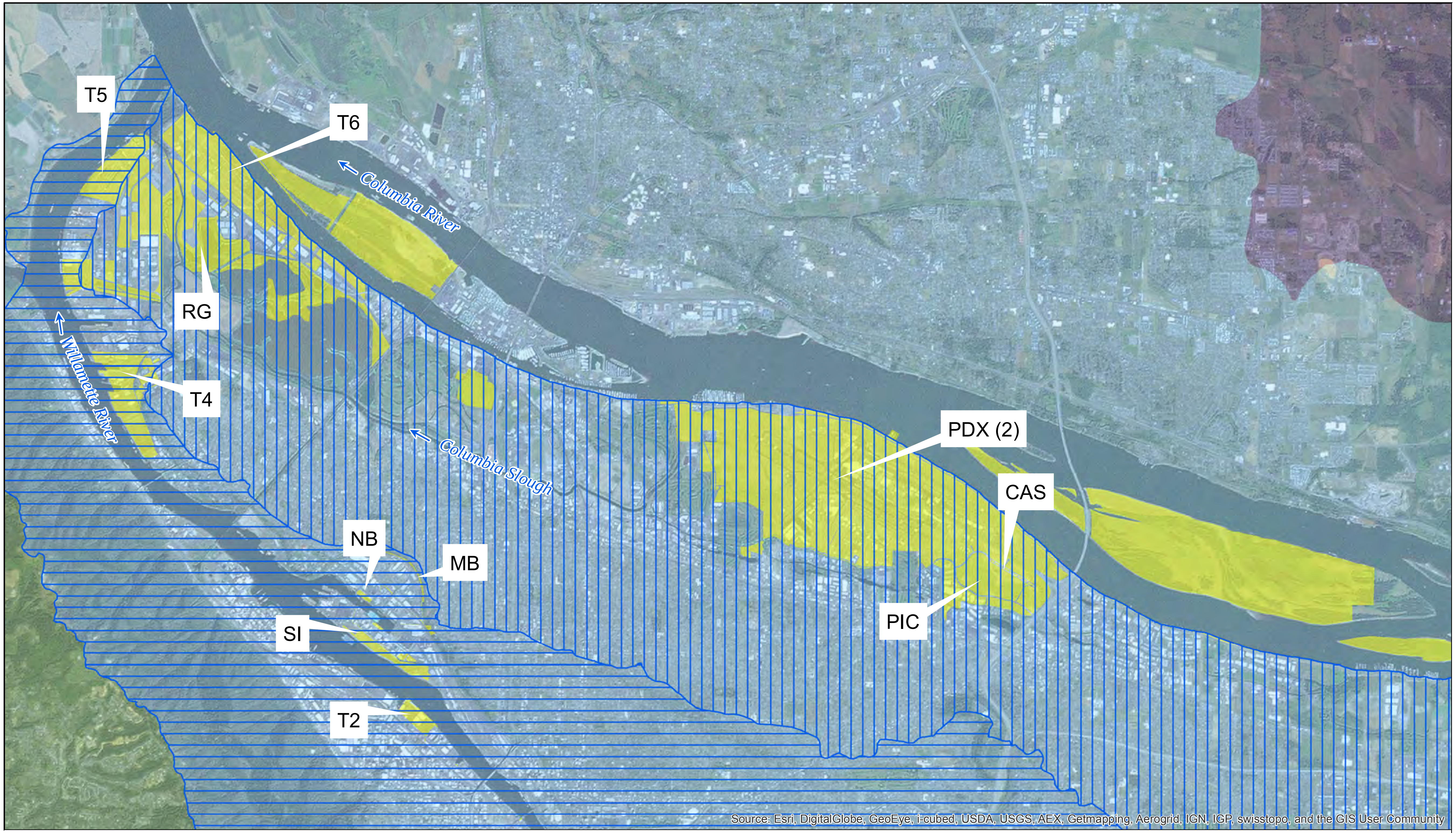
Figure 1-3: DSM Applicability at T6

Figure 1-3

Port of Portland
Stormwater Design Standards Manual
Figure 2-1: Port Facility Drainage to Receiving Waters (1)



Legend

Port Property

USGS 12-Digit HUC (3) (4)

Columbia Slough

Willamette River

USGS 8-Digit HUC (3) (4)

Lower Columbia-Sandy

Lower Willamette

Tualatin

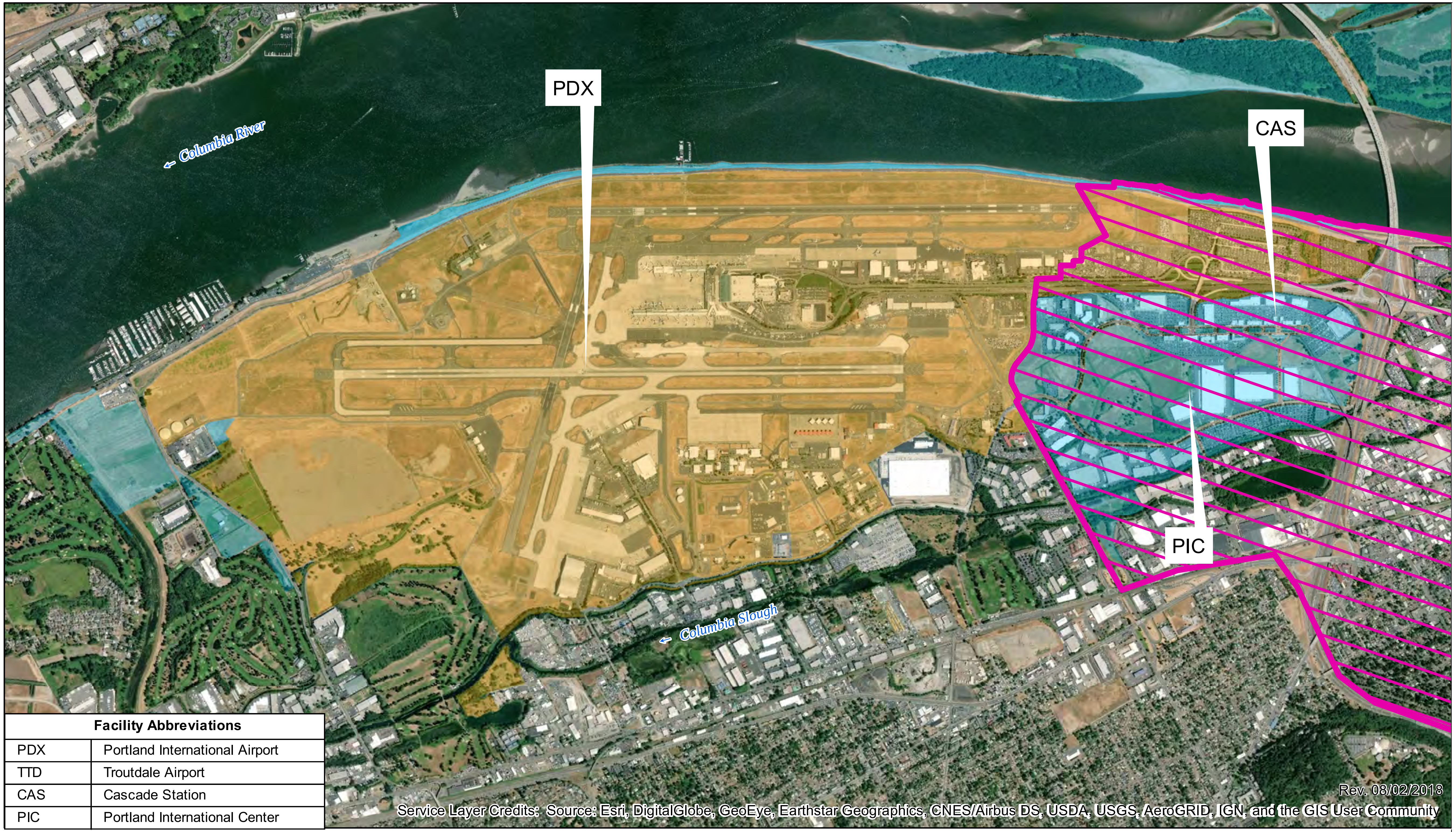
0 1.25 2.5 5 Miles

Notes:

(1) For planning purposes only.
(2) Portions of PDX airside drainage are discharged to the Columbia River during the deicing season.
(3) HUC stands for the Hydrologic Unit Code (drainage area) as defined by the United States Geological Survey (USGS).
(4) Copyright Oregon Metro www.oregonmetro.gov/rlis (9/30/2013).

Figure 2-1

Port of Portland
Stormwater Design Standards Manual
Figure 4-1: Wellhead Protection Area (1)



Facility Abbreviations	
PDX	Portland International Airport
TTD	Troutdale Airport
CAS	Cascade Station
PIC	Portland International Center

Legend

- WHPA (1)
- Port Property - DSM applicable (3)
- Port Property - DSM not applicable

0 1,000 2,000 Feet

Notes:

(1) For planning purposes only. Please refer to the City of Portland Water Bureau "Columbia South Shore Well Field Wellhead Protection Manual" for requirements and the official boundary of the wellhead protection area.
(2) This map illustrates the extents of the figure above (green rectangle) relative to the overall WHPA.
(3) Refer to Figure 1-2 for details on Port of Portland Design Standards (DSM) applicable areas at PDX.

Location Key (2)

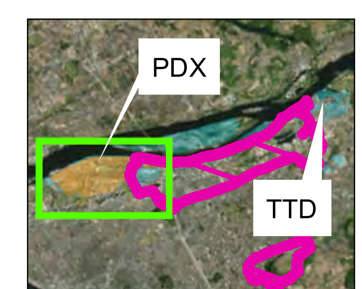
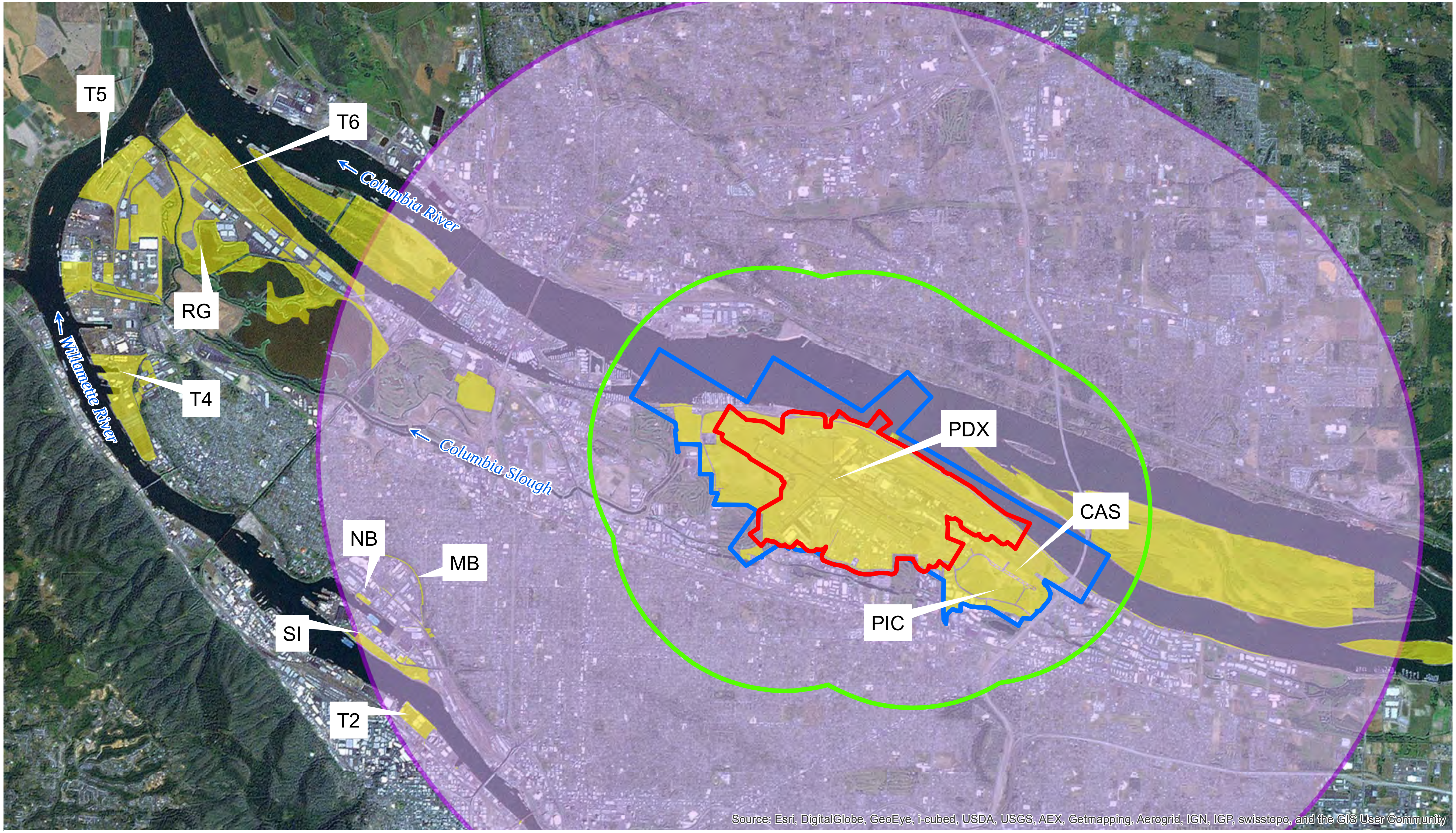


Figure 4-1



Legend

- Port Property
- Primary
- Intermediate
- Secondary
- Five-Mile

0 1.25 2.5 5 Miles

Notes:

(1) Refer to DSM Chapter 4 Hazardous Wildlife Attractants SWM Standard for requirements applicable to each zone. The Primary Zone is defined by a 300-foot buffer around the airfield perimeter fence and the runway protection zones (RPZs) at the end of each runway. The Intermediate Zone is defined by all Port owned airport land outside of Primary Zone. The Secondary Zone is defined by the remaining land within the 10,000-foot separation criteria area that is not included in the Primary or Intermediate zones. (PDX WHMP). The Five-Mile Zone is defined by a five-mile separation distance from the AOA (FAA AC 150/5200-33).

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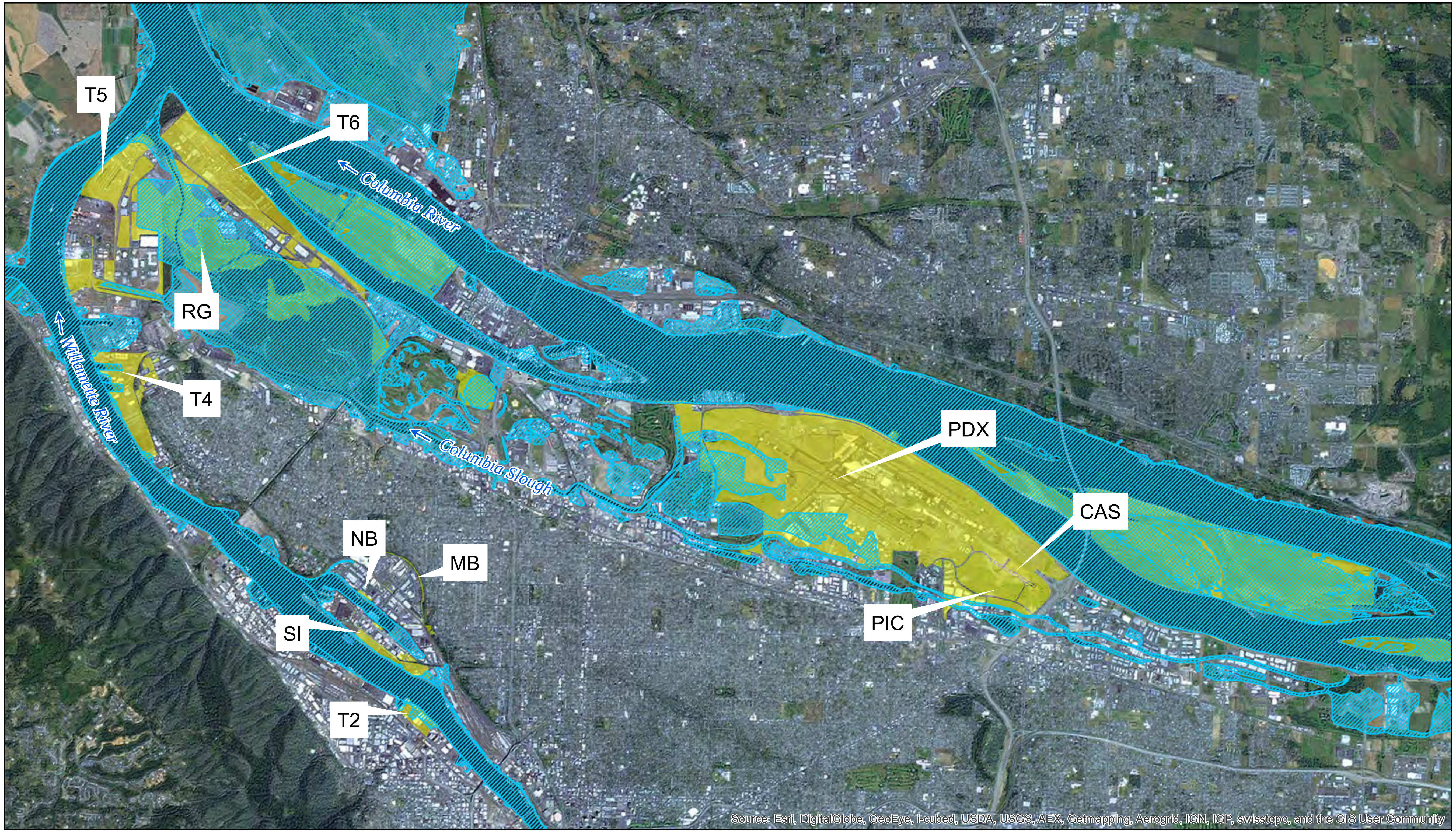
Figure 4-2: Hazardous Wildlife Attractant Zones (1)

Figure 4-2



Legend

Port Property

FEMA 100-Year Floodplain (1)

0 1.25 2.5 5 Miles

Notes:

(1) For planning purposes only. The figure shows the 100-year floodplain from 2004, as pulled from Port of Portland GIS. There have been revisions to the floodplain since 2004. Designers should review City Official Zoning Maps along with Federal Emergency Managment Agency (FEMA) Maps for the most current 100-year floodplain.

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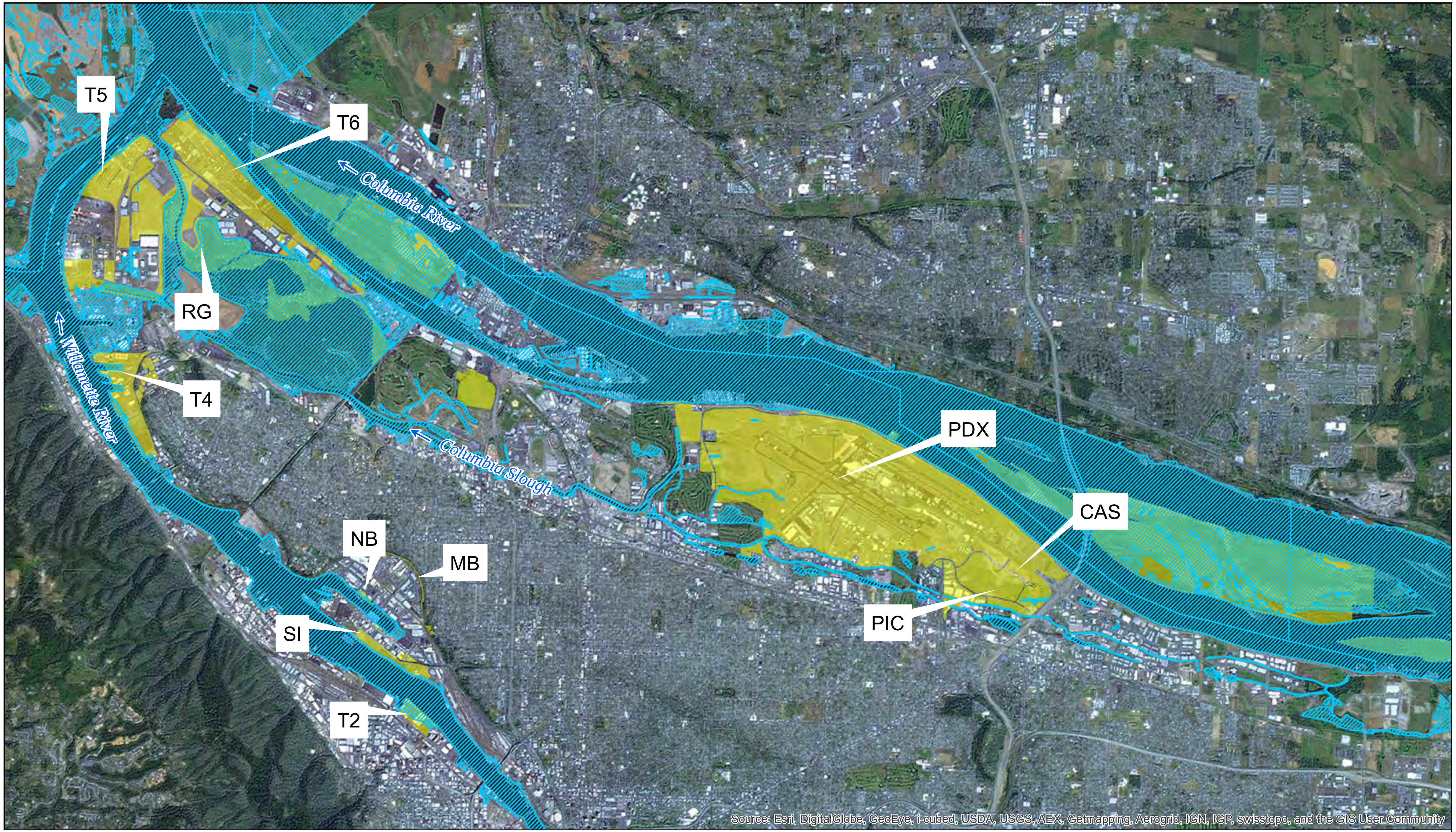
Figure 4-3: FEMA 100-Year Floodplain (1)

Figure 4-3

Port of Portland

Stormwater Design Standards Manual

Figure 4-4: February 1996 Flood Inundation Areas (1)



Legend

Port Property

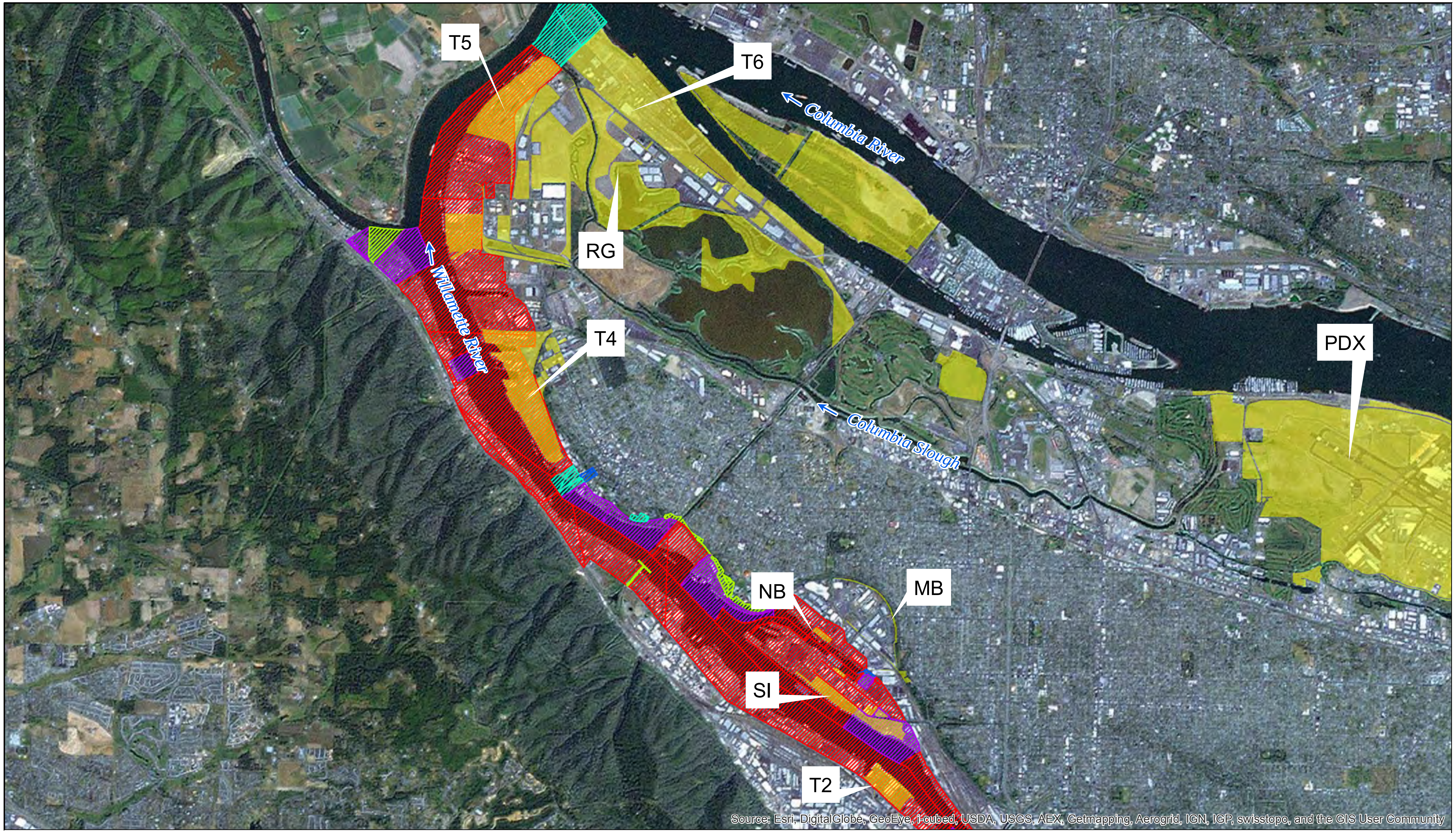
1996 Flood Inundation Areas (2)

0 1.25 2.5 5 Miles

Notes:

(1) For planning purposes only. Designers should review City Official Zoning Maps.
(2) Copyright Oregon Metro www.oregonmetro.gov/rlis (9/30/2013).

Figure 4-4



Legend

Port Property	n - River Natural
g - River General	q - River Water Quality
i - River Industrial	r - River Recreational

0 1.25 2.5 5 Miles

Notes:

(1) For planning purposes only. Designers should review City Official Zoning Maps.

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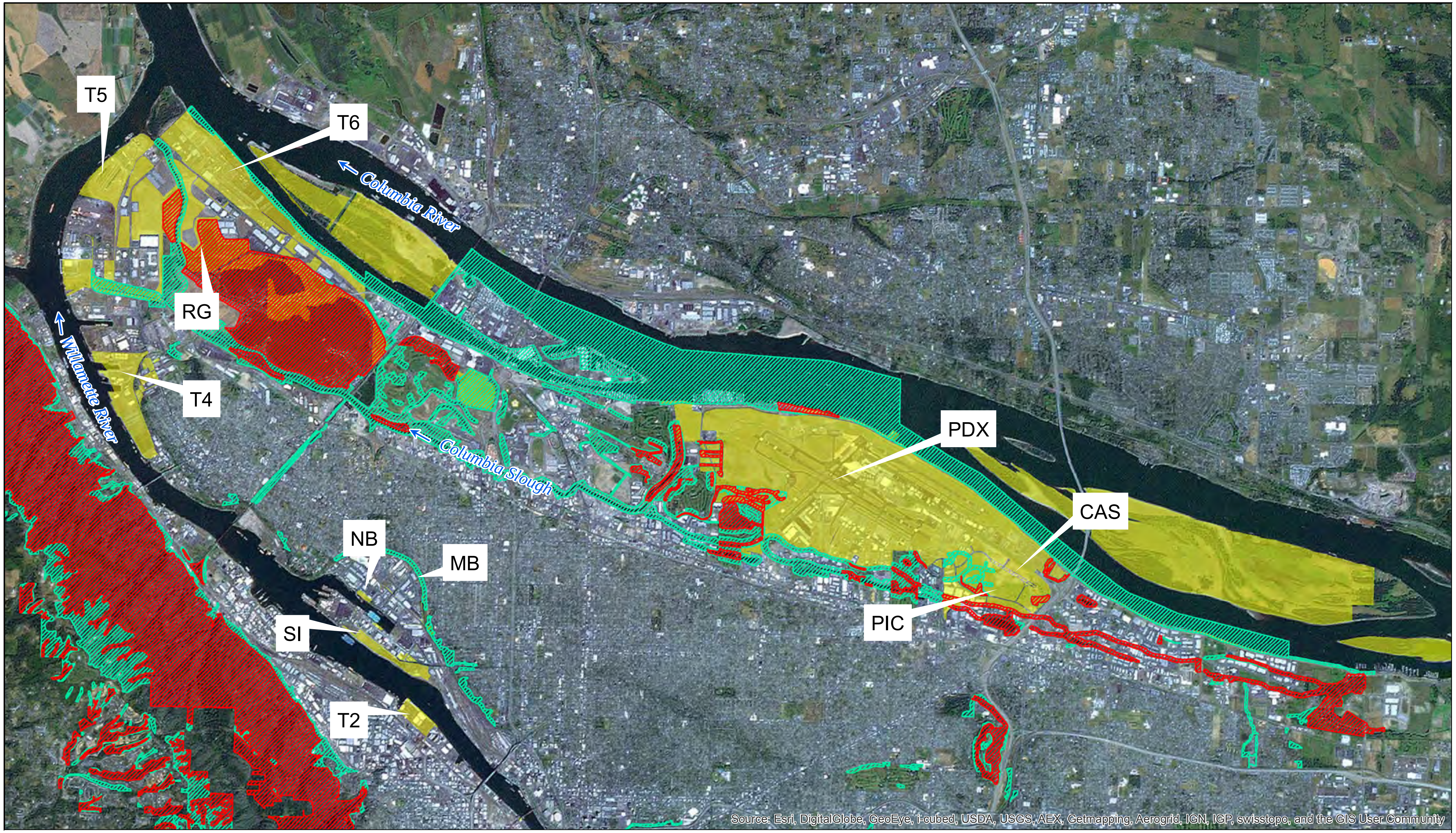
Figure 4-5: Greenway Overlay Zones (1)

Figure 4-5



Legend

Port Property

c - Conservation

p - Protection

0 1.25 2.5 5 Miles

Notes:

(1) For planning purposes only. Designers should review City Official Zoning Maps.

Port of Portland

Stormwater Design Standards Manual

Figure 4-6: Environmental Overlay Zones (1)

Figure 4-6

Appendices

Appendix A: MS4 Permit

Appendix B: Summary of MS4 Permit Requirements and Incorporation into the Port's Stormwater DSM

Appendix C: Regulatory Context

Appendix D: Groundwater and Soil On-site Testing Procedures

Appendix E: DSM Coordination Checklist

Appendix F: Variance Request Application Form

Appendix G: Stormwater Management Submittal Content List

Appendix H: Modeling Report Content List

Appendix I: Project O&M Form

Appendix J: City Draft Figure on the "Depth to Seasonally High Water (Table)"[28]

Appendix K: Drainage System Design Reference

Appendix L: Nomographs for Water Quality BMP Sizing

Appendix M: Appendix Not Used

Appendix N: Best Management Practices Capital Cost Estimation Methods

Appendix O: BMP Operations and Maintenance Level of Effort

Appendix P: Sustainability Considerations For BMPs

[28] Designers may refer to this figure for high level review, otherwise designers must refer to site-specific information such as data collected through the Port's TRC from previous geotechnical and/or groundwater data or from site-specific testing.

Appendix A

MS4 Permit

Expiration Date: January 30, 2016
Permit Number: 101314
File Number: 108015

NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM
MUNICIPAL SEPARATE STORM SEWER SYSTEM (MS4) DISCHARGE PERMIT

Oregon Department of Environmental Quality
811 SW Sixth Ave., Portland OR 97204-1390
Telephone: 503-229-5630

Issued pursuant to Oregon Revised Statute 468B.050 and the Federal Clean Water Act

ISSUED TO:
City of Portland
Port of Portland

SOURCES COVERED BY THIS PERMIT:
This permit covers all existing and new discharges of stormwater from the Municipal Separate Storm Sewer System (MS4) within the City of Portland Urban Services Boundary.

COUNTY: Multnomah

RECEIVING WATERBODIES:
Basin(s): Willamette River, Columbia River
Sub-basin(s): Lower Willamette River, Columbia Slough, Tualatin River
Stream(s): Columbia River, Columbia Slough, Fanno Creek, Balch Creek, Johnson Creek, and Tryon Creek

WASTE LOAD ALLOCATIONS: A Total Maximum Daily Load (TMDL) that includes wasteload allocations for urban stormwater has been established for the Willamette River Basin, Columbia River Basin, Tualatin River Subbasin, and the Columbia Slough. Waste load allocations are addressed in Schedule D of this permit.

EPA REFERENCE NO.: ORS108015

This permit is issued in response to Application Number 972521 received on September 2, 2008.

Annette Liebe, Surface Water Management Section Manager

Date 1/31/2011

PERMITTED ACTIVITIES

Until this permit expires or is modified or revoked, the co-permittee is authorized to discharge municipal stormwater to waters of the state in conformance with the requirements and conditions set forth in the attached schedules. Where conflict exists between specific conditions (found in Schedules A-D) and general conditions (Schedule F), the specific conditions supersede the general conditions.

		Page
Schedule A	– Controls and Limitations	2
Schedule B	– Monitoring and Reporting Requirements	14
Schedule C	– Compliance Schedules	21
Schedule D	– Special Conditions	21
Schedule F	– General Conditions	26

SCHEDULE A
Controls and Limitations for Stormwater Discharges from Municipal Separate Storm Sewer Systems

1. **Prohibit Non-stormwater Discharges**
   The co-permittees must effectively prohibit non-stormwater discharges into the MS4 unless such discharges are otherwise permitted under Subsection A.4.a.xii., another NPDES permit or other applicable state or federal permit, or are otherwise exempted or authorized by the Department.

2. **Reduce Pollutants to the Maximum Extent Practicable**
   Each co-permittee must reduce the discharge of pollutants from the MS4 to the maximum extent practicable (MEP). Compliance with this permit and implementation of a stormwater management program, including the Department-approved Stormwater Management Plan (SWMP), establishes this MEP requirement, unless or until the Department reopens the permit as provided in Oregon Administrative Rule (OAR) 340-045-0040 and 0050 to require additional controls.

3. **Implement the Stormwater Management Plan**
   The co-permittees must continue to implement and assess the effectiveness of its Department-approved SWMP. The SWMP must guide each co-permittee in the implementation of its stormwater management program.

   a. The SWMPs and any Department-approved amendments thereto, are hereby incorporated into the permit by reference. The applicable SWMP is as follows:

      i. For the City of Portland: The SWMP is the proposed SWMP submitted with the NPDES permit re-application and amendment received by the Department on August 13, 2010, the addition of the special conditions specified in Schedule D.6., and any subsequent changes made to the SWMP in accordance with the conditions of this permit.

      ii. For the Port of Portland: The SWMP is the proposed SWMP submitted with the NPDES permit re-application and amendment received by the Department on September 20, 2010, the addition of the special conditions specified in Schedule D.6., and any subsequent changes made to the SWMP in accordance with the conditions of this permit.

b. Each co-permittee is responsible for compliance within its jurisdiction as identified in this permit, and is not responsible for compliance outside of its jurisdiction.

c. The SWMP must be electronically available through direct incorporation into the co-permittee's website or other similar method approved by the Department.

4. **Stormwater Management Plan Requirements**

Each co-permittee must implement a SWMP that outlines the practices, techniques or provisions associated with protecting water quality and satisfying requirements of this permit and includes measurable goals for the stormwater program elements identified in subsections a-h. The measurable goals must identify actions the permittee will undertake to implement best management practices (BMPs), and include, where appropriate, the frequency, timeline and/or location where the BMP actions will occur.

a. **Illicit Discharge Detection and Elimination**: Co-permittees must continue to implement a program to detect, remove, and eliminate illicit discharges to the MS4. The program must:

i. Prohibit, through ordinance or other regulatory mechanism, illicit discharges into the co-permittee's MS4.

ii. Include documentation in an enforcement response plan or similar document by November 1, 2011 describing the enforcement response procedures the co-permittee will implement when an illicit discharge investigation identifies a responsible party.

iii. Develop or identify pollutant parameter action levels that will be used as part of the field screening. The action levels will identify concentrations for identified pollutants that, if exceeded, will require further investigation, including laboratory sample analyses, to identify the source of the illicit discharge. The pollutant parameter action levels and rationale for using the action levels must be documented in an enforcement response plan or similar document, and reported to the Department by November 1, 2011.

iv. Conduct annual dry-weather inspection activities during the term of the permit. By July 1, 2012, the dry-weather inspection activities must include annual field screening of identified priority locations documented by the co-permittee. Priority locations must, where possible, be located at an accessible location downstream of any source of suspected illegal or illicit activity or other location as identified by the co-permittee. Priority locations must be based on an equitable consideration of hydrological conditions, total drainage area of the location, population density of the location, traffic density, age of the structures or buildings in the area, history of the area, land use types, personnel safety, accessibility, historical complaints or other appropriate factors as identified by the co-permittee. The dry-weather field screening activities must occur after an antecedent dry period of at least 72-hours. The dry-weather field screening activities must be documented and include:

1. General observations, including visual presence of flow, turbidity, oil sheen, trash, debris or scum, condition of conveyance system or outfall, color, odor and any other relevant observations related to the potential presence of non-storm water or illicit discharges.

2. Field Screening - If flow is observed, and the source is unknown, a field analysis must be conducted to determine the cause of the dry-weather flow. The field analysis must include sampling for pollutant parameters that are likely to be found based upon the suspected source of discharge or by other effective investigatory approaches or means to identify the source or cause of the suspected illicit discharge. Where appropriate, field screening pollutant parameter action levels identified by the permittee must be considered. Suspected sources of discharge include, but are not limited to, sanitary cross-connections or leaks, spills, seepage from storage containers, non-stormwater discharges or other residential, commercial, industrial or transportation-related activities.

3. Laboratory Analysis – If general observations and field screening indicate an illicit discharge and the presence of a suspected illicit discharge cannot be identified through other investigatory methods, the co-permittee must collect a water quality sample for laboratory analyses for ongoing discharges. The water quality sample must be analyzed for pollutant parameters or identifiers that will aid in the determination of the source of the illicit discharge. The types of pollutant parameters or identifiers may include, but are not limited to genetic markers, industry-specific toxic pollutants, or other pollutant parameters that may be specifically associated with a source type.

v. Identify response procedures to investigate portions of the MS4 that, based on the results of general observations, field screening, laboratory analysis or other relevant information, such as a complaint or referral, indicates the likely presence of an illicit discharge. The response procedures must reflect the goal to eliminate the illicit discharge in an expeditious manner, as specified in subsection vii. below.

vi. Maintain a system for documenting illicit discharge complaints or referrals, and suspected illicit discharge investigation activities.

vii. Once the source of an illicit discharge is determined, the co-permittee must take appropriate action to eliminate the illicit discharges, including an initial evaluation of the feasibility to eliminate the discharge, within 5 working days. If the co-permittee determines that the elimination of the illicit discharge will take more than 15 working days due to technical, logistical or other reasonable issues, the co-permittee must develop and implement an action plan to eliminate the illicit discharge in an expeditious manner. The action plan must be completed in 20 working days of determining the source of an illicit discharge. In lieu of developing and implementing an individual action plan for common types of illicit discharges, the co-permittee may document and implement response procedures, a response plan or similar document. The action plan, response procedures, response plan or similar document must include a timeframe for elimination of the illicit discharge as soon as practicable.

viii. Describe and implement procedures to prevent, contain, respond to and mitigate spills that may discharge into the MS4. Spills, or other similar illicit discharges, that may endanger human health or the environment must be reported in accordance with all applicable federal and state laws, including proper notification to the Oregon Emergency Response System.

ix. In the case of a known illicit discharge that originates within the co-permittee's MS4 regulated area and that discharges directly to a storm sewer system or property under the jurisdiction of another municipality, the co-permittee must notify the affected municipality as soon as practicable, and at least within one working day of becoming aware of the discharge.

x. In the case of a known illicit discharge that is identified within the co-permittee's MS4 regulated area, but is determined to originate from a contributing storm sewer system or property under the jurisdiction of another municipality, the co-permittee must notify the contributing municipality or municipality with jurisdiction as soon as practicable, and at least within one working day of identifying the illicit discharge.

xi. Maintain maps identifying known co-permittee-owned MS4 outfalls discharging to waters of the State. The dry-weather screening priority locations must be specifically identified on maps by July 1, 2012. If the co-permittee identifies the need to modify these maps, the maps must be updated in digital or hard-copy within six months of identification.

xii. Unless the following non-stormwater discharges are identified in a particular case as a significant source of pollutants to waters of the State by the permittee or the Department, they are not considered illicit discharges and are authorized by this permit: water line flushing; landscape irrigation; diverted stream flows; rising ground waters; uncontaminated groundwater infiltration; uncontaminated pumped ground water; discharges from potable water sources; start up flushing of groundwater wells; potable groundwater monitoring wells; draining and flushing of municipal potable water storage reservoirs; foundation drains; air conditioning condensate; irrigation water; springs; water from crawl space pumps; footing drains; lawn watering; individual residential car washing; charity car washing; flows from riparian habitats and wetlands; dechlorinated swimming pool discharges; street wash waters; discharges of treated water from investigation, removal and remedial actions selected or approved by the Department pursuant to Oregon Revised Statute (ORS) Chapter 465; and, discharges or flows from emergency fire fighting activities. If any of these non-stormwater discharges under the co-permittee's jurisdiction is a significant source of pollutants, the permittee must develop and require implementation of appropriate BMPs to reduce the discharge of pollutants associated with the source.

b. **Industrial and Commercial Facilities:** The co-permittee must continue to implement a program to reduce pollutants in stormwater discharges to the MS4 from facilities the co-permittee identified as being subject to a Department-issued industrial stormwater NPDES permit, hazardous waste treatment, disposal and recovery facilities, industrial facilities that are subject to section 313 of title III of the Superfund Amendments and Reauthorization Act of 1986, or facilities that have been identified as contributing a significant pollutant load to the MS4. The co-permittee must:

   i. Screen existing and new industrial facilities to assess whether they have the potential to be subject to an industrial stormwater NPDES permit or have the potential to contribute a significant pollutant load to the MS4.

   ii. Within 30 days after the facility is identified, notify the industrial facility and the Department that an industrial facility is potentially subject to an industrial stormwater NPDES permit.

   iii. Implement an updated strategy to reduce pollutants in stormwater discharges to the MS4 from industrial and commercial facilities where site-specific information has identified a discharge as a source that contributes a significant pollutant load to the MS4. The strategy must include a description of the rationale for identifying commercial and industrial facilities as a significant contributor, and establish the priorities and procedures for inspection of and implementation of stormwater control measures. This strategy must be implemented by January 1, 2013, and applied within one calendar year from the date a new source contributing a significant pollutant load to the MS4 has been identified.

c. **Construction Site Runoff Control:** Co-permittees must continue to implement a program to reduce pollutants in stormwater runoff to the MS4 from construction activities. The program must:

   i. Include ordinances or other enforceable regulatory mechanisms that require erosion prevention and sediment controls to be designed, implemented, and maintained to prevent adverse impacts to water quality and minimize the transport of construction-related contaminants to waters of the State. The construction site runoff control program ordinances or other enforceable regulatory mechanism must apply to construction activities that result in a land disturbance of 500 square feet or greater.

   ii. Require construction site operators to develop erosion prevention and sediment control site plans, and to implement and to maintain effective erosion prevention and sediment control best management practices.

   iii. Require construction site operators to prevent or control non-stormwater waste that may cause adverse impacts to water quality, such as discarded building materials, concrete truck washout, chemicals, litter, and sanitary waste.

   iv. Describe site plan review procedures to ensure that stormwater BMPs are appropriate and address the construction activities being proposed. At a minimum, construction site erosion prevention and sediment control plans for sites disturbing one acre or greater must be consistent with the substantive requirements of the State of Oregon's 1200-C permit site erosion prevention and sediment control plans.

v. Co-permittees must perform on-site inspections in accordance with documented procedures and criteria to ensure that the approved erosion prevention and sediment control plan is properly implemented. Inspections of construction sites must include disturbed areas of the site, material and waste storage areas, stockpile areas, construction site entrances and exits, sensitive areas, discharge locations to the MS4, and, if appropriate, discharge locations to receiving waters. Inspections must be documented, including photographs and monitoring results as appropriate.

vi. Describe in an enforcement response plan or similar document the enforcement response procedures the co-permittee will implement. The enforcement response procedures must ensure construction activities are in compliance with the ordinances or other regulatory mechanisms.

d. **Education and Outreach:** Co-permittees must implement an education and outreach program designed to achieve measurable goals based on target audiences, specific stormwater quality issues in the community, or identified pollutants of concern. The program must:

i. Continue to implement a documented public education and outreach strategy that promotes pollutant source control and a reduction of pollutants in stormwater discharges. The strategy must identify targeted pollutants of concern, the targeted audience, specific education activities, and the entity or individual responsible for implementation. The public education and outreach strategy may incorporate cooperative efforts with other MS4 regulated permittees or efforts by other groups or organizations provided a mechanism is developed and implemented to track the public education and outreach efforts within the MS4 regulated area and the results of such efforts are reported annually.

ii. Provide educational materials to the community or conduct equivalent outreach activities describing the impacts of stormwater discharges on water bodies and the steps or actions the public can take to reduce pollutants in stormwater runoff.

iii. Provide public education on the proper use and disposal of pesticides, herbicides, fertilizers and other household chemicals.

iv. Provide public education on the proper operation and maintenance of privately-owned or operated stormwater quality management facilities.

v. Provide notice to construction site operators concerning where education and training to meet erosion prevention and sediment control requirements can be obtained.

vi. Conduct or participate in an effectiveness evaluation to measure the success of public education activities during the term of this permit. The effectiveness evaluation must focus on assessing changes in targeted behaviors. The results of the effectiveness evaluation must be used in the adaptive management of the education and outreach program, and reported to the Department no later than November 1, 2014.

vii. Include training for co-permittee employees involved in MS4-related activities, as appropriate. The training should include stormwater pollution prevention and reduction from municipal operations, including, but not limited to, parks and open space maintenance, fleet and building maintenance, new municipal facility construction and related land disturbances, design and construction of street and storm drain systems, discharges from non-emergency fire fighting-related training activities, and stormwater system maintenance.

viii. Promote, publicize and facilitate public reporting of illicit discharges through the use of newspapers, newsletters, utility bills, door hangers, radio public service announcements, videos, televised council meetings, brochures, signs, posters or other effective methods.

e. **Public Involvement and Participation:** Co-permittees must implement a public participation approach that provides opportunities for the public to effectively participate in the development, implementation and modification of the co-permittee's stormwater management program. The approach must include provisions for receiving and considering public comments on the monitoring plan due to the Department June 1, 2011, annual reports, SWMP revisions, and the TMDL pollutant load reduction benchmark development.

f. **Post-Construction Site Runoff:** Co-permittees must continue to implement their post-construction stormwater pollutant and runoff control program.

i. By January 1, 2014, the post-construction stormwater pollutant and runoff control program applicable to new development and redevelopment projects that create or replace 500 ft^2 of impervious surface must meet the following conditions:

1) Incorporate site-specific management practices that target natural surface or predevelopment hydrologic functions as much as practicable. The site-specific management practices should optimize on-site retention based on the site conditions;

2) Reduce site specific post-development stormwater runoff volume, duration and rates of discharges to the municipal separate storm sewer system (MS4) to minimize hydrological and water quality impacts from impervious surfaces;

3) Prioritize and include implementation of Low-Impact Development (LID), Green Infrastructure (GI) or equivalent design and construction approaches; and,

4) Capture and treat 80% of the annual average runoff volume, based on a documented local or regional rainfall frequency and intensity.

ii. The co-permittee must identify, and where practicable, minimize or eliminate ordinance, code and development standard barriers within their legal authority that inhibit design and implementation techniques intended to minimize impervious surfaces and reduce stormwater runoff (e.g., Low Impact Development, Green Infrastructure). Such modifications to ordinance, code and development standards are only required to the extent they are permitted under federal and state laws. The co-permittee must review ordinance, code and development standards for modification, minimization or elimination, and appropriately modify ordinance, code or development standard barriers by January 1, 2014. If an ordinance, code or development standard barrier is identified at any time subsequent to January 1, 2014, the applicable ordinance, code or development standard must be modified within three years.

iii. To reduce pollutants and mitigate the volume, duration, time of concentration and rate of stormwater runoff, the co-permittee must develop or reference an enforceable post-construction stormwater quality management manual or equivalent document by January 1, 2014 that, at a minimum, includes the following:

1) A minimum threshold for triggering the requirement for post-construction stormwater management control and the rationale for the threshold.

2) A defined design storm or an acceptable continuous simulation method to address the capture and treatment of 80% of the annual average runoff volume.

3) Applicable LID, GI or similar stormwater runoff reduction approaches, including the practical use of these approaches.

4) Conditions where the implementation of LID, GI or equivalent approaches may be impracticable.

5) BMPs, including a description of the following:
   a. Site-specific design requirements;
   b. Design requirements that do not inhibit maintenance; and,
   c. Conditions where the BMP applies.

6) Pollutant removal efficiency performance goals that maximize the reduction in discharge of pollutants.

iv. The co-permittee must review, approve and verify proper implementation of post-construction site plans for new development and redevelopment projects applicable to this section. The Port of Portland may address this permit requirement by documenting that all internal Port of Portland development projects meet the Post-Construction Site Runoff performance standards required in this subsection.

v. Where a new development or redevelopment project site is characterized by factors limiting use of on-site stormwater management methods to achieve the post-construction site runoff performance standards, such as high water table, shallow bedrock, poorly-drained or low permeable soils, contaminated soils, steep slopes or other constraints, the

Post-Construction Stormwater Management program must require equivalent pollutant reduction measures, such as off-site stormwater quality management. Off-site stormwater quality management may include off-site mitigation, such as using low impact development principles in the construction of a structural stormwater facility within the sub-watershed, a stormwater quality structural facility mitigation bank or a payment-in-lieu program.

vi. A description of the inspection and enforcement response procedures the co-permittee will follow when addressing project compliance issues with the enforceable post-construction stormwater management performance standards.

g. **Pollution Prevention for Municipal Operations:** The co-permittee must continue to implement a program to reduce the discharge of pollutants to the MS4 from properties owned or operated by the co-permittee for which the permittee has authority, including, but not limited to, parks and open spaces, fleet and building maintenance facilities, transportation systems and fire-fighting training facilities. The co-permittee must conduct, at a minimum, the following program activities:

i. Operate and maintain public streets, roads and highways in a manner designed to minimize the discharge of stormwater pollutants to the MS4, including pollutants discharged as a result of deicing activities;

ii. Implement a management program to control and minimize the use and application of pesticides, herbicides and fertilizers on co-permittee-owned properties;

iii. By January 1, 2013, inventory, assess, and implement a strategy to reduce the impact of stormwater runoff from municipal facilities that treat, store or transport municipal waste, such as yard waste or other municipal waste and are not already covered under a 1200 series NPDES, a DEQ solid waste, or other permit designed to reduce the discharge of pollutants;

iv. Limit infiltration of seepage from the municipal sanitary sewer system to the MS4;

v. Implement a strategy to prevent or control the release of materials related to fire-fighting training activities; and,

vi. Assess co-permittee flood control projects to identify potential impacts on the water quality of receiving water bodies and determine the feasibility of retrofitting structural flood control devices for additional stormwater pollutant removal. The results of this assessment must be incorporated and considered along with the results of the Stormwater Retrofit Assessment required by this permit.

h. **Stormwater Management Facilities Operation and Maintenance Activities:**

i. By January 1, 2013, the co-permittee must inventory and map stormwater management facilities and controls, and implement a program to verify that stormwater management facilities and controls are inspected, operated and maintained for effective pollutant removal, infiltration and flow control. At a minimum, the program must include the following:

1. Legal authority to inspect and require effective operation and maintenance;

2. A strategy to inventory and map public and private stormwater management facilities as provided under Schedule A.4.h.ii.; and,

3. Public and private stormwater facility inspection and maintenance requirements for stormwater management facilities that have been inventoried and mapped as provided under Schedule A.4.h.ii.

ii. As part of the Stormwater Management Facilities Inspection and Maintenance program, the co-permittee must implement a strategy that guides the long-term maintenance and management of all co-permittee-owned and identified privately-owned stormwater structural facilities. At a minimum, the strategy must describe the following:

1. Co-permittee-owned or operated stormwater management facilities
   a. Inventory and mapping process;

   b. Inspection and maintenance schedule;

   c. Inspection, operation and maintenance criteria and priorities;

   d. Description of inspector type and staff position or title; and,

   e. Inspection and maintenance tracking mechanisms.

2. Privately-owned or operated stormwater management facilities
   a. Procedures for and types of stormwater facilities that will be inventoried and mapped. At a minimum, the inventory and mapping must include the following:
      i. Private stormwater management facilities for new development and redevelopment projects constructed under the co-permittee's post-construction management manual or equivalent document after February 1, 2011.;
      ii. Private stormwater management facilities identified by the co-permittee and used to estimate the pollutant load reduction as part of the TMDL benchmark evaluation; and,
      iii. Any major private stormwater management facilities or structural controls.

   b. Inspection criteria, rationale, priorities, frequency and procedures for inspection of private stormwater facilities that have been inventoried and mapped;

   c. Required training or qualifications to inspect private stormwater facilities;

   d. Reporting requirements; and,

e. Inspection and maintenance tracking mechanism.

5. **Hydromodification Assessment:** The co-permittee must conduct an initial hydromodification assessment and submit a report by November 1, 2014 that examines the hydromodification impacts related to the co-permittee's MS4 discharges, including erosion, sedimentation, and alteration to stormwater flow, volume and duration that may cause or contribute to water quality degradation. The report shall describe existing efforts and proposed actions the co-permittee has identified to address the following objectives:

   a. Collect and maintain information that will inform future stormwater management decisions related to hydromodification based on local conditions and needs;

   b. Identify or develop strategies to address hydromodification information or data gaps related to waterbodies within the co-permittee's jurisdiction;

   c. Identify strategies and priorities for preventing or reducing hydromodification impacts related to the co-permittee's MS4 discharges; and,

   d. Identify or develop effective tools to reduce hydromodification.

6. **Stormwater Retrofit Strategy Development:** The co-permittee must develop a stormwater quality retrofit strategy identified in a plan that applies to developed areas identified by the co-permittee as impacting water quality and that are underserved or lacking stormwater quality controls.

   a. The stormwater retrofit strategy must be based on a co-permittee-defined set of stormwater quality retrofit objectives and a comprehensive evaluation of a range of stormwater quality retrofit control measures and their appropriate use. The co-permittee-defined objectives must incorporate progress towards applicable TMDL wasteload allocations. Development of the stormwater retrofit strategy must allow for public comment and consider public input.

   b. The co-permittee must develop and submit a stormwater retrofit plan to the Department by November 1, 2014 that the co-permittee will use to guide the implementation of its stormwater retrofit strategy. The stormwater retrofit plan must describe or reference the following:

      i. Stormwater retrofit strategy statement and summary, including objectives and rationale;

      ii. Summary of current stormwater retrofit control measures being implemented, and current estimate of annual program resources directed towards stormwater retrofits;

      iii. Identification of developed areas or land uses impacting water quality that are high priority retrofit areas;

      iv. Consideration of new stormwater control measures;

v. Preferred retrofit structural control measures, including rationale;

vi. A retrofit control measure project or approach priority list, including rationale, identification and map of potential stormwater retrofit locations where appropriate, and an estimated timeline and cost for implementation of each project or approach.

c. By November 1, 2013, each co-permittee must identify one stormwater quality improvement project, at a minimum, to be initiated, constructed or implemented during the permit term. The project must target the reduction of applicable TMDL pollutant parameters. The project must be associated with a Capital Improvement Project or other municipal retrofit project or strategy.

7. **Implementation Schedule:** The following implementation schedule provides a summary of due dates for the new permit conditions identified in Schedule A.

PERMIT CONDITION	SUMMARY OF IMPLEMENTATION SCHEDULE ACTIVITIES	DUE DATE
Illicit Discharge Detection and Elimination – A.4.a.	1. Document enforcement response procedures	November 1, 2011
	2. Develop or identify pollutant parameter action levels	November 1, 2011
	3. Identify and map dry-weather screening priority locations	July 1, 2012
Industrial and Commercial Facilities – A.4.b	1. Implement industrial and commercial facility inspection and stormwater control program	January 1, 2013
Education and Outreach – A.4.d.	1. Conduct or participate in effectiveness evaluation	November 1, 2014
Post-Construction Site Runoff – A.4.f.	1. Implement updated post-construction site runoff program	January 1, 2014
Pollution Prevention for Municipal Operations – A.4.g.	1. Inventory and assess municipal operations	January 1, 2013
Structural Stormwater Controls Operation and Maintenance Activities – A.4.h.	1. Implement structural stormwater controls operation and maintenance program	January 1, 2013
Hydromodification Assessment – A.5.	1. Conduct hydromodification assessment and submit report	November 1, 2014
Stormwater Retrofit Strategy Development – A.6.	1. Develop stormwater retrofit strategy and submit stormwater retrofit plan	November 1, 2014
	2. Identify stormwater quality improvement project	November 1, 2013
	3. Construct or implement stormwater quality improvement project	Permit expiration date

SCHEDULE B
Monitoring and Reporting Requirements

1. MONITORING PROGRAM - Each co-permittee must continue to implement a monitoring program to support adaptive stormwater management and the evaluation of stormwater management program effectiveness in reducing the discharge of pollutants from the MS4.

   a. The monitoring program must incorporate the following objectives:

      i. Evaluate the source(s) of the 2004/2006 303(d) listed pollutants applicable to the co-permittee's permit area;

      ii. Evaluate the effectiveness of Best Management Practices (BMPs) in order to help determine BMP implementation priorities;

      iii. Characterize stormwater based on land use type, seasonality, geography or other catchment characteristics;

      iv. Evaluate status and long-term trends in receiving waters associated with MS4 stormwater discharges;

      v. Assess the chemical, biological, and physical effects of MS4 stormwater discharges on receiving waters; and,

      vi. Assess progress towards meeting TMDL pollutant load reduction benchmarks.

   b. The monitoring program must include environmental monitoring that incorporates the requirements identified in Table B-1. The requirements in Table B-1 become effective with the approval of the monitoring plan in accordance with Schedule B.2.d., and no later than July 1, 2011.

Table B-1 Environmental Monitoring			
Monitoring Type	**Monitoring Location(s)**	**Monitoring Frequency**	**Pollutant Parameter Analyte(s)**
Instream Monitoring	Sixteen (16) sites; probabilistically selected; city-wide	Four (4) events/year	Field; Conventional; Metals; Nutrients
Continuous Instream Monitoring	Three (3) continuous monitoring stations	Ongoing	Temperature Flow
Stormwater Monitoring	Fifteen (15) sites; probabilistically selected; city-wide	Three (3) events/year	Field; Conventional; Metals; Nutrients
Stormwater Monitoring - Pesticide	Fifteen (15) sites; probabilistically selected; city-wide	Three (3) events/permit term	Pesticides
Stormwater Monitoring – Mercury	Two (2) sites	Two (2) events/year; one summer event and one winter event	Mercury
Macro-invertebrate Monitoring	Sixteen (16) sites; probabilistically selected; city-wide	One (1) event/year	N/A

Special Conditions:

1) The monitoring frequency reflects the required number of sample events per monitoring location.
2) Additional pesticide pollutant parameters that must be considered for purposes of stormwater monitoring – pesticide include any pesticides currently used by the co-permittees within their jurisdictional areas and the following: Insecticides: Bifenthrin, Cypermethrin or Permethrin, Imidacloprid, Fipronil, Malathion, Carbaryl; Herbicides: Triclopyr, 2,4-D, Glyphosate & degradate (AMPA), Trifluaralin, Pendimethalin; and, Fungicides: Chlorothalonil, Propiconazole, Myclobutanil.
3) The Macroinvertebrate monitoring must follow a generally accepted macroinvertebrate monitoring methodology (e.g., DEQ Benthic Macroinvertebrate Protocol for Wadeable Rivers and Streams). The methodology must be documented in the monitoring plan.
4) BOD_5 are only required to be monitored in streams with an established TMDL.
5) Monitoring and analysis for mercury and methyl mercury must be conducted in accordance with DEQ's December 23, 2010 "Mercury Monitoring Requirements for Willamette Basin Permittees" memo. After two years of monitoring, the co-permittee may request in writing to the Department that the mercury and methyl mercury monitoring be eliminated. The monitoring may be eliminated only after written approval by the Department. EPA Method 1669 ultra clean sampling protocol must be used to collect samples. Monitoring for total and dissolved mercury must be performed according to USEPA method 1631E with a quantitation limit of 0.5 ng/L. Monitoring for total and dissolved methyl mercury must be performed according to USEPA method 1630 with a quantitation limit of 0.05 ng/L.

Pollutant parameter(s) identified in each analyte category in Table B-1 are as follows:

Field	Conventional	Nutrients	Metals (Total Recoverable & Dissolved)
Dissolved Oxygen pH Temperature Conductivity	*Escherichia coli* (E. coli) Hardness Total Organic Carbon (TOC) Total Suspended Solids (TSS)	Nitrate (NO_3) Ammonia Nitrogen (NH_3-N) Total Phosphorus (TP) Ortho-Phosphorus (O-PO_4)	Copper Lead Zinc
		Mercury (Total & Dissolved)	Pesticides
		Mercury Methyl Mercury	2,4-D Pentachlorophenol

2. MONITORING PLAN - The co-permittee must develop and implement an approved monitoring plan by July 1, 2011. Prior to submission of the monitoring plan to the Department, the co-permittee must provide an opportunity to receive comments from the public. The monitoring plan must be submitted to the Department for review no later than June 1, 2011, and incorporate the following elements:

   a. Identifies how each monitoring objective identified in Schedule B.1.a. is addressed and the sources of information used. The co-permittee may use Stormwater Management Plan measurable goals, environmental monitoring activities, historical monitoring data, stormwater modeling, national stormwater monitoring data, stormwater research or other applicable information to address the monitoring objectives.

   b. Describes the role of the monitoring program in the adaptive management of the stormwater program.

   c. Describes the relationship between environmental monitoring and a long-term monitoring program strategy.

   d. Describes the following information for each environmental monitoring project/task:

      i. Project/task organization

      ii. Monitoring objectives, including:
         a. Monitoring question and background;
         b. Data analysis methodology and quality criteria; and,
         c. Assumptions and rationale;

      iii. Documentation and record-keeping procedures;

      iv. Monitoring process/study design, including monitoring location, description of sampling event or storm selection criteria, monitoring frequency and duration, and responsible sampling coordinator;

      v. Sample collection methods and handling/custody procedures;

      vi. Analytical methods for each water quality parameter to be analyzed;

      vii. Quality control procedures, including quality assurance, the testing, inspection, maintenance, calibration of instrumentation and equipment; and,

      viii. Data management, review, validation and verification.

   e. The monitoring plan may be modified without prior Department approval if the following conditions are met. For conditions not covered in this section, the co-permittee must provide the Department with a 30-day notice of the proposed modification to the monitoring plan, and receive written approval from the Department prior to implementation of the proposed modification. If the Department does not respond to the permittee within 30 days, the permittee may proceed with implementation of the proposed modification without written approval.

i. The co-permittee is unable to collect or analyze any sample, pollutant parameter, or information due to circumstances beyond the co-permittee's control. These circumstances may include, but are not limited to, abnormal climatic conditions, unsafe or impracticable sampling conditions, equipment vandalism or equipment failures that occur despite proper operations and maintenance; or,

ii. The modification does not reduce the minimum number of data points, which are a product of monitoring location, frequency, and length of permit term, or eliminate pollutant parameters identified in Table B-1.

f. Modifications to the monitoring plan in accordance with Schedule B.2.e. must be documented in the subsequent annual report by describing the rationale for the modification, and how the modification will allow the monitoring program to remain compliant with the permit conditions.

3. SAMPLING AND ANALYSIS – The co-permittee must exercise due diligence in collecting and analyzing all environmental monitoring samples required by this permit. All monitoring must be conducted in accordance with design and procedures identified in Schedule B.2.d.

a. In-stream monitoring
   i. A minimum of 50 percent of the water quality sample events must be collected during the wet season (October 1 to April 30).

   ii. Each unique sample event must occur at a minimum of 14 days apart.

b. Stormwater monitoring
   i. All water quality samples must be collected during a storm event that is greater than 0.1 inch of rainfall.

   ii. When possible, samples must be collected after an antecedent dry period of a minimum of 24 hours.

   iii. The intra-event dry period must not exceed 6 hours, unless a 24-hr flow-weighted composite sample collection method is employed.

   iv. Sample Collection Method: A flow-weighted composite sample must be collected during stormwater runoff producing events that represent the local or regional rainfall frequency and intensity, including event types that may be expected to yield high pollutant loads/concentrations.

      1. A time-composite sampling method or grab sampling method may be used for an environmental monitoring type, project or task, if the monitoring plan

identifies the infeasibility of the flow-weighted composite sampling method or flow-weighted composite sampling is scientifically unwarranted based upon the development of plan requirements identified in Schedule B.2.d. For time composite sampling or grab sampling to be considered valid for the purpose of this permit requirement, the rationale for the use of these alternative sampling methods and sampling procedures must be described in the monitoring plan.

2. The flow-weighted sampling method requirement is not applicable to the collection of samples for the pollutant parameters requiring the grab sampling method, such as bacteria, oil & grease, pH or volatiles or for samples collected for purposes of insecticide, herbicide and fungicide monitoring.

3. Grab samples may be collected during any part of a storm event which produces sufficient runoff for sampling. The grab samples must be collected in a manner to minimize any potential bias in the results.

v. Flow or rainfall data must be collected, estimated or modeled for each stormwater monitoring event. If flow or rainfall is modeled or estimated, the procedure must be described in the monitoring plan.

c. Samples must be analyzed in accordance with EPA approved methods listed in the most recent publication of 40 CFR 136. Sample analysis for total and dissolved mercury and methyl mercury must adhere to the methods referenced in DEQ's December 23, 2010 "Mercury Monitoring Requirements for Willamette Basin Permittees" memo. The analysis must utilize appropriate Quality Assurance/Quality Control protocols, such as routinely analyzing replicates, blanks, laboratory control samples and spiked samples, and quantitation limits appropriate for the sampling objective. Field analytical kits are acceptable if the kits use a method approved under 40 CFR 136. This requirement does not apply to illicit detection and discharge elimination field screening activities conducted by the co-permittee as required by Schedule A.4.a.iv. Use of alternative test procedures must be done in accordance with 40 CFR 136.

d. If an approved analytical method is not identified in 40 CFR 136, the co-permittee may use a suitable analytical method if the method is described in the monitoring plan, and submitted to the Department for review and approval prior to use.

e. Analyzed samples must comply with preservation, transportation and holding time recommendations cited in 40 CFR 136, in the most recent edition of Standard Methods for the Examination of Water and Wastewater, a DEQ management directive, or as applicable to the analytical method if no approved analytical method in 40 CFR 136 or the most recent edition of Standard Methods for the Examination of Water and Wastewater exists.

f. Analytical data must be available to the Department in a useable electronic format.

4. COORDINATED MONITORING – Environmental monitoring conducted to meet a permit condition in Table B-1 may be coordinated among co-permittees or conducted on behalf of a co-

permittee by a third party. Each co-permittee is responsible for environmental monitoring in accordance with Schedule B requirements. The co-permittee may utilize data collected by another permittee, a third party, or in another co-permittee's jurisdiction to meet a permit condition in Table B-1 provided the co-permittee establishes an agreement prior to conducting coordinated environmental monitoring.

5. ANNUAL REPORTING REQUIREMENT – The co-permittee must submit, by November 1 of each year, an annual report for the time period July 1 of the previous year through June 30 of the same year. One printed copy and an electronic copy must be submitted to the appropriate Department regional office. An electronic copy must also be made available on the co-permittee's website and/or other similar method approved by the Department. Each co-permittee is responsible for the portion of the annual report applicable to its jurisdiction. Each annual report must contain:

   a. The status of implementing the stormwater management program and each SWMP program element, including progress in meeting the measurable goals identified in the SWMP.

   b. Status or results, or both, of any public education program effectiveness evaluation conducted during the reporting year and a summary of how the results were or will be used for adaptive management.

   c. A summary of the adaptive management process implementation during the reporting year, including any proposed changes to the stormwater management program (e.g., new BMPs) identified through implementation of the adaptive management process.

   d. Any proposed changes to SWMP program elements that are designed to reduce TMDL pollutants to the MEP.

   e. A summary of total stormwater program expenditures and funding sources over the reporting fiscal year, and those anticipated in the next fiscal year.

   f. A summary of monitoring program results, including monitoring data that are accumulated throughout the reporting year and any assessments or evaluations conducted.

   g. Any proposed modifications to the monitoring plan that are necessary to ensure that adequate data and information are collected to conduct stormwater program assessments.

   h. A summary describing the number and nature of enforcement actions, inspections, and public education programs, including results of ongoing field screening and follow-up activities related to illicit discharges.

   i. An overview, as related to MS4 discharges, of concept planning, land use changes and new development activities that occurred within the Urban Growth Boundary (UGB) expansion areas during the previous year, and those forecast for the following year, including the number of new post-construction permits issued, and an estimate of the total new and replaced impervious surface area related to new development redevelopment projects that commenced during the reporting year.

j. In addition to the elements listed under Schedule B.5.a. through B.5.i., the annual report submitted by November 1, 2014 must include:
   i. The TMDL Pollutant Load Reduction Evaluation as described in Schedule D.3.c.
   ii. The Wasteload Allocation Attainment Assessment as described in Schedule D.3.b.
   iii. The 303(d) evaluation as described in Schedule D.2.

6. MS4 PERMIT RENEWAL APPLICATION PACKAGE - At least 180 days prior to permit expiration, the co-permittee must submit a permit renewal application package to support their proposed modifications to the SWMP for the renewed permit. One printed copy and an electronic copy must be submitted to the appropriate DEQ regional office. An electronic copy must also be made available on the co-permittee's website or other similar method approved by the Department. The application package must include an evaluation of the adequacy of the proposed SWMP modifications in reducing pollutants in discharges from the MS4 to the MEP. The application package must contain:

   a. Proposed program modifications including the modification, addition or removal of BMPs incorporated into the SWMP, and associated measurable goals.

   b. The information and analysis necessary to support the Department's independent assessment that the co-permittee's stormwater management program addressed the requirements of the existing permit. Co-permittees must also describe how the proposed management practices, control techniques, and other provisions implemented as part of the stormwater program were evaluated using a co-permittee-defined and standardized set of objective criteria relative to the following MEP general evaluation factors:

      i. Effectiveness – program elements effectively address stormwater pollutants.
      ii. Local Applicability – program elements are technically feasible considering local soils, geography, and other locale specific factors.
      iii. Program Resources – program elements are implemented considering availability to resources and the co-permittees stormwater management program priorities.

   c. An updated estimate of total annual stormwater pollutant loads for applicable TMDL pollutants or applicable surrogate parameters, and the following pollutant parameters: BOD_5, COD, nitrate, total phosphorus, dissolved phosphorus, cadmium, copper, lead and zinc. The estimates must be accompanied by a description of the procedures for estimating pollutant loads and concentrations, including any modeling, data analysis and calculation methods.

   d. A proposed monitoring program objectives matrix and proposed monitoring plan including the information required in Schedule B.2.d. for each proposed monitoring project/task.

   e. A description of any service area expansions that are anticipated to occur during the following permit term and a finding as to whether or not the expansion is expected to result in a substantial increase in area, intensity or pollutant loads.

f. A fiscal evaluation summarizing program expenditures for the current permit cycle and projected program allocations for next permit cycle.

g. Updated MS4 maps, including the service boundary of the MS4, projected changes in land use and population densities, projected future growth, location of co-permittee-owned operations, facilities, or properties with storm sewer systems, and the location of facilities issued an industrial NPDES permit that discharge to the MS4.

h. If applicable, the established TMDL pollutant load reduction benchmarks, as required in Schedule D.3.d.

SCHEDULE C
Compliance Conditions and Dates

Compliance conditions and dates are not included at this time.

SCHEDULE D
Special Conditions

1. **Legal Authority**
   Each co-permittee must maintain adequate legal authority through ordinance(s), interagency agreement(s) or other means to implement and enforce the provisions of this permit.

2. **303(d) Listed Pollutants**
   a. The requirements of this section apply to receiving waters listed as impaired on the 303(d) list without established TMDL waste load allocations to which the co-permittee's MS4 discharges. The co-permittee must:
      i. Review the applicable pollutants that are on the 2004/2006 303(d) list, or the most recent USEPA list if approved within three years of the issuance date of this permit, that are relevant to the co-permittee's MS4 discharges by November 1, 2014. Based on a review of the most current 303(d) list, evaluate whether there is a reasonable likelihood for stormwater from the MS4 to cause or contribute to water quality degradation of receiving waters.
      ii. Evaluate whether the BMPs in the existing SWMP are effective in reducing the 303(d) pollutants. If the co-permittee determines that the BMPs in the existing SWMP are ineffective in reducing the applicable 303 (d) pollutants, the co-permittee must describe how the SWMP will be modified or updated to address and reduce these pollutants to the MEP.
      iii. By November 1, 2014, submit a report summarizing the results of the review and evaluation, and that identifies any proposed modifications or updates to the SWMP that are necessary to reduce applicable 303(d) pollutants to the MEP.

3. **Total Maximum Daily Loads (TMDLs)**
   a. Applicability: The requirements of this section apply to the co-permittee's MS4 discharges to receiving waters with established TMDLs or to receiving waters with new or modified TMDLs approved by EPA within three years of the issuance date of this permit. Established TMDLs are noted on page 1 of this permit. Pollutant discharges for those parameters listed in the TMDL with applicable wasteload allocations (WLAs) must be reduced to the maximum extent practicable through the implementation of BMPs and an adaptive management process.

   b. Wasteload Allocation Attainment Assessment: The co-permittee must complete an assessment of WLA attainment, including identifying information related to the type and extent of BMPs necessary to achieve pollutant load reductions associated with an established TMDL WLA and the financial costs and other resources that may be associated with the implementation, operation and maintenance of BMPs. The results of the assessment must be submitted to the Department by November 1, 2014.

c. TMDL Pollutant Load Reduction Evaluation: Progress towards reducing TMDL pollutant loads must be evaluated by the co-permittee through the use of a pollutant load reduction empirical model, water quality status and trend analysis, and other appropriate qualitative or quantitative evaluation approaches identified by the co-permittee. The results of this TMDL pollutant load reduction evaluation must be described in a report and submitted to the Department by November 1, 2014. The report must contain the following:

    i. The rationale and methodology used to evaluate progress towards reducing TMDL pollutant loads.
    ii. An estimate of current pollutant loadings without considering BMP implementation, and an estimate of current pollutant loadings considering BMP implementation for each TMDL parameter with an established WLA. The difference between these two estimated loads is the pollutant load reduction.
    iii. A comparison of the estimated pollutant loading with and without BMP implementation to the applicable TMDL WLA.
    iv. A comparison of the estimated pollutant load reduction to the estimated TMDL pollutant load reduction benchmark established for the permit term, if applicable.
    v. A description of the estimated effectiveness of structural BMPs.
    vi. A description of the estimated effectiveness of non-structural BMPs, if applicable, and the rationale for the selected approach.
    vii. A water quality trend analysis, as sufficient data are available, and the relationship to stormwater discharges for receiving waterbodies within the co-permittee's jurisdictional area with an approved TMDL. If sufficient data to conduct a water quality trend analysis is unavailable for a receiving waterbody, the co-permittee must describe the data limitations. The collection of sufficient data must be prioritized and reflected as part of the monitoring project/task proposal required in Schedule B.6.d.
    viii. A narrative summarizing progress towards the applicable TMDL WLAs and existing TMDL benchmarks, if applicable. If the co-permittee estimates that an existing TMDL benchmark was not achieved during the permit term, the co-permittee must apply their adaptive management process to reassess the SWMP and current BMP implementation in order to address TMDL pollutant load reduction over the next permit term. The results of this reassessment must be submitted with the permit renewal application package described in Schedule B.6.; and,
    ix. If the co-permittee estimates that TMDL WLAs are achieved with existing BMP implementation, the co-permittee must provide a statement supporting this conclusion.

d. Establishment of TMDL Pollutant Reduction Benchmarks: A TMDL pollutant reduction benchmark must be developed for each applicable TMDL parameter where existing BMP implementation is not achieving the WLA. An updated TMDL pollutant reduction benchmark must be submitted with the permit renewal application at least 180 days prior to expiration of this permit, as follows:

    i. The TMDL pollutant load reduction benchmark must reflect:
        1. Additional pollutant load reduction necessary to achieve the benchmark estimated for

the current permit term, if not achieved per Schedule D.3.c.iv.; and,
2. The pollutant load reduction proposed to achieve additional progress towards the TMDL WLA during the next permit term.

ii. The TMDL pollutant load reduction benchmark submittal must include the following:
1. An explanation of the relationship between the TMDL wasteload allocations and the TMDL benchmark for each applicable TMDL parameter;
2. A description of how SWMP implementation contributes to the overall reduction of the TMDL pollutants during the next permit term;
3. Identification of additional or modified BMPs that will result in further reductions in the discharge of the applicable TMDL pollutants, including the rationale for proposing the BMPs; and,
4. An estimate of current pollutant loadings that reflect the implementation of the current BMPs and the BMPs proposed to be implemented during the next permit term.

4. Adaptive Management

Each co-permittee must follow an adaptive management approach to assess annually and modify, as necessary, any or all existing SWMP components and adopt new or revised SWMP components to achieve reductions in stormwater pollutants to the MEP. The adaptive management approach must include routine assessment of the need to further improve water quality and protection of beneficial uses, review of available technologies and practices, review of monitoring data and analyses required in Schedule B, review of measurable goals and tracking measures, and evaluation of resources available to implement the technologies and practices. The co-permittee must submit a description of the process for conducting this adaptive management approach during the permit term by November 1, 2011.

5. SWMP Revisions

The co-permittee may revise their SWMP during the permit term in accordance with the following procedures:

i. Adding BMPs, controls or requirements to the SMWP may be made at any time. The co-permittee must provide notification to the Department prior to implementation, and submit a summary of such revisions to the Department in the subsequent annual report.

ii. Reducing, replacing or eliminating BMP components, controls or requirements from the SWMP require submittal of a written request to the Department at least 60 days prior to the planned reduction, replacement, and/or elimination. The co-permittee's request must provide information that will allow the Department to determine within 60 days if the nature or scope of the SWMP is substantially changed, and include the following:
1. Proposed reduction, replacement or elimination of the BMP(s), control, or requirement and schedule for implementation.
2. An explanation of the need for the replacement, reduction or elimination.
3. An explanation of how the replacement or reduction is expected to better achieve the goals of the stormwater management program or how the elimination is a result of the satisfactory completion of the BMP component, control or requirement.

iii. The co-permittee must not implement a reduction, replacement or elimination of a BMP until approved by the Department. If a request is denied, the Department must send the co-permittee a written response providing a reason for the decision.

iv. Adding, reducing, replacing or eliminating BMPs in the SWMP are considered permit revisions, and such revisions are minor or major permit modifications. Revisions that substantially change the nature and scope of the BMP component, control or requirement will be considered a major permit modification. Revisions requested by the permittee or initiated by the Department will be made in accordance with 40 CFR §§124.5, 122.62, or 122.63, and OAR 340-045-0040 and 0055.

v. Revisions initiated by the Department will be made in writing, set forth the time schedule for the co-permittee to develop the revisions, and offer the co-permittee the opportunity to propose alternatives to meet the objective of the requested revisions.

6. **SWMP Measurable Goals**
The following conditions must be incorporated into the City of Portland SWMP by April 1, 2011:
   a. **BMP PI-1 Task 8**: By January 1, 2012, reconvene the Stormwater Advisory Committee to advise general stormwater management policy and implementation issues or effectively replace with another stormwater-related advisory committee that may be more narrowly focused.
   b. **BMP OM-1 Task 1**: Amend to include the following: Inspect all public stormwater management facilities once annually. This amendment will replace the first bullet point under OM-1measurable goals.
   c. **BMP OM-1 Task 3**: Amend to include the following: Enter all newly constructed public stormwater system components into an inspection and maintenance database within six (6) months of the completion of construction.
   d. **BMP OM-1 Task 6**: Amend to include the following: Complete and implement the materials management section of the Portland Bureau of Transportation (PBOT) training guide by January 1, 2012. Complete and implement the remainder of the PBOT training guide by January 1, 2015.
   e. **BMP OM-2 Task 6**: Implement a Street Leaf Removal Program in designated leaf removal districts. Residential streets may be swept between 3-6 times per year in these areas as an alternative to implementing the Leaf Removal Program.
   f. **BMP OM-3 Task 2**: Replace the second sentence to include the following: By January 1, 2013, identify, evaluate, and prioritize stormwater pollution prevention opportunities and improvements (e.g., improved materials storage, use, or transportation) to reduce potential impacts at properties owned or operated by the City of Portland.
   g. **BMP OM-3 Task 4**: Amend to include the following: Annually conduct a minimum of one formal education and outreach activity with each volunteer group that assists with maintaining Pesticide-Free Parks. Pesticide-free parks management must be maintained at a minimum of three (3) parks.
   h. **BMP IND-1 Task 4**: Amend to include the following: Beginning January 1, 2013, annually conduct an industrial facilities inspection "sweep" in at least one targeted area.
   i. **BMP IND-2 Task 6**: Amend to include the following: Conduct a minimum of one targeted

stormwater education and outreach activity with each of the following groups: Portland Community College, Association of Car Washers, International Society of Arborists (ISA local chapter), and Oregon Association of Nurseryman (OAN).

j. **BMP IND-2 Task 7**: Amend to include the following: Evaluate one new business sector for implementation of the Eco-Logical Business Program by January 1, 2013. This amendment will replace the second bullet point under IND-2 measurable goals.

k. **BMP ND-1 Task 7**: Conduct and document erosion control checks during each routine building permit inspection for land disturbing activities at construction sites requiring a City of Portland permit (e.g., grading and clearing, electrical, mechanical, plumbing).

The following conditions must be incorporated into the Port of Portland SWMP by April 1, 2011:

l. **BMP Table 7-2 Implement an Inspection Program for Pollutant Source Areas Task 2**: Ensure implementation of appropriate control measures to minimize pollutant loading from priority facilities in an expeditious manner.

m. **BMP Table 7-7 Limit Landscape Maintenance Activities Impact on Stormwater Task 2**: Annually review the Port's program to control pesticides, herbicides and fertilizers, and update as appropriate.

n. **BMP Table 7-8 Implement a Program for the Tracking and Maintenance of Private Structural Controls Task 1**: Develop an inventory and mechanism for tracking private structural controls on tenant properties by December 31, 2012.

7. Implementation Schedule

The following implementation schedule provides a summary of due dates for the permit conditions identified in Schedule B & Schedule D.

PERMIT CONDITION	SUMMARY OF IMPLEMENTATION SCHEDULE ACTIVITIES	DUE DATE
Monitoring Plan and Environmental Monitoring – B.1.b, B.2 & Table B-1	1. Submit monitoring plan	June 1, 2011
	2. Implement an approved monitoring plan	July 1, 2011
Annual Report – B.5	1. Submit annual report	November 1 - annually
Permit Renewal Application Package – B.6	1. Submit permit renewal package	180 days prior to permit expiration

303(d) List Evaluation – D.2	1. Submit 303(d) list evaluation report	November 1, 2014
Total Maximum Daily Load (TMDL) – D.3	1. Submit Wasteload Allocation Attainment Assessment	November 1, 2014
	2. Submit TMDL Pollutant Load Reduction Evaluation	November 1, 2014
	3. Submit TMDL Pollutant Load Reduction Benchmark	180 days prior to permit expiration
Adaptive Management – D.4	1. Submit Adaptive Management Approach	November 1, 2011
SWMP Measurable Goals – D.6	1. Incorporate SWMP Measurable Goal conditions	April 1, 2011

Definitions:

a. **Adaptive Management:** A structured, iterative process designed to refine and improve stormwater programs over time by evaluating results and adjusting actions on the basis of what has been learned.

b. **Antecedent dry period:** The period of dry time between precipitation events greater than 0.1 inch of precipitation.

c. **Best Management Practices (BMPs):** The schedule of activities, controls, prohibition of practices, maintenance procedures and other management practices designed to prevent or reduce pollution. BMPs also include treatment requirements, operating procedures and practices to control stormwater runoff.

d. **Dry-weather field screening pollutant parameter action levels**: Pollutant concentrations or concentration ranges used by a co-permittee to identify an illicit discharge may be present and further investigation is needed.

e. **Green Infrastructure (GI)**: A comprehensive approach to water quality protection defined by a range of natural and built systems and practices that use or mimic natural hydrologic processes to infiltrate, evapotranspirate, or reuse stormwater runoff on the site where the runoff is generated.

f. **Illicit Discharge**: Any discharge to a municipal separate storm sewer system that is not composed entirely of stormwater except discharges authorized under Section A.4.a.xii., discharges permitted by a NPDES permit or other state or federal permit, or otherwise authorized by the Department.

g. **Impervious Surface:** Any surface resulting from development activities that prevents the infiltration of water or results in more runoff than in the undeveloped condition. Common impervious surfaces include: building roofs, traditional concrete or asphalt paving on walkways, driveways, parking lots, gravel roads, and packed earthen materials.

h. **Low Impact Development (LID)**: A stormwater management approach that seeks to mitigate the impacts of increased runoff and stormwater pollution using a set of planning, design and construction approaches and stormwater management practices that promote the use of natural systems for infiltration, evapotranspiration, and reuse of rainwater, and can occur at a wide range of landscape scales (i.e., regional, community and site).

i. **Maximum Extent Practicable (MEP):** The statutory standard that establishes the level of pollutant reductions that operators of regulated MS4s must achieve. This standard is considered met if the conditions of the permit are met.

j. **Measurable Goals:** BMP objectives or targets used to identify progress of SWMP implementation. Measurable goals are prospective and, wherever possible, quantitative. Measurable goals describe *what* the co-permittee intends to do and *when* they intend to do it.

k. **Redevelopment:** A project on a previously developed site that results in the addition or replacement of impervious surface.

l. **Replace or Replacement:** The removal of an impervious surface that exposes soil followed by the placement of an impervious surface. Replacement does not include repair or maintenance activities on structures or facilities taken to prevent decline, lapse or cessation in the use of the existing impervious surface as long as no additional hydrologic impact results from the repair or maintenance activity.

m. **Stormwater Management Program:** A comprehensive set of activities and actions, including policies, procedures, standards, ordinances, criteria, and best management practices established to reduce the discharge of pollutants from the Municipal Separate Storm Sewer System to the Maximum Extent Practicable, to protect water quality, and to satisfy the appropriate water quality requirements of the Clean Water Act.

n. **Time of Concentration:** Travel time for a drop of water to travel from most hydrologically remote location in a defined catchment to the outlet for that catchment where remoteness relates to time of travel rather than distance.

o. **TMDL Pollutant Load Reduction Benchmark (TMDL benchmark):** An estimated total pollutant load reduction target for each parameter or surrogate, where applicable, for waste load allocations established under an EPA-approved TMDL. A benchmark is the anticipated pollutant load reduction goal to be achieved during the permit cycle through the implementation of the stormwater management program and BMPs identified in the SWMP. A benchmark is used to measure the effectiveness of the stormwater management program in making progress toward the waste load allocation, and is a tool for guiding adaptive management. A benchmark is not a numeric effluent limit; rather it is an estimated pollutant reduction target that is subject to the maximum extent practicable standard. Benchmarks may be stated as a pollutant load range based upon the results of a pollutant reduction empirical model.

p. **Water Quality Trend Analysis:** A statistical analysis of in-stream water quality data to identify improvement or deterioration.

q. **Waters of the State:** Lakes, bays, ponds, impounding reservoirs, springs, wells, rivers, streams, creeks, estuaries, marshes, inlets, canals, the Pacific Ocean within the territorial limits of the State of Oregon, and all other bodies of surface or underground waters, natural or artificial, inland or coastal, fresh or salt, public or private (except those private waters that do not combine or effect a junction with natural surface or underground waters) that are located wholly or partially within or bordering the state or within its jurisdiction.

SCHEDULE F
NPDES Permit General Conditions for Municipal Separate Storm Sewer Systems

<u>SECTION A. STANDARD CONDITIONS</u>

1. <u>Duty to Comply with Permit</u>
   The co-permittees must comply with all conditions of this permit. Failure to comply with any permit condition is a violation of the Clean Water Act and Oregon Revised Statutes (ORS) 468B.025, and 40 Code of Federal Regulations (CFR) §122.41(a), and grounds for an enforcement action. Failure to comply is also grounds for the Department to modify, revoke, or deny renewal of a permit.

2. <u>Penalties for Water Pollution and Permit Condition Violations</u>
   a. ORS 468.140 allows the Department to impose civil penalties up to $10,000 per day for violation of a term, condition, or requirement of a permit. Additionally 40 CFR §122.41(a) provides that any person who violates any permit condition, term, or requirement may be subject to a federal civil penalty not to exceed $32,500 per day for each violation.

   b. Under ORS 468.943 and 40 CFR §122.41(a), unlawful water pollution, if committed by a person with criminal negligence, is punishable by a fine of up to $25,000 imprisonment for not more than one year, or both. Each day on which a violation occurs or continues is a separately punishable offense.

   c. Under ORS 468.946, a person who knowingly discharges, places, or causes to be placed any waste into the waters of the state or in a location where the waste is likely to escape or be carried into the waters of the state is subject to a Class B felony punishable by a fine not to exceed $200,000 and up to 10 years in prison. Additionally, under 40 CFR §122.41(a) any person who knowingly discharges, places, or causes to be placed any waste into the waters of the state or in a location where the waste is likely to escape into the waters of the state is subject to a federal civil penalty not to exceed $100,000, and up to 6 years in prison.

3. <u>Duty to Mitigate</u>
   The co-permittees must take all reasonable steps to minimize or prevent any discharge or sludge use or disposal in violation of this permit that has a reasonable likelihood of adversely affecting human health or the environment. In addition, upon request of the Department, the permittee must correct any adverse impact on the environment or human health resulting from noncompliance with this permit, including such accelerated or additional monitoring as necessary to determine the nature and impact of the non-complying discharge.

4. <u>Duty to Reapply</u>
   If any or all of the co-permittees wish to continue an activity regulated by this permit after the expiration date of this permit, the co-permittee must apply to have the permit renewed. The application must be submitted at least 180 days before the expiration date of this permit.

   The Department may grant permission to submit an application less than 180 days in advance but no later than the permit expiration date.

5. Permit Actions
   This permit may be modified, revoked and reissued, or terminated for cause including, but not limited to, the following:
   a. Violation of any term, condition, or requirement of this permit, a rule, or a statute
   b. Obtaining this permit by misrepresentation or failure to disclose fully all material facts
   c. A change in any condition that requires either a temporary or permanent reduction or elimination of the authorized discharge
   d. The permittee is identified as a Designated Management Agency or allocated a waste load under a Total Maximum Daily Load (TMDL)
   e. New information or regulations
   f. Modification of compliance schedules
   g. Requirements of permit reopener conditions
   h. Correction of technical mistakes made in determining permit conditions
   i. Determination that the permitted activity endangers human health or the environment
   j. Other causes as specified in 40 CFR §§122.62, 122.64, and 124.5

   The filing of a request by the co-permittee for a permit modification, revocation or reissuance, termination, or a notification of planned changes or anticipated noncompliance, does not stay any permit condition. The permittee must comply with all terms, conditions of the permit pending approval.

6. Toxic Pollutants
   The co-permittee must comply with any applicable effluent standards or prohibitions established under Oregon Administrative Rules (OAR) 340-041-0033 for toxic pollutants within the time provided in the regulations that establish those standards or prohibitions, even if the permit has not yet been modified to incorporate the requirement.

7. Property Rights and Other Legal Requirements
   The issuance of this permit does not convey any property rights of any sort, or any exclusive privilege, or authorize any injury to persons or property or invasion of any other private rights, or any infringement of federal, tribal, state, or local laws or regulations.

8. Permit References
   Except for effluent standards or prohibitions established under OAR 340-041-0033 for toxic pollutants and standards for sewage sludge use or disposal established under Section 405(d) of the Clean Water Act, all rules and statutes referred to in this permit are those in effect on the date this permit is issued.

9. Permit Fees
   The co-permittee must pay the fees required by OAR 340-045-0070 to 0075.
   The co-permittee must pay annual compliance fees by the last day of the month prior to when the permit was issued. For example, if the permit was issued or last renewed in April, the due date will be March 31st. If the payment of annual fees is 30 days or more past due, the permit registrant must pay 9% interest per annum on the unpaid balance. Interest will accrue until the fees are paid in full. If the Department does not receive payment of annual fees when they are

due, the Department will refer the account to the Department of Revenue or to a private collection agency for collection.

SECTION B. OPERATION AND MAINTENANCE OF POLLUTION CONTROLS

1. Proper Operation and Maintenance
   The co-permittee must at all times properly operate and maintain all facilities and systems of treatment and control (and related appurtenances) that are installed or used by the permittee to achieve compliance with the conditions of this permit. Proper operation and maintenance also includes adequate laboratory controls and appropriate quality assurance procedures. This provision requires the operation of back-up or auxiliary facilities or similar systems that are installed by the permittees only when the operation is necessary to achieve compliance with the conditions of the permit.

2. Need to Halt or Reduce Activity Not a Defense
   It must not be a defense for the permittee in an enforcement action that it would have been necessary to halt or reduce the permitted activity in order to maintain compliance with this permit.

3. Removed Substances
   Solids or other pollutants removed in the course of maintaining the MS4 must be disposed of in such a manner as to prevent any pollutant from such materials from entering waters of the state, causing nuisance conditions, or creating a public health hazard.

SECTION C. MONITORING AND RECORDS

1. Representative Sampling
   Sampling and measurements taken as required under this Permit must be representative of the volume and nature of the monitored discharge. All samples must be taken at the monitoring points specified in this permit, and must be taken, unless otherwise specified, before the effluent joins or is diluted by any other waste stream, body of water, or substance. Monitoring points may not be changed without notification to and the approval of the Department.

2. Monitoring Procedures
   Monitoring must be conducted according to test procedures approved under 40 CFR part 136, unless other test procedures have been specified in this permit or subsequent permit actions.

3. Penalties of Tampering
   The Clean Water Act provides that any person who falsifies, tampers with, or knowingly renders inaccurate any monitoring device or method required to be maintained under this permit may, upon conviction, be punished by a fine of not more than $10,000 per violation, imprisonment for not more than two years, or both. If a conviction of a person is for a violation committed after a first conviction of such person, punishment is a fine not more than $20,000 per day of violation, or by imprisonment of not more than four years, or both.

4. Additional Monitoring by the Co-permittees

If the co-permittees monitor any pollutant more frequently than required by this permit, using test procedures approved under 40 CFR part 136 or as specified in this permit, the results of this monitoring must be included in the calculation and reporting of the data submitted in annual reports required by Schedule B. Such increased frequency must also be indicated.

5. Retention of Records
   The co-permittees must retain records of all monitoring information, including: all calibration, maintenance records, all original strip chart recordings for continuous monitoring instrumentation, copies of all reports required by this permit, and records of all data used to complete the application for this permit for a period of at least 3 years from the date of the sample, measurement, report, or application. This period may be extended by request of the Department at any time.

6. Records Contents
   Records of monitoring information must include:
   a. The date, exact place, time, and methods of sampling or measurements;
   b. The individual(s) who performed the sampling or measurements;
   c. The date(s) analyses were performed;
   d. The individual(s) who performed the analyses;
   e. The analytical techniques or methods used; and
   f. The results of such analyses.

7. Inspection and Entry
   The co-permittees must allow the Department representative upon the presentation of credentials to:
   a. Enter upon a co-permittee's premises where a regulated facility or activity is located or conducted, or where records must be kept under the conditions of this permit;
   b. Have access to and copy, at reasonable times, any records that must be kept under the conditions of this permit;
   c. Inspect at reasonable times any facilities, equipment (including monitoring and control equipment), practices, or operations regulated or required under this permit, and
   d. Sample or monitor at reasonable times, for the purpose of assuring permit compliance or as otherwise authorized by state law, any substances or parameters at any location within the MS4.

SECTION D. REPORTING REQUIREMENTS

1. Planned Changes
   The permittee must comply with OAR chapter 340, division 52, "Review of Plans and Specifications" and 40 CFR §122.41(1)(l). Except where exempted under OAR chapter 340, division 52, no construction, installation, or modification involving disposal systems, treatment works, sewerage systems, or common sewers may be commenced until the plans and specifications are submitted to and approved by the Department. The permittee must give notice to the Department as soon as possible of any planned physical alterations or additions to the permitted facility.

2. Anticipated Noncompliance
The co-permittees must give advance notice to the Department of any planned changes in the permitted facility or activities that may result in noncompliance with permit requirements.

3. Transfers
This permit may be transferred to a new co-permittee(s) provided the transferee(s) acquires a property interest in the permitted activity and agrees in writing to fully comply with all the terms and conditions of the permit and the rules of the Commission. No permit may be transferred to a third party without prior written approval from the Department. The Department may require modification, revocation, and reissuance of the permit to change the name of the permittee and incorporate such other requirements as may be necessary under the Clean Water Act (see 40 CFR §122.61; in some cases, modification or revocation and reissuance is mandatory). The co-permittees must notify the Department when a transfer of property interest takes place that results in a change of co-permittee(s).

4. Compliance Schedule
Reports of compliance or noncompliance with, or any progress reports on, interim and final requirements contained in any compliance schedule of this permit must be submitted no later than 14 days following each schedule date. Any reports of noncompliance must include the cause of noncompliance, any remedial actions taken, and the probability of meeting the next scheduled requirements.

5. Duty to Provide Information
The co-permittees must furnish to the Department within a reasonable time any information that the Department requests to determine compliance with this permit. The co-permittees must also furnish to the Department, upon request, copies of records required to be kept by this permit.

   Other Information: When a co-permittee becomes aware that it has failed to submit any relevant facts or has submitted incorrect information in a permit application or any report to the Department, it must promptly submit such facts or information.

6. Signatory Requirements
All applications, reports or information submitted to the Department must be signed and certified in accordance with 40 CFR §122.22.

7. Falsification of Information
Under ORS 468.953, any person who knowingly makes any false statement, representation, or certification in any record or other document submitted or required to be maintained under this permit, including monitoring reports or reports of compliance or noncompliance, is subject to a Class C felony punishable by a fine not to exceed $100,000 per violation and up to 5 years in prison. Additionally, according to 40 CFR §122.41(k)(2), any person who knowingly makes any false statement, representation, or certification in any record or other document submitted or required to be maintained under this permit including monitoring reports or reports of compliance or non-compliance must, upon conviction, be punished by a federal civil penalty not to exceed $10,000 per violation, or by imprisonment for not more than 6 months per violation, or by both.

SECTION E. DEFINITIONS

1. *CFR* means Code of Federal Regulations.
2. *Clean Water Act* or *CWA* means the Federal Water Pollution Control Act enacted by Public Law 92-500, as amended by Public Laws 95-217, 95-576, 96-483 and 97-117; 33 U.S.C. 1251 et seq.
3. *Department* means Department of Environmental Quality.
4. *Director* means Director of the Department of Environmental Quality.
5. *Flow-Weighted Composite Sample* means a sample formed by collection and mixing discrete samples taken periodically and based on flow.
6. *Grab Sample* means an individual discrete sample collected over a period of time not to exceed 15 minutes.
7. *Illicit Discharges* means any discharge to a municipal separate storm sewer that is not composed entirely of stormwater except discharges pursuant to a NPDES permit (other than the NPDES permit for discharges from the municipal separate storm sewer) and discharges resulting from fire fighting activities.
8. *Major Outfall* means a municipal separate storm sewer outfall that discharges from a single pipe with an inside diameter 36 inches or more or its equivalent (discharge from a single conveyance other than circular pipe which is associated with a drainage area of more than 50 acres); or for municipal separate storm sewers that receive stormwater from lands zoned for industrial activities (based on comprehensive zoning plans or the equivalent), an outfall that discharges from a single pipe with an inside diameter of 12 inches or more or from its equivalent (discharge from other than a circular pipe associated with a drainage area of 2 acres or more).
9. *mg/L* means milligrams per liter.
10. *mL/L* means milliliters per liter.
11. *MS4* means a municipal separate storm sewer system.
12. *Municipal Separate Storm Sewer* (MS4) means a conveyance or system of conveyances (including roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, manmade channels, or storm drains):
    a. Owned or operated by a State, city, town, borough, county, parish, district, association, or other public body (created by or pursuant to State Law) having jurisdiction over disposal of sewage, industrial wastes, stormwater or other wastes, including special districts under State Law such as a sewer district, flood control district or drainage district, or similar entity, or an Indian tribe or an authorized Indian Tribal organization, or a designated and approved management agency under §208 of the CWA that discharges to waters of the United States;
    b. Designed or used for collection or conveying stormwater;
    c. Which is not a combined sewer; and
    d. Which is not part of a Publicly Owned Treatment Works (POTW) as defined by 40 CFR §122.2.
13. *Outfall* means a point source as defined by 40 CFR §122.2 at the point where a municipal separate storm sewer discharges to waters of the United States and does not include open conveyances connecting two municipal separate storm sewers, or pipes, tunnels or other conveyances which connect segments of the same stream or other waters of the United States and are used to convey waters of the United States.
14. *Permit* means the NPDES municipal separate storm sewer system (MS4) permit specified herein, authorizing the permittees listed on Page 1 of this permit to discharge from the MS4.
15. *Stormwater* means stormwater runoff, snowmelt runoff, and surface runoff and drainage.
16. *Year* means calendar year except where otherwise defined.

Appendix B

Summary of MS4 Permit Requirements and Incorporation into the Port’s Stormwater DSM

Appendix B: Summary of MS4 Permit Requirements and Incorporation into the Port's Stormwater DSM

The table below summarizes the primary MS4 permit criteria (DEQ MS4 Permit No. 101314) driving the development of the Port of Portland Design Standards Manual (DSM), and demonstrates where in the DSM each requirement is addressed.

		Category					
	MS4 Permit Language	**Port Authority / Role / Process**	**LID**	**Quantity Control**	**Quality Control**	**BMP Design / Applicability**	**SWM Standards and/or Design Criteria, DSM Reference**
A.4.f.i.	**By January 1, 2014, the post-construction stormwater pollutant and runoff control program applicable to new development and redevelopment projects that create or replace 500 ft2 of impervious surface must meet the following conditions:**	X					Applicability of the DSM to projects, including the impervious surface threshold, is described in Chapter 1. The DSM is currently only applicable to projects within select portions of Port facilities, as described in Chapter 1. Projects in areas where the DSM is not applicable are subject to the City SWMM.
A.4.f.i.1.	Incorporate site-specific management practices that target natural surface or predevelopment hydrologic functions as much as practicable. The site-specific management practices should optimize on-site retention based on the site conditions;		X	X			Chapter 4 includes a Stormwater Management (SWM) Standard for Low-Impact Development (including Green Infrastructure) to target predevelopment functions, as well a SWM Standard for Infiltration to optimize on-site retention.
A.4.f.i.2.	Reduce site specific post-development stormwater runoff volume, duration and rates of discharges to the municipal separate storm sewer system (MS4) to minimize hydrological and water quality impacts from impervious surfaces;			X	X		Chapter 4 includes SWM Standards for several topics that contribute to flow control, including: Water Quantity Control, Low Impact Development, and Infiltration. The Water Quantity Control SWM Standard requires the implementation of flow controls as needed to meet on-site flooding objectives. It also includes the option for the Port to require additional project-specific flow controls as necessary to address potential flooding and capacity issues.
A.4.f.i.3.	Prioritize and include implementation of Low-Impact Development (LID), Green Infrastructure (GI) or equivalent design and construction approaches; and,		X				Chapter 4 includes a SWM Standard to promote Low-Impact Development, which incorporates Green Infrastructure. Chapter 6 and the BMP Fact Sheets provide criteria for the selection and design of GI BMPs. The applicability and feasibility of LID practices is encouraged to be considered early on in the design, through the DSM Compliance Process laid out in Chapter 3.
A.4.f.i.4.	Capture and treat 80% of the annual average runoff volume, based on a documented local or regional rainfall frequency and intensity.				X		Chapter 4 includes a SWM Standard for "Water Quality - Capture and Treat," which addresses minimum water quality capture and treat requirements that drive the sizing of water quality BMPs. The requirements are based on a local rainfall analysis, which is summarized in Appendix L.
A.4.f.ii.	**The co-permittee must identify, and where practicable, minimize or eliminate ordinance, code and development standard barriers within their legal authority that inhibit design and implementation techniques intended to minimize impervious surfaces and reduce stormwater runoff (e.g., Low Impact Development, Green Infrastructure). Such modifications to ordinance, code and development standards are only required to the extent they are permitted under federal and state laws. The co-permittee must review ordinance, code and development standards for modification, minimization or elimination, and appropriately modify ordinance, code or development standard barriers by January 1, 2014. If an ordinance, code or development standard barrier is identified at any time subsequent to January 1, 2014, the applicable ordinance, code or development standard must be modified within three years.**	X	X				Although no formal code or development standard barriers were identified, the DSM incorporates initiatives that promote the consideration of LID and GI early on in the development project planning process, including as part of pre-design planning to be performed initially by the Port. DSM Chapter 3 requires that designers initially coordinate with the Port on the applicability of various LID techniques at the Project Kickoff Meeting, so that decisions to incorporate LID (where applicable) may be made at a time when the project concept may be flexible to accommodate changes.
A.4.f.iii.	**To reduce pollutants and mitigate the volume, duration, time of concentration and rate of stormwater runoff, the co-permittee must develop or reference an enforceable post-construction stormwater quality management manual or equivalent document by January 1, 2014 that, at a minimum, includes the following:**	X					The DSM fulfills the requirement for an enforceable post-construction stormwater quality management manual. The Port's authority and enforcement mechanisms are described in Chapter 1. Enforcement is performed through the Port submittal and review process described in Chapter 3. Port facilities within the Port MS4 permit area that have not been selected to implement the DSM at this time will continue to be subject to stormwater management requirements established by the City of Portland within the City Stormwater Management Manual (SWMM).
A.4.f.iii.1.	A minimum threshold for triggering the requirement for post-construction storm water management control and the rationale for the threshold.	X					Applicability of the DSM to projects, including the impervious surface threshold, is described in Chapter 1.
A.4.f.iii.2.	A defined design storm or an acceptable continuous simulation method to address the capture and treatment of 80% of the annual average runoff volume.				X		Chapter 4 includes a SWM Standard for "Water Quality - Capture and Treat," which addresses minimum water quality capture and treat requirements that drive the sizing of water quality BMPs. The requirements are based on a local rainfall analysis, which is summarized in an appendix to the DSM.
A.4.f.iii.3.	Applicable LID, GI or similar stormwater runoff reduction approaches, including the practical use of these approaches.		X				Chapter 4 includes a SWM Standard to promote Low-Impact Development, including Green Infrastructure. The DSM identifies a series of LID practices and strategies that designers are required to consider in coordination with the Port, and document their applicability and implementation within the DSM Coordination Checklist. Chapter 4 also provides an approach for complying with this SWM Standard, and Chapter 3 requires that designers coordinate on LID opportunities with the Port at the Kickoff Meeting and subsequent milestones. Chapter 6 and the BMP Fact Sheets provide criteria for the selection and design of GI BMPs.
A.4.f.iii.4.	Conditions where the implementation of LID, GI or equivalent approaches may be impracticable.		X				The SWM Standard for LID in Chapter 4 identifies specific implementation considerations that may limit the practicability or the extent to which some LID practices can be implemented, including conflicts related to site constraints, soil conditions, project objectives, and safety. Designers, in coordination with the Port, are required to document their consideration of applicability for each identified LID strategy within the DSM Coordination Checklist. Where particular strategies are impracticable, justification is required. Where practicable, designers are required to demonstrate how the strategy was incorporated into the design.

Appendix B: Summary of MS4 Permit Requirements and Incorporation into the Port's Stormwater DSM

The table below summarizes the primary MS4 permit criteria (DEQ MS4 Permit No. 101314) driving the development of the Port of Portland Design Standards Manual (DSM), and demonstrates where in the DSM each requirement is addressed.

		Category					
	MS4 Permit Language	Port Authority / Role / Process	LID	Quantity Control	Quality Control	BMP Design / Applicability	SWM Standards and/or Design Criteria, DSM Reference
A.4.f.iii.5.	BMPs, including a description of the following: a. Site-specific design requirements; b. Design requirements that do not inhibit maintenance; and, c. Conditions where the BMP applies.					X	Chapter 6 provides guidance, matrices, and an overall process for the selection of BMPs that are appropriate for a particular project and site, taking into account site constraints, soil characteristics, project pollutants of concern, and other considerations. Additionally, Chapter 6 and the BMP Fact Sheets provide BMP-specific design criteria that have been selected to enhance BMP performance and facilitate operations and maintenance. Chapter 6 and the BMP Fact Sheets also recommend specific operations and maintenance activities to be conducted at defined frequencies. Finally, Chapter 3 identifies required components of the SWM Submittal to the Port, including an O&M Plan.
A.4.f.iii.6.	Pollutant removal efficiency performance goals that maximize the reduction in discharge of pollutants.				X	X	Chapter 6 prescribes an overall process for the selection of BMPs that are appropriate for a particular project and site, taking into account project pollutants of concern. Chapter 6 and the BMP Fact Sheets also provide BMP-specific design criteria that have been selected to enhance BMP performance and facilitate operations and maintenance, based on best available industry BMP guidance. Chapter 6 identifies a performance goal for TSS of 25 mg/L (as a median effluent concentration) based on a review of BMP performance in the International Stormwater BMP Database. The DSM does not specify a numeric percent pollutant removal efficiency, due to concerns in the stormwater community about the quality and inconsistency of published data for percent removal by BMP type, and its applicability to different site and project conditions. This position is consistent with the International Stormwater BMP Database and its published white paper "Why does the International Stormwater BMP Database Project omit percent removal as a measure of BMP performance?" (http://www.bmpdatabase.org/Docs/FAQPercentRemoval.pdf).
A.4.f.iv.	**The co-permittee must review, approve and verify proper implementation of post-construction site plans for new development and redevelopment projects applicable to this section. The Port of Portland may address this permit requirement by documenting that all internal Port of Portland development projects meet the Post-Construction Site Runoff performance standards required in this subsection.**	X					Chapter 1 of the DSM requires that all applicable development projects obtain Port approval of the stormwater management design in their SWM Submittal and obtain a Port Construction Permit before the project can proceed to construction. Additionally, Chapter 3 describes required design review and coordination milestones, which represent points in the design process where the designer must coordinate with the Port and submit the SWM Strategy to the Port for review and approval. The Port has an existing rigorous construction oversight process and BMP inspection and maintenance program that will continue to be used to verify BMP performance as designed and approved under the DSM.
A.4.f.v.	**Where a new development or redevelopment project site is characterized by factors limiting use of on-site stormwater management methods to achieve the post-construction site runoff performance standards, such as high water table, shallow bedrock, poorly drained or low permeable soils, contaminated soils, steep slopes or other constraints, the Post-Construction Stormwater Management program must require equivalent pollutant reduction measures, such as off-site stormwater quality management. Off-site stormwater quality management may include off-site mitigation, such as using low impact development principles in the construction of a structural stormwater facility within the sub-watershed, a stormwater quality structural facility mitigation bank or a payment-in-lieu program.**	X					Chapter 4 SWM Standards describe post-construction runoff control requirements and applicability considerations for each based on site conditions and other factors. The "Water Quality - Capture and Treat" SWM Standard specifies off-site mitigation as an option if on-site quality management is not feasible. Off-site mitigation is evaluated for applicability by the Port based on a Variance Request from the designer, in which the designer identifies what can be performed on-site and the extent of deviation from the Standard. As described in Chapter 4, the Port will consider whether off-site mitigation shall be incorporated into the project design or implemented by the Port in conjunction with other projects or Port initiatives. Payment-in-lieu is not currently in the DSM, but will be considered by the Port for future incorporation if necessary to address tenant projects.
A.4.f.vi.	**A description of the inspection and enforcement response procedures the co-permittee will follow when addressing project compliance issues with the enforceable post-construction stormwater management performance standards.**	X					The Port will be enforcing the use of and compliance with the DSM through a variety of means. As described in Chapter 1, the Port has the ability to enforce the use of the DSM, amongst other Port-defined stormwater management requirements, through the existing Port Stormwater Ordinance 361R, tenant lease agreements, and contract mechanisms with design firms. Within the DSM, Chapter 1 requires that all applicable development projects obtain Port approval of the stormwater management design in their SWM Submittal and obtain a Port Construction Permit before the project can proceed to construction. Additionally, Chapter 3 describes required design review and coordination milestones, which represent points in the design process where the designer must coordinate with the Port and submit the SWM Strategy to the Port for review and approval. The Port has an existing rigorous construction oversight process and BMP inspection and maintenance program that will continue to be used to maintain BMP performance as designed and approved under the DSM.

Appendix C

Regulatory Context

APPENDIX C: REGULATORY CONTEXT

C.1 Introduction

The contents of this appendix are intended to make the designer aware of existing regulations that may need to be coordinated with on a stormwater management design. The regulatory information includes federal, state, and local regulations that the Port is subject to, many of which serve as drivers for the required Stormwater Management (SWM) Standards presented in Chapter 4, as well as design criteria in Chapters 5 and 6. Beyond the contents of this appendix, designers are required to design their project in accordance with all applicable regulations pertaining to the stormwater management design. Compliance with DSM requirements does not entail compliance with all applicable regulatory requirements. Should applicable regulatory requirements (not including the City SWMM) become more restrictive than DSM requirements, those regulatory requirements will supersede any less restrictive requirements in the DSM.

C.2 Clean Water Act

The protection of the nation's waters originally began with Congress passing the Federal Water Pollution Control Act of 1948. The amendments passed by Congress in 1972 are now generally referred to as the Clean Water Act (CWA).

Section 402 of the CWA authorized the creation of the National Pollutant Discharge Elimination System (NPDES) permit program, which protects stormwater by regulating point source discharges of pollutants into waters of the United States.[1] In the State of Oregon, the EPA has delegated the administration of the NPDES permit program to the Oregon Department of Environmental Quality (DEQ). In late 1990, the U.S. Environmental Protection Agency (EPA) began to require municipal communities with populations of 100,000 or more to obtain a NPDES Municipal Separate Storm Sewer System (MS4) permit, which was called the Phase I stormwater rule. Information on Port NPDES permits, including industrial, construction, and MS4 permits is provided in several of the following sub-sections.

Section 303 of the CWA required that authorized states designate beneficial uses for state waters (e.g., agriculture, recreation, aquatic life) and then establish and adopt water quality standards that are protective of those uses. Water quality standards may include specific numeric water quality criteria as well as general provisions for protection of the waters, such as surface water anti-degradation policies. In the State of Oregon, the Water Quality Standards program is regulated and enforced by DEQ. Section 303(d) of the CWA requires each state to develop a prioritized list of impaired waters within their state ("303(d) List") that do not meet established water quality standards. Under this requirement, authorized states perform studies to identify quality issues for state surface waters and, if necessary, establish Total Maximum Daily Loads (TMDLs). A TMDL is a limit on the discharge of a particular pollutant (e.g., nutrients or bacteria) to a specific water body that is impaired for that pollutant. The limit for pollutant discharges is designed to help the water body meet its designated water quality standards. Information on TMDLs and 303(d) listed parameters is summarized in Section C.2.5.

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[1] Environmental Protection Agency, *National Pollutant Discharge Elimination System (NPDES),* March 12, 2009. http://cfpub.epa.gov/npdes/. (accessed on October 4, 2013).

Sections 401 and 404 of the CWA regulate impacts to wetlands and other surface water resources. For more information on these sections of the CWA please refer to Section C.6 on natural resource regulations.

C.2.1 Portland Group NPDES MS4 Permit

Within the City of Portland (City) Urban Services Boundary (USB), the City and Port both operate storm sewer systems in accordance with their joint Phase I MS4 permit #101314 (referred to as the "Portland Group" permit by DEQ). DEQ originally issued the permit to the City, Port, and Multnomah County in 1995, with the City as the lead agency. The permit was renewed in 2004 and further modified in 2005.[2] The current Portland Group MS4 permit ("MS4 permit") was issued with the City and Port as the sole co-permittees. Each of the co-permittees is responsible for implementing the requirements of the MS4 permit within their area of permit responsibility. The Port's area of MS4 permit responsibility includes all Port-owned property within the City USB[3]. The Port and City coordinate MS4 permit-driven responsibilities and activities through an Intergovernmental Agreement (IGA). The current MS4 permit can be found in Appendix A.

The requirements of the MS4 permit include six minimum control measures that define required controls and limitations for stormwater discharges within each of the co-permittees' areas of responsibility:

1. <u>Prohibit Non-Stormwater Discharges</u> – Effectively prohibit non-stormwater discharges into the MS4 unless otherwise permitted.
2. <u>Reduce Pollutants to the Maximum Extent Practicable</u> – Reduce the discharge of pollutants from the MS4 to the maximum extent practicable.
3. <u>Implement the Stormwater Management Plan (SWMP)</u> – Implement and assess the effectiveness of the SWMP, which establishes stormwater management Best Management Practices (BMPs) to reduce the discharge of pollutants to the maximum extent practicable within each area of responsibility.
4. <u>Stormwater Management Plan Requirements</u>
    a. <u>Illicit discharge detection and elimination</u> – Implement a program to detect, remove and eliminate illicit discharges to the MS4.
    b. <u>Industrial and commercial facilities</u> – Implement a program to reduce pollutants in stormwater discharges to the MS4 from facilities identified as being subject to an industrial NPDES permit or as contributing a significant pollutant load to the MS4.
    c. <u>Construction site runoff control</u> – Implement a program to reduce pollutants in stormwater runoff to the MS4 from construction activities.
    d. <u>Education and outreach</u> – Implement an education and outreach program designed to achieve measurable goals for target audiences, stormwater quality issues, or pollutants of concern.

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[2] City of Portland Bureau of Environmental Services, *City of Portland Stormwater Management Plan (SWMP) Summary*. Available online at http://www.portlandoregon.gov/bes/article/322159 (accessed on September 20, 2013).
[3] Port of Portland, *Stormwater Management Plan* (September 20, 2010, last updated April 1, 2011).

e. Public Involvement and participation – Implement a public participation approach providing opportunities for the public to participate in the co-permittee's stormwater management program.
f. Post-construction site runoff – Implement a post-construction stormwater pollutant control program.
g. Pollution prevention for municipal operations – Implement a program to reduce the discharge of pollutants to the MS4 from properties owned or operated by the co-permittee.
h. Stormwater management facilities operation and maintenance activities – Inventory and map stormwater management facilities and implement a program to verify the operation, inspection and maintenance of these facilities.

5. Hydromodification Assessment – Conduct an initial hydromodification assessment examining impacts related to MS4 discharges, including erosion, sedimentation and alternation to stormwater flow, volume, and duration.
6. Stormwater Retrofit Strategy Development – Develop a stormwater quality retrofit strategy that applies to developed areas that have been identified as underserved or lacking stormwater quality controls.

C.2.2 MS4 SWMP Implementation

In accordance with MS4 permit requirements, the Port was required to develop a SWMP, detailing the measures and tasks that will be implemented to comply with each of the MS4 permit minimum control measures, except where covered by the City under their IGA. The Port states within its SWMP that it will "develop, adopt, and implement new Port-specific post-construction runoff control standards" as the chosen practice to meet Schedule A.4.f. of the MS4 permit. As described in Chapter 1, the DSM is intended to meet the objective of defining post-construction runoff control standards for stormwater management at applicable Port facilities. Where applicable, use of the DSM is intended to replace compliance with the City's *Stormwater Management Manual,*[4] which was implemented by the City as part of their own post-construction runoff control program. The relationship of MS4 permit requirements and various elements of the DSM is summarized in a table in Appendix B.

C.2.3 NPDES Industrial Permit Program

As described previously, DEQ has authorization over the NPDES industrial permit program in the State of Oregon to control the discharge of pollutants associated with industrial activities that are exposed to stormwater. Industrial permit coverage allows a permitted industrial facility to construct, install, modify, or operate stormwater treatment or control facilities and discharge stormwater and non-stormwater to public waters as authorized by the permit. An IGA between the City of Portland and DEQ allows the City to administer general NPDES stormwater permits

[4] City of Portland, *Stormwater Management Manual* (2008). Available online at http://www.portlandoregon.gov/bes/47952.

for industrial stormwater discharges to the City MS4 on behalf of DEQ.[5] The bullets below describe the general industrial permits offered by DEQ, as well as Port applicability:[6]

- 1200-Z – For applicable industrial activities throughout the state that are not covered by one of the permits below. Many of the Port's facilities have coverage under this permit for discharges to the Willamette River.
- 1200-COLS – For applicable industrial activities that discharge to the Columbia Slough. The Port has coverage under this permit for PDX discharges to the Columbia Slough.
- 1200-A – For sand and gravel operations, rock quarries, concrete batch plant operations and hot mix asphalt operations. This permit does not apply to any Port facilities.

DEQ continues to administer the NPDES industrial permit program for industrial stormwater discharges that are not eligible for coverage under the general permits. These include discharges from less common industrial activities including aircraft and pavement deicing at airports, for which PDX has an individual industrial NPDES permit (#101647).

Other Port and Port tenant industrial activities that are exposed to stormwater and discharge stormwater to public waters are covered under either the 1200-Z or 1200-COLS general industrial permit, as applicable. These permits require completion and implementation of a Stormwater Pollution Control Plan (SWPCP). These plans are useful for understanding the industrial activities and current stormwater BMPs at the facilities.

C.2.4 Erosion and Sediment Control

The City regulates erosion and sediment control from ground disturbing activities, including construction activities. Within Oregon Administrative Rule (OAR) Division 41, DEQ allows local jurisdictions to implement erosion and sediment control programs in accordance with baseline DEQ requirements. City Code Title 10 "Erosion and Sediment Control Regulations" and the City *Erosion and Sediment Control Manual* are the result of the City's program to regulate ground-disturbing activities and prevent significant environmental impacts from erosion and sedimentation. City requirements are applicable for all ground-disturbing activities unless exempted (e.g. where there is a hazard to life or property). Ground-disturbing activities 500 square feet or greater in area require submittal of an ESPCP for permitted development projects (building, public works, or development permit). An ESPCP may also be required for sites that are located with the following site conditions:

- On steep slopes
- In environmental overlay zones
- In greenway overlay zones
- In response to a violation of the City's erosion control requirements

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[5] IGA between DEQ and City of Portland for "Administration of NPDES 1200-Z, 1200-COLS and 1200-A General Permits for Stormwater Discharges from Industrial Activities. Available online at http://www.portlandoregon.gov/bes/article/443292.

[6] Definitions from the DEQ "Water Quality Permit Program" accessed on September 5, 2013. http://www.deq.state.or.us/wq/stormwater/industrial.htm.

DEQ NPDES construction permit coverage is required for the discharge of stormwater to public waters from construction sites where the development plan meets the area thresholds defined below. Applicable construction activities include clearing, grading, excavating and stockpiling. The permit may include effluent limitations, erosion and sediment control requirements, and a submittal of an ESPCP. There are three general construction permits offered within the State of Oregon:[7]

- 1200-C – For construction activities throughout the state, where the development plan equals or exceeds one acre.
- 1200-CA – For construction activities under a government agency, including the Port, where the development plan equals or exceeds one acre.
- 1200-CN – Applicable only to specific jurisdictions not including the City of Portland. Allows automatic permit coverage for small construction activities (size varies with jurisdiction).

The Port has an ongoing 1200-CA construction permit which covers applicable Port-initiated construction activities. Port tenants obtain coverage under the 1200-C permit, as applicable, on a project-by-project basis. The 1200-CN permit is not applicable to Port facilities because it is not authorized within the City of Portland.

C.2.5 Total Maximum Daily Loads (TMDLs), Wasteload Allocations (WLAs) and 303(d) Listed Parameters

As previously described, the CWA required that states maintain a 303(d) list and if necessary, establish TMDLs. As part of the MS4 permit requirements, the Port must review the Category 5, 303(d) listed constituents (those without TMDL wasteload allocations, but for which TMDLs are needed) and determine if Port sites have the risk of discharging the constituents. For the Columbia Slough, the only Category 5 listed constituents are iron and manganese (DEQ, 2012b). For the Willamette River, there are thirteen Category 5 constituents, including aldrin, biological criteria, chlordane, chlorophyll-a, cyanide, dichloro-diphenyl-trichloroethane (DDT), p,p'-dichloro-diphenyl-dichloroethylene (DDE), hexachlorobenzene, iron, manganese, polychlorinated biphenyls (PCBs), pentachlorophenol, and polycyclic aromatic hydrocarbons (PAHs) (DEQ 2012b). There are no Category 5 listed constituents for the Columbia River.

The MS4 permit also requires an evaluation of total maximum daily load (TMDL) pollutants. A TMDL for the Columbia Slough was established in 1998, which covers chlorophyll-a, dissolved oxygen, pH, phosphorus, bacteria, lead, and several organics (DDE/DDT, PCBs, Dieldrin, and 2,3,7,8 TCDD) (DEQ 1998). The organics in the TMDL are addressed through use of total suspended solids (TSS) as a surrogate measure. Dissolved oxygen is addressed through the use of biochemical oxygen demand (BOD) as a surrogate, and orthophosphate and chlorophyll-a are addressed through the use of total phosphorus as a surrogate measure. A TMDL for the Willamette Basin was established in 2006 and covers bacteria, mercury, and temperature which applies to the Willamette River (DEQ 2006). Since the Columbia Slough flows into the Willamette River Basin, this TMDL also applies to the Columbia Slough, though only

[7] Oregon Department of Environmental Quality, *NPDES Stormwater Discharge Permits – Construction Activities*. Available online at http://www.deq.state.or.us/wq/stormwater/construction.htm

temperature requirements apply through the use of shade curves as a surrogate. While mercury is included in the TMDL for the Willamette River with interim wasteload allocations (WLAs) based on percent reductions, no specific load allocations or effluent limitations are currently included in this version of the TMDL, though it is understood that a future version will likely contain specific WLAs and/or effluent limitations. Temperature is also included in the TMDL, but, because stormwater is not considered to be a major source of temperature impairment to either waterbody, MS4s are not assigned heat WLAs.

The Port must assess the type and level of BMP implementation necessary to attain the WLAs established for the TMDL pollutants. The estimated costs and other resources associated with implementation, operation, and maintenance of those BMPs must also be evaluated. The MS4 permit requires that progress is made toward reducing TMDL pollutant loads. The DSM has a process for determining pollutants of concern based upon TMDL requirements as well as other considerations, as described in Chapter 6.

C.3 National Environmental Policy Act

The National Environmental Policy Act (NEPA) requires federal agencies to assess the environmental impacts of planned federal actions. For the Port, NEPA may be applicable when a development or redevelopment project is federally funded or authorized by a federal agency, such as FAA. NEPA is intended to assist public officials by providing the framework to better understand the environmental consequences of planned actions. An appropriate level of documentation is required to provide information on the proposed action and the understanding of the impacts that the proposed action may have on the environment. There are three levels of NEPA review:

1. Categorical Exclusion (CatEx)
2. Environmental Assessment (EA)
3. Environmental Impact Statement (EIS)

CatEx is the least extensive review while EIS is the most extensive, requiring the evaluation of multiple design alternatives with varying potential for environmental impacts. The level of review determines the level of documentation and is dependent upon both the identified water resource issues and the findings during the evaluation of environmental impacts. Potential water resource issues include any potential impacts to the following areas, parameters, and organisms:

- Wetlands
- Floodplains
- Water quality
- Coastal zone management
- Plants, fish, and wildlife
- Wild and scenic rivers

For airports, the FAA has established NEPA compliance guidance within FAA Order 1050.1E, *Environmental Impacts: Policies and Procedures*, and FAA Order 5050.4B, *National Environmental Policy Act (NEPA) Implementing Instructions for Airport Actions*. The FAA also provides guidance within the *Environmental Desk Reference for Airport Actions*. The NEPA process concludes with the issuance of a Record of Decision (ROD) by the lead federal agency, which authorizes the project to proceed with the preferred alternative, based on the results of the evaluation.

C.4 Oil Pollution Act and Spill Prevention Countermeasure and Control

The Oil Pollution Control Act (OPA) is an amendment to the CWA and is designed to prevent and respond to oil spills. If facilities store oil in significant volumes as detailed within the OPA, then that facility is subject to follow the prescribed requirements of the OPA for that volume of oil. Requirements include:

- Developing and implementing an Spill Prevention, Control, and Countermeasure (SPCC) Plan
- Providing appropriately sized secondary containment for oil storage containers
- Following the requirements for new underground storage tanks and upgrades to existing tanks

C.5 Floodplain Regulations

Floodplain regulations are designed to maintain floodplain capacity and protect facilities from impacts due to flooding during large, infrequent storm events. These regulations originate at the federal level with Title 44 of the Code of Federal Regulations (CFR). CFR Title 44 contains the rules and regulations pertaining to emergency management and assistance made available through the Federal Emergency Management Agency. CFR Title 44 states that flood insurance shall not be sold or renewed unless the community has adopted consistent floodplain management regulations. Enforcement of the regulations from CFR Title 44 that are pertinent to new development occurs at the local or regional level through establishing the floodplain. Most Port facilities are adjacent to a surface water with an established 100-year floodplain, and may be subject to flood hazard zoning requirements.

Metro, the regional government for the Portland metropolitan area, maintains the Urban Growth Management Functional Plan, which includes flood management performance standards. These performance standards are focused on mitigating impacts from flooding. To reduce impacts to structures from flooding, the lowest floors of structures (including basements) must be at least one foot above the 100-year flood water surface elevation. To mitigate increases in water surface elevation during flooding, Metro Title 3 states that any fill placed within the flood management area shall be balanced with an equal amount of material removal. Some exclusions apply to these requirements for construction activities.

The City complies with Metro Title 3 through defining and regulating development within “Flood Hazard Areas.” These areas are zoned per City Code Chapter 33.631, “Sites in Special Flood Hazard Areas,” to limit the creation of lots on lands subject to regular or periodic flooding in order to protect the safety of citizens and property while preserving the function of the floodplain. City Code Chapter 24.50, “Flood Hazard Areas,” then restricts or prohibits development within defined flood hazard areas that may increase flood heights or velocities. City Title 24 meets or exceeds Metro requirements, with the following variations from Metro Title 3:

- Flood protection requires two feet of freeboard between the lowest floor of a structure (including basements) and the 100-year storm water surface elevation, except in the

Columbia River floodplain and the floodplain for the Columbia Slough in Multnomah County Drainage District No. 1 (MCDD), where the required freeboard is one foot.

- Encroachments or development on the floodway are prohibited unless it can be demonstrated, through technical analysis, that no increase in flood elevation is anticipated. This flood encroachment requirement is similar to the federal or regional requirement, which requires an equal balance of cut for any fill placed within the flood hazard zones.

Flood hazard areas are defined based on the following mapping resources as specified within the City Code Chapter 24.50.040:

- Flood Insurance Rate Maps (FIRMs) produced by FEMA, which indicate the areas that have been designated as being within a floodplain that is subject to a "one percent or greater chance of flooding in any given year,"[8] or what is known as the 100-year flood.[9] Refer to Figure 4-3 for an overview of the 100-year floodplain as defined by FEMA, but during design, review the Official FIRMs for the project site.
- The "February 1996 Flood Inundation"[10] areas as defined within the Metro Geospatial Information System (GIS) data. Refer to Figure 4-4 for an overview of the area covered by the February 1996 storm as defined by Metro.

C.6 Natural Resource Regulations

Natural resource regulations are intended to protect defined resources and the specified buffer zones surrounding the resources from physical impacts. The natural resources can be those that provide a functional value to the surrounding community and environment. The functional value can pertain to, but is not necessarily limited to, water quality, wildlife habitat, coastal protection, and historical or cultural significance. Some examples of natural resource regulations that may need to be considered and incorporated into the design of the stormwater management systems at Port facilities are described below. For groundwater protection regulations see Section C.6.

Wetlands and waterways are protected federally by the United States Army Corps of Engineers (USACE) under Section 404 of the CWA and Section 10 of the Rivers and Harbors Act.[11] Section 404 of the CWA regulates the placement of dredged or fill materials to waters of the state or waters of the United States, through the issuance of permits. If structures, disturbance,

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[8] City Code Title 24, Chapter 24.50, "Flood Hazard Areas" (November 2010).
[9] FIRMs are available online at https://msc.fema.gov/webapp/wcs/stores/servlet/CategoryDisplay?catalogId=10001&storeId=10001&categoryId=12001&langId=-1&userType=G&type=1&dfirmCatId=12009&future=false. Find the FIRM and follow the instructions to create a "FIRMette" which is a full-scale section of a FIRM that is created and formatted online for ease of access.
[10] Select Metro maps and data are available online for free download at http://www.oregonmetro.gov/. The "February 1996 Flood Inundation" areas is available as a free GIS shapefile. Click the link for "Maps and data" followed by the link for "RLIS Discovery site" and the data set name is "February 1996 Flood with Metro Goal 5 Updates."
[11] Oregon Department of Environmental Quality, *NPDES Stormwater Discharge Permits – Construction Activities*. Available online at http://www.oregon.gov/dsl/PERMITS/Pages/404_assumption.aspx

or discharges of material are proposed within surface waters as part of a project, then a permit authorizing the activities may be required by the USACE prior to initiating the activities.

Dredging, filling, and other impacts to waters of the state are regulated at a state level by DEQ, in accordance with Section 401 of the CWA. Section 401 requires a water quality certification prior to issuance of a federal permit for discharge to surface waters (e.g., rivers, streams, ditches, wetlands, etc.) from projects that propose dredging, filling, or other impacts to waters of the state.[12] The certification is completed by DEQ to certify that the proposed discharge is consistent with the CWA and meets the state water quality standards and requirements. Additionally, the Oregon Department of State Lands (DSL) regulates the fill or removal of materials from waters and wetlands of the state through permit issuance under Oregon's Removal-Fill Law.[13] This permit program is intended to protect designated uses of waters of the state, including navigation, fishery, and recreational uses.

Designers should coordinate with the Port to determine if there may be other federal or state natural resource regulations that may need to be considered on a particular site or project, such as the Endangered Species Act, the Magnuson–Stevens Fishery Conservation and Management Act, or the Migratory Bird Treaty Act.

On a regional level, Metro Title 3 includes water quality performance standards aimed at protecting and improving water quality to support designated beneficial water uses, as well as protect the function and value of the water resource. Metro code establishes water quality resource areas, which include protected water features such as streams, lakes, wetlands, and springs, as well as required vegetated corridors alongside the water feature to provide a buffer from development areas. Vegetated corridors are defined from the edge of the water feature (as further defined in the code), and widths vary between 15 feet and 100 feet depending on the type of water feature and slope of land adjacent to the water feature. Additional water quality goals in Metro Title 3 are non-numeric and include minimizing erosion, use of native vegetation, minimizing nutrient and pollutant loadings, stabilizing slopes, and protecting fish and wildlife habitat.

The requirements established by Metro Title 3 are incorporated into the City's Title 33 Zoning Code under Chapter 33.440 "Greenway Overlay Zones." City Title 33 incorporates and implements the land use pattern defined in the Willamette Greenway Plan, and establishes use restrictions and development standards within the defined greenway along the Willamette River. Five greenway zones have been established on the City's Official Zoning Maps[14], each with its own purpose.

- River Natural (denoted with an "n" symbol): Intended to protect and conserve the land with scenic quality or valuable wildlife habitats.

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[12] State of Oregon, *Dredge and Fill Section 401 Water Quality Certification*. Available online at http://licenseinfo.oregon.gov/index.cfm?fuseaction=license_seng&link_item_id=14091
[13] State of Oregon, *Working in Waters of the State*. Available online at http://www.oregon.gov/dsl/PERMITS/Pages/index.aspx
[14] City of Portland Zone Maps available online at http://www.portlandoregon.gov/bps/30420.

- River Recreational (denoted with an "r" symbol): Encourages river-dependent and river related recreational uses.
- River General (denoted with a "g" symbol): Allows for development consistent with the base zoning.
- River Industrial (denoted with an "i" symbol): Promotes the development of river-dependent and river-related industries.
- River Water Quality (denoted with a "q" symbol): Protects water quality resources.

The River Industrial greenway overlay zone incorporates a majority of the Port's marine terminal properties along the Willamette, including T2, T4, and T5. As such, greenway requirements are expected to be applicable to the Port, unless the facilities have otherwise been defined by the City as pre-existing and exempt "non-conforming situations." Refer to Figure 4-5 for an overview of the locations of the greenway overlay zones, but during design review the Official Zoning Maps for the project site.

Greenway overlay zone requirements vary between the detailed zones and based on the location relative to a defined greenway setback within each zone (25 feet from top of riverbank in the River Industrial zone). Within the River Industrial zone, river-dependent and river-related land uses on sites that front the river are allowed by right. Other land uses may be allowed on these sites if approved through the Greenway Review process.

Within the River Industrial zone, river-dependent or river-related development may be allowed within the greenway setback if approved through the Greenway Review process. Outside of this setback but within the zone, development is not required to be river-dependent or river related, but is still subject to Greenway Review. Development must meet the standards defined in City Title 33 and Willamette River design guidelines in the Willamette Greenway Plan. Specific requirements include maximum floor area ratios (ratio of building floor area to site area), landscaping and native plant standards, and recreational trail and viewing requirements.[15]

Alterations to development in the River Industrial zone that are outside the following areas are exempt from Greenway Review:

- Greenway setback
- Riverward of the greenway setback
- Within 50 feet landward of the greenway setback
- Within 50 feet of the River Natural zoned land

In addition to the greenway overlay zones, the City has also defined environmental overlay zones (also known as "e-zones") in Title 33 (Chapter 33.430). Environmental overlay zones pertain to City-defined areas that have been inventoried and identified as having natural resource value. Generally the overlay zones are related to drainage ways, wetlands, lakes, and forests. There are two environmental overlay zones; the Environmental Protection overlay zone and the Environmental Conservation overlay zone, which are defined as follows.

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[15] City Code Title 33, Chapter 33.440 "Greenway Overlay Zones" (July 2010).

- Environmental Protection – Resources within the Environmental Protection overlay zone (denoted with a "p" symbol) are considered very significant and have been assigned value in the inventory and economic, social, environmental and energy (ESEE) analysis within the study area. Approval of development is atypical within the protection zone.
- Environmental Conservation – Resources within the Environmental Conservation overlay zone (denoted with a "c" symbol) are considered significant and are protected while allowing environmentally sensitive urban development.

Within the environmental overlay zones there are development standards, which are meant to set a clear limitation on disturbance within the resource area of the zone. Each defined environmental overlay zone boundary incorporates the designated resource area as well as a transition area serving as a buffer for the designated resource area from urban uses. The transition area surrounds the resource area, starting at the external boundary of the environmental overlay zone and extending 25 feet inside the boundary. Required development standards within the environmental overlay zone consists of specific standards for the transition area and the resource area. This includes general development standards that must be followed for all development and establishes additional standards for the following development types:

- Utilities
- Land divisions
- Property line adjustment
- Resource enhancement
- Rights-of-way improvements
- Stormwater outfalls
- Public recreational trails

For development within an environmental overlay zone, there are additional information requirements for the building or land development permit application regarding how the design incorporates the zones' development standards. The development standards include a limit on the disturbance area within the resource area of the environmental overlay zone; setbacks from the resource area of environmental protection zone and certain water bodies; and limitations on tree removal, slopes, planting, use of riprap and stormwater outfall pipe size. Compliance with all of the applicable development standards is required. An Environmental Review[16] is required in addition to the general permit application review for building or development applicants (through Bureau of Development Services [BDS]) if applicable development standards are unable to be met within the proposed design.

Key exemptions relating to development in environmental overlay zones are summarized below. Please see City Code for the complete list of potentially applicable exemptions.

- Environmental Overlay Zones – Activities exempt from following the development standards within the environmental overlay zone include the operation, maintenance, and repair of the following:

[16] City Code Title 33, Chapter 33.730, "Quasi-Judicial Procedures" details the review procedure based upon what type is prescribed within Chapter 33.430 "Environmental Review."

- Irrigation systems
- Stormwater management systems
- Pumping stations
- Erosion control and soil stabilization features
- Operation, maintenance, and repair of drainage facilities, flood control structures, and conveyance channels that are managed by Drainage Districts as defined in ORS 547, and where the activity is conducted or authorized by the Drainage District
- Development over existing paved surfaces that are over 50 feet from any identified wetland or waterbody

Refer to Figure 4-6 for an overview of the locations of the environmental overlay zones, but during design the designer should review the Official Zoning Maps[17] for the project site.

City Code Titles 24 and 33 are among the codes and rules enforced by the City's Bureau of Development Services (BDS) through its development review process. Therefore, Port development projects adjacent to flood hazard areas or resource areas are subject to these zoning requirements and City review. This holds true unless specifically exempted through City Code or within an IGA. One example of exemption to the City Code is the PDX airside (which includes airfield and all related development), where the requirements within City Code Title 33 have been waived through an IGA with the City.[18]

C.7 Groundwater Protection

Groundwater is a natural resource that is relied upon as a source of drinking water for approximately half of the country and also serves as a water supply for industrial and agricultural applications. Groundwater is protected at a federal level under the Safe Drinking Water Act of 1974, as amended in 1986 and 1996 (SDWA). The SDWA led to various groundwater protection measures, including the Wellhead Protection (WHP) and Underground Injection Control (UIC) Programs, which are implemented at the state level by DEQ. These programs, which are described in further detail below, are intended to minimize the potential for the contamination of groundwater resources due to the infiltration of surface runoff.

C.7.1 Underground Injection Control (UIC) Systems

The DEQ UIC Program regulates UIC systems under OAR 340 Division 44[19]. DEQ defines UIC systems as "devices that place fluids below the ground."[20] Infiltration BMPs may be regulated as Class V UIC systems if they meet particular criteria defined by DEQ. An overview of UIC systems classification pertaining to infiltration BMPs is provided here for reference. For additional details related to current UIC-qualifying criteria and approval requirements, please refer to the DEQ website or regulatory code under OAR 340 Division 44.

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[17] City of Portland Zone Maps available online at http://www.portlandoregon.gov/bps/30420.
[18] *Intergovernmental Agreement for Natural Resources Related to the Airport Futures Project* (2011). Available online at http://www.pdxairportfutures.com/Documents.aspx.
[19] OAR 340 Division 44, "Construction and Use of Waste Disposal Wells or Other Underground Injection Activities" (September 2001). Available online at http://www.deq.state.or.us/regulations/rules.htm.
[20] Oregon Department of Environmental Quality, "Underground Injection Control Program," http://www.deq.state.or.us/wq/uic/uic.htm (accessed August 19, 2013).

In general, infiltration BMPs that provide surface infiltration, including infiltration basins and trenches, are typically not considered UIC systems as long as the depth does not exceed the length or width along the surface.[21] BMPs that provide for subsurface infiltration, such as drywells, soakage trenches, and facilities that use a perforated pipe to directly inject stormwater into groundwater may qualify as UIC systems. UIC systems that only inject stormwater runoff from rooftops are authorized and therefore do not need to be approved by DEQ, but are still required to be inventoried with DEQ. The UIC Program requires potential UIC systems to be registered and approved by DEQ. Among other requirements, approval of a proposed UIC system (other than qualifying rooftop systems) requires a demonstration that no other method of stormwater disposal is appropriate. The Infiltration SWM Standard in Chapter 4 covers the minimum requirements for infiltration as part of stormwater management design where applicable. Chapter 6 and the BMP factsheets provide more information on implementing infiltration within BMP design.

C.7.2 Columbia South Shore Well Field Wellhead Protection Area (WHPA)

In the City of Portland, the WHPA is a groundwater drinking water supply area that is administered by the Portland Water Bureau under the City's Well Field Protection Program. The goal of the program is to protect drinking water resources through source controls, pollution prevention procedures and prevention of infiltration into the ground. Portland Water Bureau requires compliance with the *Columbia South Shore Well Field Wellhead Protection Program Reference Manual*,[22] which includes containment design standards for areas within the WHPA that handle and store hazardous materials, oil and fuel. Cascade Station (CAS) and Portland International Center (PIC)[23] are located within the WHPA. The Source Controls SWM Standard within Chapter 4 identifies key requirements for source control as part of stormwater management design.

C.8 Portland Harbor Superfund

Superfund is the environmental program established under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) of 1980 (as amended) to address sites that have been defined by the EPA as "abandoned hazardous waste sites."[24] Under this program, EPA performs a preliminary assessment and site inspection (PA/SI) to determine site conditions and if there is a need for immediate response actions. Next, the EPA places non-emergency sites on the National Priorities List (NPL) for future long-term cleanup. After this, the EPA determines the responsible parties and enforces the long-term cleanup process against the parties, which includes the following milestones[25]:

- Remedial Investigation and Feasibility Study (RI/FS) – Assesses the site on a more detailed level and evaluates methods of treatment and cleanup.

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[21] http://www.deq.state.or.us/wq/pubs/factsheets/uic/uicstormwater.pdf

[22] Portland Water Bureau, *Columbia South Shore Well Field Wellhead Protection Program Reference Manual*, (2010), available online at http://www.portlandoregon.gov/water/29880.

[23] CAS and PIC which have been included within the Portland International Airport (PDX) area, as described within Chapter 1.

[24] http://www.epa.gov/superfund/about.htm

[25] http://www.epa.gov/superfund/cleanup/index.htm

- Records of Decision (ROD) – Details the selected cleanup alternatives.
- Remedial Design and Remedial Action (RD/RA) – Preparation of plans and specifications for cleanup and performing cleanup.
- Construction Completion – Construction of cleanup alternatives are completed but not necessarily the achievement of the final level of cleanup.
- Post Construction Completion – This includes additional actions to ensure long-term protection of the site and includes long-term actions, operation and maintenance, institutional controls, reviews, and remedy optimization.
- NPL Delete – Once the site is confirmed to have achieved all cleanup goals it is then removed from the NPL.
- Site Reuse and Redevelopment – Working on returning the sites safely to the community for use without impacting the remedy.

A portion of the Willamette River from river miles 1.9 to 11.8, defined as the Portland Harbor Superfund Site, was placed on the NPL in December 2000. The Site's preliminary assessment performed by the EPA determined that the water and sediments along the Site were contaminated with hazardous substances including "heavy metals, polychlorinated biphenyls (PCBs), polynuclear aromatic hydrocarbons (PAH), dioxin, and pesticides."[26]

The Portland Harbor Superfund Site is currently in the draft RI/FS phase. This step is being performed by a coalition of potentially responsible parties, known as the Lower Willamette Group (LWG). The City and the Port are both part of the LWG, among other parties. EPA is leading the effort to investigate the extent and potential sources of contamination within the water (e.g., contaminated sediments), while DEQ is leading the effort to investigate potential upland sources of contamination (e.g., stormwater). For more background information on the progress of the Portland Harbor Superfund please see EPA Region 10 webpage.[27] The DSM requirements are not specifically related to any Superfund efforts at this time.

C.9 Stormwater Management Requirements at Airports

C.9.1 Federal Aviation Administration (FAA) Advisory Circulars

Stormwater management at PDX must comply with FAA Advisory Circulars (ACs) that provide standards for compliance with the FAA's Federal Aviation Regulations (FARs). As such, PDX is the only Port facility within the Urban Services Boundary that is required to comply with FAA ACs. As stated within the "Applicability" or "To whom does this AC apply" section of ACs, use of the ACs and the standards, practices, and recommendations that are within the ACs is required for airports that receive federal grants.

The FAA AC for *Airport Drainage Design* (AC 150/5320-5D) is focused on the design and maintenance of airport stormwater drainage systems. The primary objective of this AC is to provide for safe passage of vehicles and operation of the airport facility in accordance with

[26] EPA Region 10: the Pacific Northwest, "Portland Harbor Superfund Site," http://yosemite.epa.gov/R10/CLEANUP.NSF/sites/ptldharbor.
[27] EPA Region 10: the Pacific Northwest, "Portland Harbor Superfund Site," http://yosemite.epa.gov/R10/CLEANUP.NSF/sites/ptldharbor.

design storm criteria for conveyance sizing and ponding. Port criteria for drainage system design are included in Chapter 5. Designers are responsible for complying with DSM design criteria as well as detailed FAA requirements in the current version of this FAA AC.

One of the FAA's major safety concerns is the management of hazardous wildlife attractants to minimize the risk for wildlife strikes. The AC for *Hazardous Wildlife Attractants On or Near Airports* (AC 150/5200-33[28]) prescribes requirements for mitigating the potential for wildlife impacts at an airport due to various land uses, including stormwater management facilities. Hazardous wildlife strikes and near-strikes have the potential to result in the following impacts to airport operations and safety:

- Injuries and fatalities
- Aircraft damage
- Aircraft downtime
- Operations interruptions
- Operations downtime
- Event investigations
- Increased monitoring and managing of hazards

The AC is directly applicable to airports, but also recommended for developers of projects near airports. For airports serving turbine-powered aircraft, such as PDX, the AC requires a 10,000-foot separation between an airport's Air Operations Area (AOA) and identified wildlife attractants. It also establishes a minimum separation distance of 5 miles between the AOA and attractants with the potential to cause wildlife movement into an airport's approach or departure airspace. Although there is a potential for wildlife attractants to exist at Port facilities other than PDX, all other Port-owned facilities fall outside of the 10,000-foot separation distance.

C.9.2 PDX Wildlife Hazard Management Plan

In addition to the compliance guidance provided by the FAA ACs, PDX has a Wildlife Hazard Management Plan (WHMP).[29] The WHMP focuses on avian wildlife, because bird strikes are statistically a higher risk to aircraft than terrestrial wildlife, especially during departure and landing operations. The Port understands that the location of PDX adjacent to the Columbia River makes it impossible to completely eliminate the risk of bird strikes, but the goal is to bring risk down to a manageable level. The Port implements several adaptive management strategies to deter birds and other wildlife which manages the current risk level without having to retrofit existing structures. In order to prevent new hazardous wildlife attractants, the WHMP requires that incorporation of wildlife deterrent concepts be brought in during the early phases of projects for compatible land-use planning.

Within the WHMP, the 10,000-foot separation distance at PDX has been divided into three zones, as shown on Figure 4-2 and listed below:

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[28] Advisory Circular 150/5200-33B was in effect and 150/5200-33C was in draft form at the time of Manual release.

[29] *Portland International Airport Wildlife Hazard Management Plan* (2009).), available online at http://www.portofportland.com/PDX_WldLife_Mngmnt.aspx.

- Primary Zone
- Intermediate Zone
- Secondary Zone

The zones assist with management prioritization. Each zone has standards to follow for stormwater management facilities in order to prevent creating new hazardous wildlife attractants. The key standards pulled from the PDX WHMP, FAA ACs, and ORS 836.623 are detailed within the Hazardous Wildlife Attractants SWM Standard in Chapter 4.

Appendix D

Groundwater and Soil On-site Testing Procedures

APPENDIX D: GROUNDWATER AND SOIL ON-SITE TESTING PROCEDURES

For purposes of the DSM, the Port has adopted select methods for infiltration testing and the analysis of seasonal high groundwater elevations. Designers are required to follow these testing procedures as applicable to determine the feasibility of promoting infiltration on a project site.

The required methodology for depth to groundwater investigations and infiltration testing for small-scale projects (less than 1 acre drainage area to infiltration BMP) was adopted from the City of Portland Stormwater Management Manual (SWMM) Section 2.3.6. The required methodology for large-scale infiltration testing (infiltration BMP drainage area greater than or equal to 1 acre) was adopted from the Stormwater Management Manual for Western Washington (SWMMWW) Section 3.3.6 of Volume III (Large Scale Pilot Infiltration Test).

The excerpts from the City SWMM and SWMMWW include occasional text references to documents, criteria, and review processes that are not directly applicable for the DSM. Please reference the table below for the clarification of requirements that are applicable to the DSM. As noted in the table, Section D.1 below prescribes DSM-specific requirements for calculating the design infiltration rate that supersede select City SWMM and SWMMWW requirements.

City SWMM Excerpt Original Text	Clarification of Port DSM Applicability
”Depth to Groundwater Investigation”,	For the purposes of the DSM, this investigation is required for UIC systems, as well as all infiltration BMPs.
Simplified Approach.	Not applicable to the DSM.
Presumptive and Performance Approaches.	Testing methodology associated with City Presumptive and Performance Approaches are applicable to the DSM.
References to Chapter sections.	Section references do not refer to the DSM.
References to tables or figures.	Applicable for only within Appendix D.
Factors of Safety and Table 2-2.	This section and table shall be replaced with Section D.1 below, Calculating the Design Infiltration Rate.
SWMMWW Excerpt Original Text	**Clarification of Port DSM Applicability**
Mounding analysis	Refer to SWMMWW Section 3.3.8 Step 10.
Application of correction factors (Sections 3.3 and 3.4 references)	Correction factors shall be calculated using D.1 below, Calculating the Design Infiltration Rate.

D.1 Calculating the Design Infiltration Rate

The *Santa Barbara Stormwater BMP Guidance Manual* (2008) provides a method for determining the design infiltration rate by applying correction factors to the field measured infiltration rate. This methodology is recommended although the Port may approve the use of other methods used to determine appropriate correction factors. These factors take into account uncertainty in measurement procedure, depth to water table or impermeable strata, infiltration facility geometry, and long term reductions in permeability due to biofouling and accumulation of fines, and ensure that the design infiltration rate is always less than the observed field infiltration rate.

The following is the given method within the *Santa Barbara Stormwater BMP Guidance Manual* (2008)[1] and provided here for reference.

Equation D-1: Determination of Design Infiltration Rate from On-Site Measurements[2]

$$\mathbf{k_{design}} = \mathbf{k_{measured}} \times \mathbf{F_{testing}} \times \mathbf{F_{plugging}} \times \mathbf{F_{geometry}}$$

k_{design}=design infiltration rate (in/hr)
$k_{measured}$=field measures infiltration rate (in/hr)
$F_{testing}$=correction factor for testing method
$F_{plugging}$=correction factor for soil plugging
$F_{geometry}$=correction factor for facility geometry

"$F_{testing}$ takes into account uncertainties in the testing method and is 0.3 for small-scale percolation tests and 0.5 for large-scale testing.

$F_{plugging}$ accounts for reductions in infiltration rates over the long term caused by plugging of soils. The factor is:

- 0.7 for loams and sandy loams
- 0.8 for fine sands and loamy sands
- 0.9 for medium sands
- 1.0 for coarse sands or cobbles or for any facility preceded by a full specification filter strip or vegetated swale.

$F_{geometry}$ accounts for the influence of facility geometry and depth to groundwater table or impervious strata on the actual infiltration rate. $F_{geometry}$ must be between 0.25 and 1.0 as determined by the following equation:"

Equation D-2: Correction Factor to Account for Facility Geometry[3]

$$\boldsymbol{F_{geometry} = 4D/w + 0.05}$$

Where:

D	=	depth from the bottom of the facility to the maximum seasonally high groundwater table or nearest impervious layer, whichever is less (ft)
W	=	width of the facility (ft)

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[1] Geosyntec Consultants, "City of Santa Barbara Storm Water BMP Guidance Manual" (June 2008).
[2] Chapter 6, Equation 6-1 of the "City of Santa Barbara Storm Water BMP Guidance Manual" (June 2008).
[3] Chapter 6, Equation 6-2 of the "City of Santa Barbara Storm Water BMP Guidance Manual" (June 2008).

2.3.6 Infiltration and Soil Requirements

This section presents information about depth to groundwater investigations, infiltration testing, and the specification for the blended soil used in vegetated stormwater facilities.

Depth to Groundwater Investigation

Several areas within the City of Portland have known shallow groundwater. Within areas of known or suspected shallow groundwater, additional information about the depth to groundwater (DTW) may be required to ensure that a proposed underground injection control (UIC) system meets minimum separation distances between the bottom of a UIC and seasonal high groundwater. Minimum separation distances are required by Oregon Department of Environmental Quality (DEQ) under UIC requirements. The minimum separation distance between the bottom of the UIC and seasonal high groundwater is 5 feet.

When a public or private UIC is proposed within areas of known or suspected shallow groundwater, a site specific investigation may be required to determine the seasonal high depth to groundwater. A DTW investigation may be required for areas where the estimated depth to seasonal high groundwater is estimated to be less than 50 feet of ground surface. To identify areas of shallow groundwater within the City please consult the map which the City of Portland derived from the Estimation of Depth to Ground Water and Configuration of the Water Table in the Portland, Oregon Area, prepared by the United States Geological Survey (USGS). This map is available online in two locations:

- Through www.PortlandMaps.com.
- Through USGS mapping at http://or.water.usgs.gov/projs_dir/puz/.

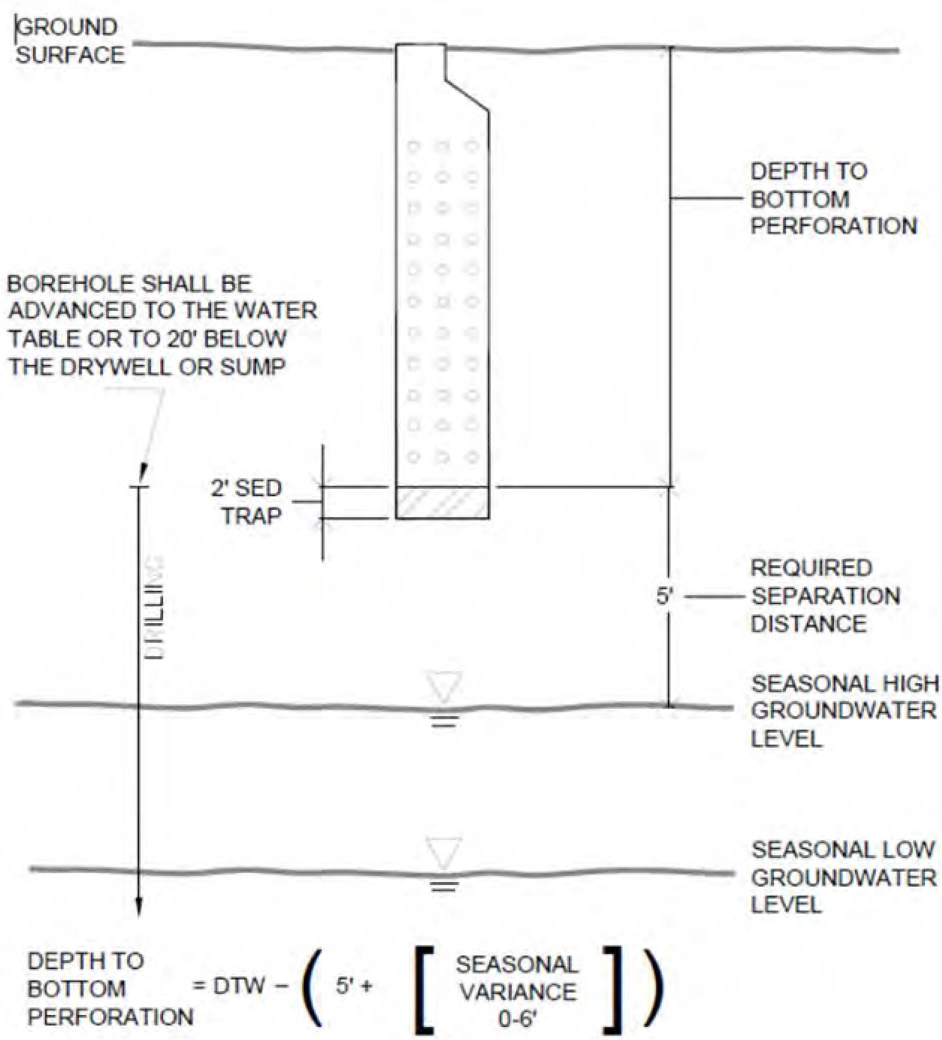
Depth to Groundwater Investigation Requirements

The DTW investigation requires sufficient time to plan for and perform the necessary steps to collect a reliable measurement, including obtaining permits, performing utility locates, borings, piezometer/well installation, collection of water level measurements, and decommissioning of the monitoring well. The DTW investigation, including design, installation oversight, water measurements, and decommissioning, must be performed by an Oregon licensed registered geologist (RG), certified engineering geologist (CEG), or professional engineer (PE) with experience in hydrogeologic investigations and well design and installation; the investigation may include either the installation of a temporary piezometer(s) or groundwater monitoring well(s). The qualified professional is responsible for developing an appropriate scope of work to document the DTW, including:

- Determining the number and location(s) of the DTW measurements needed to address project objectives. It is recommended, but not required, to have each piezometer or well location surveyed to a datum.
- Determining the appropriate method for obtaining DTW measurements (e.g., piezometer or monitoring well).
- Determining the appropriate depth of the boring(s). Boring depth must be a minimum of 20 feet deeper than the proposed UIC depth.
- Observing and describing soils encountered during drilling.
- Developing an appropriate well or piezometer design.
- Ensuring that construction and abandonment of piezometer or monitoring well complies with Oregon Administration Rules 690-240.
- Obtaining depth to groundwater measurements (see Figure 2-32 for an illustration of the process). If groundwater is not encountered (e.g. saturated conditions are not observed, no water seeps are observed) within 20 feet of the proposed bottom of the UIC, a piezometer or monitoring well does not need to be installed.
- Estimating the measured DTW to be representative of the “groundwater seasonal high,” based on available data and best professional judgment.
- Documenting the procedures used and the results of the DTW investigation.
- Submitting a signed and stamped DTW investigation report.

To the extent practicable, DTW measurements should be obtained in the immediate vicinity (less than or equal to 75 feet) of the proposed UIC. If high-quality shallow groundwater level data is available (e.g., piezometer, monitoring well, drinking water well, irrigation well) within 200 feet of the proposed UIC location, this data may be considered in lieu of site-specific data.

Figure 2-32. Depth to Groundwater Investigation



Piezometer/Well Borehole Drilling and Installation

Continuous soil sampling is recommended to allow detailed characterization of subsurface soil and identification of groundwater depth. The RG, CEG, or PE must prepare and submit a detailed boring log of subsurface conditions. Soil boring logs should be in accordance with the *Standard Practice for Description and Identification of Soils* (Visual-Manual Procedure) (ASTM D2488-00). Borings must be advanced to the groundwater level, or to a minimum of 20 feet below the proposed total depth of the UIC or 10 feet below a proposed UIC of 5 feet or less. If water is encountered in the boring, it must be noted on the drilling log.

The appropriate drilling method should be selected by the RG, CEG, or PE in conjunction with the driller, based on anticipated site-specific geologic and hydrogeologic conditions, anticipated boring depth, site accessibility, availability of equipment, and piezometer/well design. All equipment placed into the boreholes must be properly decontaminated prior to use.

Any investigation-derived material (e.g., soil cutting, water, personal protective gear) generated during drilling activities must be properly contained, characterized, and disposed in accordance with applicable state and federal regulations. Soil and water disposal must be documented.

Depth to Water Measurements

Following piezometer/well installation, water levels must be allowed to equilibrate for a minimum of 24 hours in fine-grained soils. After the water level has stabilized, an electronic water level indicator or a weighed tape should be used to measure the depth to water. Measurements should be made relative to ground surface and to the nearest 1/8 inch (~0.01 feet). The observer must make at a minimum two measurements over a period of about 15 minutes to show the results are static.

Estimating Depth to Seasonal High Groundwater

The site-specific DTW measurement must be used to estimate the depth to seasonal high groundwater. Seasonal water-table fluctuations were evaluated in the *Estimation of Depth to Ground Water and Configuration of the Water Table in the Portland, Oregon Area* report, prepared by the USGS and used to determine the seasonal correction factor (SCF). The SCF represents a long-term measurement of the seasonal water-table fluctuations. The SCF was set at 6 feet, using the USGS estimated mean of observed seasonal water table fluctuations for the unconsolidated sedimentary aquifer. To correct for seasonal variation, the SCF used to estimate depth to seasonal high groundwater is applied during periods of seasonal groundwater lows (late fall) and water level transition (summer and winter months). In March through May (seasonal high groundwater), no correction is added.

To correct site-specific DTW measurements to seasonal high DTW estimates, the following correction should be made:

$DTW_{SH} = DTW_{SS} - SCF$

Where: DTW_{SH} = Estimated seasonal high depth to groundwater (feet)

DTW_{SS} = Measured site-specific depth to groundwater (time specific)

SCF = Seasonal correction factor

6 feet for measurements June through February

0 feet for measurements in March through May

If water is not encountered in the soil boring, advanced 20 feet below the proposed UIC completion depth, it must be documented on the boring log and in the investigation report. In this case, the depth to water is assumed to be outside the range of seasonal fluctuation; the minimum required separation distance for the proposed bottom of the UIC to seasonal high groundwater is therefore met by default. The borehole may be decommissioned immediately, in accordance with OAR 690-240.

Decomissioning

Borings, piezometers, temporary wells, and wells must be abandoned in accordance with OAR 690-240. Specific decommissioning procedures must be determined by a licensed driller and the registered geologist or professional engineer.

Minimum Requirements for DTW Investigation Report

The DTW Investigation report must contain, but is not limited to:

- A copy of the State of Oregon Monitoring Well Log Report or Geotechnical Hole Report, as appropriate.
- A map showing the final location of each well or piezometer and tax lot boundaries.
- Latitude and longitude of each well or piezometer.
- Description of field procedures (drilling method, sampling method, development method, depth to groundwater measurements, etc.).
- Measured water level to the nearest hundredth of a foot.
- Detailed soils log prepared by, or under the direct supervision of, the RG, CEG, or PE.

- Construction diagram for each well/piezometer.
- Summary of groundwater depth measurements (depth measured, elevation, date, time).
- Discussion/basis for estimation of seasonal high depth to groundwater measurement.
- Construction and investigation reports stamped and signed by the RG, CEG, or PE.

Depth to Groundwater Investigation Report Submittal and Usage

Two copies of the OWRD well or piezometer construction report and the signed and stamped DTW investigation report must be submitted with the development permit application to the City and to DEQ with the UIC rule authorization application, which can be obtained at http://www.deq.state.or.us/wq/uic/forms.htm.

The corrected site-specific depth to seasonal high groundwater must be used to verify that the proposed UIC will meet the separation distances set by DEQ to obtain rule authorization for private UICs or ensure compliance under the City's WPCF permit. If separation distances cannot be met, an alternative design must be developed that meets separation distance requirements.

Infiltration Testing

To properly size and locate stormwater management facilities, it is necessary to characterize the soil infiltration conditions at the location of the proposed facility. All projects that propose onsite infiltration must evaluate existing site conditions and determine:

- If the infiltration rate is adequate to support the proposed stormwater management facility (satisfied through the Simplified Approach Infiltration Test), or
- The design infiltration rate prior to facility design (satisfied through Presumptive or Performance infiltration testing conducted by a qualified professional).

The following sections provide the approved standard infiltration testing specifications.

Minimum Number of Required Tests

The number of required infiltration tests may vary by type of development proposal or by design approach.

Land Division

- A total of two infiltration tests for every 10,000 square feet of lot area available for new or redevelopment.
- An additional test for every 10,000 square feet of lot area available for new or redevelopment.
- At least one test for any potential street facility.
- One test for every 100 lineal feet of infiltration facility.
- No more than five tests are required per development (at the discretion of the qualified professional assessing the site, as well as the City of Portland).

Tests performed for a proposed land division can be used at the building permit stage as long as the results of the test are submitted with the separate applications and were conducted within twenty-four months prior to the date the plans were submitted for review.

Building Permits

- The Simplified Approach requires one infiltration test for every proposed facility.
- The Presumptive and Performance Approaches require at least one test for any proposed street facility; require one test for every 100 lineal feet of proposed

infiltration facility; and the number of tests is at the discretion of the qualified professional assessing the site, as well as the City of Portland.

Where multiple types of facilities are used, it is likely that multiple tests will be necessary, since an infiltration test can test only a single location. It is highly recommended to conduct an infiltration test at each stratum used. BES staff may require additional testing. If additional testing is required during plan review, the applicant must provide 24-hour notice to BES staff and specify the time and location that the test will take place.

Simplified Approach Infiltration Test Requirements

The Simplified Approach provides a design approach that can be used by a nonprofessional for design of simple stormwater systems on small projects. This method, the Simplified Approach Infiltration Test, is applicable only to projects on private property with less than 10,000 square feet of new or redeveloped impervious area (see Section 2.2.1). The results of infiltration testing must be documented on the Simplified Approach Form (see Section 2.4.3).

On a site with steep slopes or shallow groundwater, BES may require a geotechnical report in order to evaluate the suitability of the proposed facility and its location. BES staff may also require an encased falling head or a double-ring infiltrometer infiltration test (see below for instructions) in order to verify that the facilities designed under the Simplified Approach are appropriate.

The Simplified Approach Infiltration Test cannot be used to find a design infiltration rate. The intent of the Simplified Approach Infiltration Test is to determine whether or not the local infiltration rate is adequate (2 inches/hour or greater) for the predesigned stormwater facilities described in Section 2.3 (infiltration swales, basins, planters, drywells, and trenches). The Simplified Approach Infiltration Test does not need to be conducted by a licensed professional.

Simplified Approach Infiltration Test Procedure

1. A Simplified Approach Infiltration Test is required at the location of where the facility is proposed or within the immediate vicinity. The test must be conducted in the twenty-four months prior to the date the plans are submitted for review.

2. Excavate a test hole to the depth of the bottom of the infiltration system. The test hole can be excavated with small excavation equipment or by hand using a shovel, auger, or post hole digger. If a layer hard enough to prevent further excavation is encountered, or if noticeable moisture/water is encountered in the

soil, stop and measure this depth from the surface and record it on the Simplified Approach Form. Proceed with the test at this depth.

3. Fill the hole with water to a height of about 6 inches from the bottom of the hole, and record the exact time it takes for the water to draw down to the bottom of the test pit. Check the water level at regular intervals (every 1 minute for fast-draining soils to every 10 minutes for slower-draining soils) for a minimum of 1 hour or until all of the water has infiltrated. Record the distance the water has dropped from the top edge of the hole for each time interval.
4. Repeat this process two more times, for a total of three rounds of testing. These tests should be performed as close together as possible to accurately portray the soil's ability to infiltrate at different levels of saturation. The third test provides the best measure of the infiltration rate at saturated conditions.
5. For each test pit required, submit all three testing results with the date, duration, drop in water height, and conversion into inches per hour.

If the result from the third round of testing is greater than 2.0 inches per hour, the applicant can proceed with Simplified Approach facility design (where applicable). The Simplified Approach requires one infiltration test for every proposed facility. If the applicant would like to use an infiltration rate for design purposes, a Presumptive or Performance Infiltration Test must be conducted.

Presumptive and Performance Infiltration Test Requirements
The Presumptive Approach (Section 2.2.2) or Performance Approach (Section 2.2.3) must be used for all public and private developments where the Simplified Approach is not applicable. The qualified professional must exercise judgment in the selection of the infiltration test method. The three infiltration testing methods used to determine a design infiltration rate are:

- Open pit falling head.
- Encased falling head.
- Double-ring infiltrometer.

Where satisfactory data from adjacent areas using similar infiltration testing methods is available that demonstrates infiltration testing is not necessary, the infiltration testing requirement may be waived by the BES design reviewer. A recommendation for forgoing infiltration testing must be submitted in a report which includes supporting data and is stamped and signed by the project geotechnical engineer or project geologist.

Testing Criteria

- Testing must be conducted or overseen by a qualified professional. This professional must be a Professional Engineer (PE) or Registered Geologist (RG) licensed in the State of Oregon.
- The depth of the test must correspond to the facility depth. If a confining layer, or soil with a greater percentage of fines, is observed during the subsurface investigation to be within 4 feet of the bottom of the planned infiltration system, the testing should be conducted within that confining layer. Based on DEQ requirements and conformance with any required Depth to Groundwater Investigation Requirements, the boring log must be continued to a depth adequate to show separation between the bottom of the infiltration facility and the seasonal high groundwater level. (The boring depth will vary, based on facility depth.)
- Tests must be performed in the immediate vicinity of the proposed facility. Exceptions can be made to the test location provided the qualified professional can support that the strata are consistent from the proposed facility to the test location. The test must be conducted in the twenty-four months prior to the date the plans were submitted for review.
- Infiltration testing should not be conducted in engineered or undocumented fill.

Factors of Safety

Table 2-2 lists the minimum allowable factors of safety applied to field obtained infiltration rates for use in stormwater system design under the Presumptive and Performance design approaches. To obtain the infiltration rate used in design, divide the infiltration rate measured in the field by the factor of safety. The factor of safety used in design should be chosen by collaboration between the geotechnical engineer or geologist overseeing the infiltration testing and the civil engineer designing the stormwater management system. Determination of the factor of safety should include consideration of project specific conditions such as soil variability, testing methods, consequences of system failure, complexity of proposed construction, etc.

Table 2-2. Minimum Allowable Factor of Safety

Test Method	Minimum Required Factor of Safety
Open Pit Falling Head	2
Encased Falling Head	2
Double-Ring Infiltrometer	1

Presumptive and Performance Infiltration Testing Instructions

The following sections provide instructions for completing the open pit falling head infiltration test, the encased falling head infiltration test, and the double-ring infiltrometer infiltration test.

Open Pit Falling Head Procedure

The open pit falling head procedure is performed in an open excavation and therefore is a test of the combination of vertical and lateral infiltration.

1) Excavate a hole with bottom dimensions of approximately 2 feet wide by 2 feet deep into the native soil to the elevation of the proposed facility bottom. The test can be conducted in a machine-excavated pit or a hand-dug pit using a shovel, post hole digger, or hand auger. If smooth augering tools or a smooth excavation bucket are used, scratch the sides and bottom of the hole with a sharp pointed instrument, and remove the loose material from the bottom of the test hole.
2) Fill the hole with clean water a minimum of 12 inches, and maintain this depth of water for at least 4 hours (or overnight if clay soils are present) to presoak the native material.
3) Determine how the water level will be accurately measured. The measurements should be made with reference to a fixed point. A lath placed in the test pit prior to filling or a sturdy beam across the top of the pit are convenient reference points. The tester and excavator should conduct all testing in accordance with OSHA regulations.
4) After the presaturation period required by #2 above, refill the hole with water to 12 inches and record the draw-down time. Alternative water head heights may be used for testing provided the presaturation height is adjusted accordingly and the water head height used in infiltration testing is no more than 50 percent of water head height in the proposed stormwater system during the design storm event. Measure the water level to the nearest 0.01 foot (⅛ inch) at 10-minute

intervals for a total period of 1 hour (or 20-minute intervals for 2 hours in slower draining soils) or until all of the water has drained. In faster draining soils (sands and gravels), it may be necessary to shorten the measurement interval in order to obtain a well defined infiltration rate curve. Constant head tests may be substituted for falling head tests at the discretion of the professional overseeing the infiltration testing.

5) Repeat the infiltration test until the change in measured infiltration rate between two successive trials is no more than 10 percent. The trial should be discounted if the infiltration rate between successive trials increases. At least three trials must be conducted. After each trial, the water level must be readjusted to the 12 inch level. Enter results into the data table (see Table 2-3 for an example infiltration test table and Table 2-4 for a blank table).

6) The average infiltration rate over the last trial should be used to calculate the design infiltration rate without a factor of safety applied. Alternatively, the infiltration rate measured over the range of water head applicable to the project stormwater system design may be used at the discretion of the professional overseeing the testing. The final rate must be reported in inches per hour.

7) Upon completion of the testing, the excavation must be backfilled.

8) For very rapidly-draining soils, it may not be possible to maintain a water head above the bottom of the test pit. If the infiltration rate meets or exceeds the flow of water into the test pit, approximate the area over which the water is infiltrating, measure the rate of water discharging into the test pit (using a water meter, bucket or other device), and calculate the infiltration rate by dividing the rate of discharge (cubic inches per hour) by the area over which it is infiltrating (square inches). A maximum infiltration rate of 20 inches per hour can be used in stormwater system design with this type of infiltration test..

Encased Falling Head Procedure

The encased falling head procedure is performed with a 6-inch diameter casing that is embedded approximately 6 inches into the native soil. The goal of this field test is to evaluate the vertical infiltration rate through a 6-inch plug of soil, without allowing any lateral infiltration. The test is not appropriate in gravelly soils or in other soils where a good seal with the casing cannot be established.

1) Embed a solid 6-inch diameter casing into the native soil at the elevation of the proposed facility bottom (see Figure 2-33). Ensure that the embedment provides a good seal around the pipe casing so that percolation will be limited to the 6-

inch plug of the material within the casing. This method can also be used when testing within hollow stem augers, provided the driller and tester are reasonably certain that a good seal has been achieved between the soil and auger.

2) Fill the pipe with clean water a minimum of 1 foot above the soil to be tested, and maintain this depth for at least 4 hours (or overnight if clay soils are present) to presoak the native material. Any soil that sloughed into the hole during the soaking period should be removed. In sandy soils with little or no clay or silt, soaking is not necessary. If after filling the hole twice with 12 inches of water, the water seeps completely away in less than 10 minutes, the test can proceed immediately.

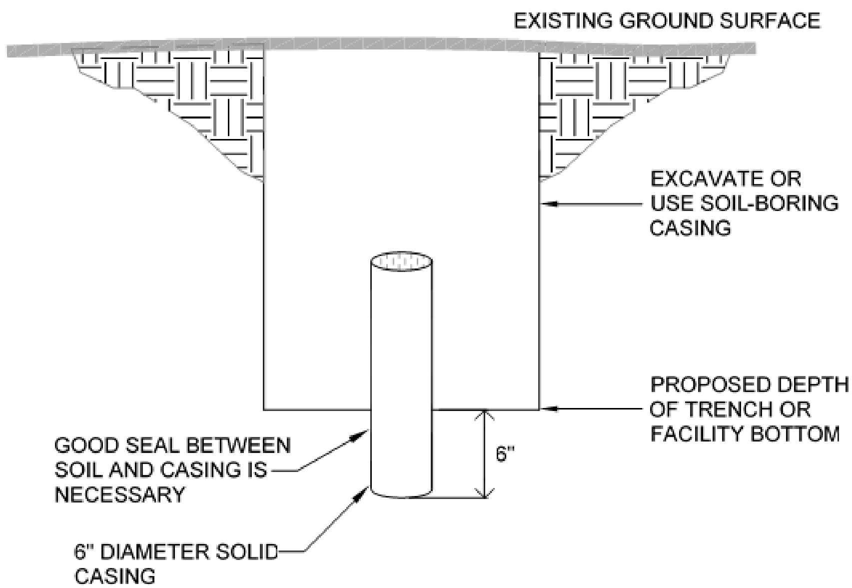
3) To conduct the first trial of the test, fill the pipe to approximately 12 inches above the soil and measure the water level to the nearest 0.01 foot (⅛ inch). Alternative water head heights may be used for testing provided the presaturation height is adjusted accordingly and the water head height used in infiltration testing is 50 percent or less than the water head height in the proposed stormwater system during the design storm event. The level should be measured with a tape or other device with reference to a fixed point. The top of the pipe is often a convenient reference point. Record the exact time.

4) Measure the water level to the nearest 0.01 foot (⅛ inch) at 10-minute intervals for a total period of 1 hour (or 20-minute intervals for 2 hours in slower soils) or until all of the water has drained. In faster draining soils (sands and gravels), it may be necessary to shorten the measurement interval in order to obtain a well defined infiltration rate curve. Constant head tests may be substituted for falling head tests at the discretion of the professional overseeing the infiltration testing. Successive trials should be run until the percent change in measured infiltration rate between two successive trials is minimal. The trial should be discounted if the infiltration rate between successive trials increases. At least three trials must be conducted. After each trial, the water level is readjusted to the 12 inch level. Enter results into the data table (see Table 2-3 for an example infiltration test data table and Table 2-4 for a blank data table).

5) The average infiltration rate over the last trial should be used to calculate the unfactored infiltration rate. Alternatively, the infiltration rate measured over the range of water head applicable to the project stormwater system design may be used at the discretion of the professional overseeing the testing. The final rate must be reported in inches per hour.

6) Upon completion of the testing, the casing should be pulled and the test pit backfilled.

Figure 2-33. Encased Falling Head Illustration



Double-Ring Infiltrometer Test

The double-ring infiltrometer test procedure should be performed in accordance with ASTM 3385-94. The test is performed within two concentric casings embedded and sealed to the native soils. The outer ring maintains a volume of water to diminish the potential of lateral infiltration through the center casing. The volume of water added to the center ring to maintain a static water level is used to calculate the infiltration rate. The double-ring infiltrometer is appropriate only in soils where an adequate seal can be established.

Infiltration Test Report Requirements

If an Infiltration Test Report is required under the Simplified Approach, it must be submitted within two weeks of BES staff request. For Presumptive and Performance Approaches, the Infiltration Test Report must be attached to the project's Stormwater Management Report. The following information must be included in the Infiltration Testing Report:

- Statement of project understanding (proposed stormwater system).
- Name, contact information, professional license information and qualifications of the person conducting the infiltration test.
- Summary of subsurface conditions encountered, including soil textures and the depth that they were found.
- Summary of pre-saturation timing.
- Summary of infiltration testing including location and number of tests and testing method used. Discussion of how the tests were performed (i.e. pipe type or diameter or test pit dimensions).
- Infiltration testing results in inches per hour for each interval as well as the average for the entire testing period
- Recommended design infiltration rate.
- Groundwater observations within exploration and an estimate of the depth to seasonal high groundwater.
- Site plan showing location of infiltration tests.
- Boring or test pit logs. Boring or test pit logs will be required when an applicant's proposal relies on the presence of specific subsurface strata that allows infiltration. The logs must include an associated soil classification consistent with ASTM D2488-00, Standard Practice for Classification for Description and Identification of Soils (Visual-Manual Procedure). The logs must also include any additional pertinent subsurface information, such as soil moisture conditions, depth and description of undocumented or engineered fill, soil color and mottling conditions, soil stiffness or density, and approximate depth of contact between soil types.
- A summary of the Infiltration Test Data Tables (see Table 2-3 for an example data table and see Table 2-4 for a blank data table).

Table 2-3. **Example Infiltration Test Table**

<table>
<tr><td colspan="3">Location: Lot 105,
Point Heights Subdivision</td><td colspan="2">Date: 6/28/2008</td><td>Test Hole Number: 3</td></tr>
<tr><td colspan="3">Depth to bottom of hole: 57 inches</td><td colspan="2">Dimension of hole: 0.5 feet diameter</td><td>Test Method: Encased Falling Head</td></tr>
<tr><td colspan="6">Tester's Name: C.J. Tester
Tester's Company: Tester Company
Tester's Contact Number: 555-1212</td></tr>
<tr><td colspan="3">Depth (feet):</td><td colspan="3">Soil Texture:</td></tr>
<tr><td colspan="3">0-0.5</td><td colspan="3">Black Top Soil</td></tr>
<tr><td colspan="3">0.5-1.0</td><td colspan="3">Brown SM</td></tr>
<tr><td colspan="3">1.0-2.2</td><td colspan="3">Brown ML</td></tr>
<tr><td colspan="3">2.2-5.1</td><td colspan="3">Brown CL</td></tr>
<tr><td colspan="6">Presaturation Start Time:
Presaturation End Time:</td></tr>
<tr><td>Time:</td><td>Time interval (minutes):</td><td>Measure ment, (feet):</td><td>Drop in water level, (feet):</td><td>Infiltration rate, (inches per hour):</td><td>Remarks:</td></tr>
<tr><td>9:00</td><td>0</td><td>3.75</td><td>-</td><td></td><td>Filled with 6”</td></tr>
<tr><td>9:20</td><td>20</td><td>3.83</td><td>0.08</td><td></td><td></td></tr>
<tr><td>9:40</td><td>20</td><td>3.91</td><td>0.08</td><td>2.88</td><td></td></tr>
<tr><td>10:00</td><td>20</td><td>3.98</td><td>0.07</td><td>2.52</td><td></td></tr>
<tr><td>10:20</td><td>20</td><td>4.04</td><td>0.06</td><td>2.16</td><td></td></tr>
<tr><td>10:40</td><td>20</td><td>4.11</td><td>0.07</td><td>2.52</td><td></td></tr>
<tr><td>11:00</td><td>20</td><td>4.17</td><td>0.06</td><td>2.16</td><td></td></tr>
<tr><td>11:20</td><td>20</td><td>4.225</td><td>0.055</td><td>1.98</td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td>Adjusted to 6” level for Trial #2</td></tr>
</table>

Table 2-4. **Infiltration Test Data Table**

<table>
<tr><td colspan="3">Location:</td><td colspan="2">Date:</td><td>Test Hole Number:</td></tr>
<tr><td colspan="3">Depth to bottom of hole:</td><td colspan="2">Dimension of hole:</td><td>Test Method:</td></tr>
<tr><td colspan="6">Tester’s Name:
Tester’s Company:
Tester’s Contact Number:</td></tr>
<tr><td colspan="3">Depth (feet):</td><td colspan="3">Soil Texture:</td></tr>
<tr><td colspan="3"></td><td colspan="3"></td></tr>
<tr><td colspan="3"></td><td colspan="3"></td></tr>
<tr><td colspan="3"></td><td colspan="3"></td></tr>
<tr><td colspan="3"></td><td colspan="3"></td></tr>
<tr><td colspan="6">Presaturation Start Time:
Presaturation End Time:</td></tr>
<tr><td>Time:</td><td>Time Interval (minutes):</td><td>Measure ment, (feet):</td><td>Drop in water level, (feet):</td><td>Infiltration rate, (inches per hour):</td><td>Remarks:</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td></tr>
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</table>

Blended Soil Specification for Vegetated Stormwater Systems

Public facilities must use the Vegetated Stormwater Facility Blended Soil specification taken from the *City of Portland Standard Construction Specifications*, as amended or corrected. Public facilities, either in the public right-of-way or on property, are required to use the specification from the most current version of the *City of Portland Standard Construction Specifications*. Facilities include swales, planters, curb extensions, and basins. As of the adoption of the 2016 SWMM, the most current specification is located in 01040.14 (d) (1) and was made effective on November 11, 2015.

Private facilities must use a blended soil that supports healthy plants growth. Testing and submittals are not required for private facilities unless they are requested by the Bureau permitting the work.

limitations that would adversely affect drawdown, and if a ground water mounding analysis should be conducted.

4. Determination of:
   - Depth to ground water table and to bedrock/impermeable layers.
   - Seasonal variation of ground water table based on well water levels and observed mottling.
   - Existing ground water flow direction and gradient.
   - Lateral extent of infiltration receptor.
   - Horizontal hydraulic conductivity of the saturated zone to assess the aquifer's ability to laterally transport the infiltrated water.
   - Impact of the infiltration rate and volume at the project site on ground water mounding, flow direction, and water table; and the discharge point or area of the infiltrating water. Conduct a ground water mounding analysis at all sites where the depth to seasonal ground water table or low permeability stratum is less than 15 feet from the estimated bottom elevation of the infiltration facility, and the runoff to the infiltration facility is from more than one acre.

3.3.6 Design Saturated Hydraulic Conductivity – Guidelines and Criteria

Measured (initial) saturated hydraulic conductivity (Ksat)rates can be determined using in-situ field measurements, or, if the site has soils unconsolidated by glacial advance, by a correlation to grain size distribution from soil samples. The latter method uses the ASTM soil size distribution test procedure (ASTM D422), which considers the full range of soil particle sizes, to develop soil size distribution curves. Using the Simplified Approach in Section 3.3.4, the estimate obtained for the measured (initial) K_{sat} is used as the initial infiltration rate. Using the Detailed Approach in Section 3.3.8, the initial Ksat is combined with other information to compute an estimate for an initial infiltration rate.

Three Methods for Determining Saturated Hydraulic Conductivity for Sizing Infiltration Facilities

For designing the infiltration facility the site professional should select one of the three methods described below that will best represent the measured (a.k.a., initial) saturated hydraulic conductivity (K_{sat}) rate at the site. Use the measured saturated hydraulic conductivity to determine the design (long-term) infiltration rate. Then use the design (long-term) infiltration rate for routing and sizing the basin/trench, and for checking for compliance with the maximum drawdown time of 48 hours.

In the Simplified Approach (Section 3.3.4), the design infiltration rate is derived by applying appropriate correction factors to the measured K_{sat} as specified below.

In the Detailed Approach (Section 3.3.8), the design infiltration rate is derived by applying correction factors and additional equations to the measured (initial) $K_{sat.}$ Verification testing of the completed facility is strongly encouraged. (See Site Suitability Criterion # 7-Verification Testing)

1. **<u>Large Scale Pilot Infiltration Test (PIT)</u>**

Large-scale in-situ infiltration measurements, using the Pilot Infiltration Test (PIT) described below is the preferred method for estimating the measured (initial) saturated hydraulic conductivity (K_{sat}) of the soil profile beneath the proposed infiltration facility. The PIT reduces some of the scale errors associated with relatively small-scale double ring infiltrometer or "stove-pipe" infiltration tests. It is not a standard test but rather a practical field procedure recommended by Ecology's Technical Advisory Committee.

Infiltration Test

- Excavate the test pit to the estimated surface elevation of the proposed infiltration facility. Lay back the slopes sufficiently to avoid caving and erosion during the test. Alternatively, consider shoring the sides of the test pit.
- The horizontal surface area of the bottom of the test pit should be approximately 100 square feet. Accurately document the size and geometry of the test pit.
- Install a vertical measuring rod (minimum 5-ft. long) marked in half-inch increments in the center of the pit bottom.
- Use a rigid 6-inch diameter pipe with a splash plate on the bottom to convey water to the pit and reduce side-wall erosion or excessive disturbance of the pond bottom. Excessive erosion and bottom disturbance will result in clogging of the infiltration receptor and yield lower than actual infiltration rates.
- Add water to the pit at a rate that will maintain a water level between 6 and 12 inches above the bottom of the pit. A rotameter can be used to measure the flow rate into the pit.

  Note: The depth should not exceed the proposed maximum depth of water expected in the completed facility. For infiltration facilities serving large drainage areas, designs with multiple feet of standing water can have infiltration tests with greater than 1 foot of standing water.

Every 15-30 min, record the cumulative volume and instantaneous flow rate in gallons per minute necessary to maintain the water level at the same point on the measuring rod.

Keep adding water to the pit until one hour after the flow rate into the pit has stabilized (constant flow rate; a goal of 5% variation or less variation in the total flow) while maintaining the same pond water level. The total of the pre-soak time plus one hour after the flow rate has stabilized should be no less than 6 hours.

- After the flow rate has stabilized for at least one hour, turn off the water and record the rate of infiltration (the drop rate of the standing water) in inches per hour from the measuring rod data, until the pit is empty. Consider running this falling head phase of the test several times to estimate the dependency of infiltration rate with head.
- At the conclusion of testing, over-excavate the pit to see if the test water is mounded on shallow restrictive layers or if it has continued to flow deep into the subsurface. The depth of excavation varies depending on soil type and depth to hydraulic restricting layer, and is determined by the engineer or certified soils professional. Mounding is an indication that a mounding analysis is necessary.

Data Analysis

Calculate and record the saturated hydraulic conductivity rate in inches per hour in 30 minutes or one-hour increments until one hour after the flow has stabilized.

Note: Use statistical/trend analysis to obtain the hourly flow rate when the flow stabilizes. This would be the lowest hourly flow rate.

Apply appropriate correction factors to determine the site-specific design infiltration rate. See the discussion of correction factors for infiltration facilities in this Section 3.3, and the discussion of correction factors for bioretention facilities and permeable pavement in Section 3.4.

Example

The area of the bottom of the test pit is 8.5-ft. by 11.5-ft.

Water flow rate was measured and recorded at intervals ranging from 15 to 30 minutes throughout the test. Between 400 minutes and 1,000 minutes the flow rate stabilized between 10 and 12.5 gallons per minute or 600 to 750 gallons per hour, or an average of (9.8 + 12.3) / 2 = 11.1 inches per hour.

2. <u>Small-Scale Pilot Infiltration Test</u>

A smaller-scale PIT can be substituted for the large-scale PIT in any of the following instances.

- The drainage area to the infiltration site is less than 1 acre.

Appendix E

DSM Coordination Checklist

APPENDIX E: DSM COORDINATION CHECKLIST

As introduced in Chapter 3, the purpose of the DSM Coordination Checklist is to provide a method of documenting the project stormwater management design compliance toward SWM Standards, design criteria, and other regulations. This Checklist should be maintained throughout the project and used as a basis for coordination with the Port at design meetings. It is also required to be submitted along with each required design milestone submittal. The following sections ask the designer to document compliance with the following:

- SWM Standards:
  - Low-Impact Development
  - Infiltration
  - Water Quantity Control
  - Water Quality – Capture and Treat
  - Source Controls
  - Hazardous Wildlife Attractants
  - Floodway and Natural Resource Protection
  - Erosion and Sediment Control
- Design criteria within Chapter 5 and Chapter 6
- Variance Requests

E.1 Project Specific Information

Project: ____

Designer Contact: ____
(Name, Company, E-mail)

Port Facility / Project Location: ____

Date: ____

Total Project Area in Acres: ____

Treated Acreage: ____

Project Milestone:

- ☐ Preliminary Design Milestone(s) – Specify percent complete:
- ☐ Final Design Milestone

E.2 Low-Impact Development

Designers shall complete the following portion of the Coordination Checklist to demonstrate the consideration and implementation of LID strategies and the supporting practices into project designs, where applicable. Where LID strategies were considered but found to be not applicable, designers shall provide justification based on project or site constraints, as discussed in Chapter 4 of the DSM. Responses to the LID questions shall incorporate a summary of direction or decisions provided by the Port during project planning or as part of the design review and coordination process.

E.2.1 Strategy 1: Minimize Disturbance of Sensitive Areas (Site Selection and Layout)

- Description: Design the project to preserve or minimize disturbance of buffers, floodplains, wetlands, natural resources, and natural or undeveloped areas that may be especially susceptible to impacts from stormwater runoff (See DSM Chapter 4). Practices supporting this strategy include:

  ☐ Site the development to avoid natural resource areas.
  ☐ Minimize disturbance of natural or undeveloped areas.
  ☐ Minimize disturbance of areas that may be highly susceptible to erosion.

- Was strategy incorporated into the project design? ☐Yes ☐No

- Describe practices used to incorporate strategy into project design (if demonstration is provided within drawings or attached documentation, please indicate below).

- Describe project or site constraints or other applicability considerations that limited the incorporation of this strategy into the project design (if justification is provided within drawings or attached documentation, please indicate below).

E.2.2 Strategy 2: Minimize the Impact of Development (Footprint Minimization)

- Description: Design project to result in compact development, in a way that reduces the footprint and minimizes the disturbance area (area of clearing and grading or exposed soil). (See DSM Chapter 4). Practices supporting this strategy include:

  ☐ Minimize development footprint.
  ☐ Minimize compaction of soil in specially designated areas.
  ☐ Minimize clearing and grading and changes to natural drainage pattern.
  ☐ Reduce extent of effective impervious areas.

- Was strategy incorporated into the project design? ☐Yes ☐No

- Describe practices used to incorporate strategy into project design (if demonstration is provided within drawings or attached documentation, please indicate below).

- Describe project or site constraints or other applicability considerations that limited the incorporation of this strategy into the project design (if justification is provided within drawings or attached documentation, please indicate below).

E.2.3 Strategy 3: Manage Runoff from Disturbed Areas (GI and Runoff Management)

- Description: Incorporate measures into the project design to manage the quality and quantity of runoff from disturbed areas to minimize the potential for impacts to receiving waters. Place an emphasis on GI practices that contribute to mimicking pre-development hydrologic functions and promote infiltration, evapotranspiration, or stormwater reuse (See DSM Chapter 4). Practices supporting this strategy include:

  ☐ Disconnect impervious areas to direct runoff from impervious areas into pervious areas that are designed to promote infiltration.
  ☐ Implement green infrastructure to collect, treat, and infiltrate runoff from developed areas.

- Was strategy incorporated into the project design? ☐Yes ☐No

- Describe practices used to incorporate strategy into project design (if demonstration is provided within drawings or attached documentation, please indicate below).

- Describe project or site constraints or other applicability considerations that limited the incorporation of this strategy into the project design (if justification is provided within drawings or attached documentation, please indicate below).

E.3 Infiltration

Designers shall complete the following portion of the Coordination Checklist to demonstrate the selection and implementation of the Infiltration Strategy. Designers shall provide justification for the selection of the Infiltration Strategy based on project or site constraints, as discussed in Chapter 4 of the DSM.

☐ Completed screen for infiltration feasibility based on historical data.

Provide the current understanding of the following parameters for the project design.

- Field infiltration rate: ______________________________
  - ☐ Based on historical data screen ☐ From project field investigations
- Design infiltration rate: ______________________________
  - ☐ Based on historical data screen ☐ From project field investigations
- Depth to groundwater: ______________________________
  - ☐ Based on historical data screen ☐ From project field investigations
- Groundwater separation from the bottom of BMP(s): ______________

- ☐ There is no known contamination of groundwater or soil column.
- ☐ There is known contamination of groundwater or soil column that has the potential to migrate into groundwater. Describe the findings (if information is provided within attached documentation, please indicate)

Selected infiltration strategy:

- ☐ Infiltration Strategy #1: Full Infiltration of the Water Quality Design Storm (Design infiltration capacity = WQ_V or WQ_F)
- ☐ Infiltration Strategy #2: Partial Infiltration of the Water Quality Design Storm (Design infiltration capacity < WQ_V or WQ_F)
- ☐ Infiltration Strategy #3: No Reliance on Infiltration

Describe the selected BMP(s) to meet the infiltration strategy:

BMP	Design Infiltration Capacity (specify units)	Portion of Total WQ_V or WQ_F	Drawdown Time of Surface Ponding (Hours)

E.4 Water Quantity Control

Designers shall complete the following portion of the DSM Coordination Checklist to demonstrate compliance with the water quantity objectives. Designers shall also provide brief discussion of the model results.

- ☐ 10-year, 24-hour storm event – The model results demonstrate that the max water surface elevations (MWSEs) do not exceed the elevation of pavement surfaces.
- ☐ 100-year, 24-hour storm event – The model results MWSEs do not reach buildings and are in compliance with City freeboard requirements and all applicable freeboard requirements.
- ☐ Drainage system design (collection and conveyance) is in compliance with the ponding allowances identified in Chapter 5.

Identify any pre-existing capacity issues affecting the design. Discuss any capacity concerns or any area where the objectives cannot be met. Explain any changes (increases or decreases) in the max water surface elevation (MWSE). Document any Port feedback on results. If this discussion is included in an attached document please specify.

Identify the BMPs or controls needed to meet the objectives. Provide the following information.

BMP/Control	Surface Elevation of Lowest Spot on Pavement (NAVD88 Ft.)	MWSE With/Without Control During 10-year Design Storm (NAVD88 Ft.)	Surface Elevation of Lowest Freeboard Requirement for Buildings Nearby (NAVD88 Ft.)	MWSE With/Without Control During 100-year Design Storm (NAVD88 Ft.)	Drawdown Time (Hours)
		Without: With:		Without: With:	
		Without: With:		Without: With:	
		Without: With:		Without: With:	
		Without: With:		Without: With:	
		Without: With:		Without: With:	

E.5 Water Quality – Capture and Treat

Designers shall complete the following portion of the DSM Coordination Checklist to demonstrate compliance with this SWM Standard. Designers shall also provide the necessary BMP information to communicate the level of treatment provided by each BMP.

Provide the total project disturbance area and calculation for WQ_F and/or WQ_V, as appropriate for treatment approach (if information is provided within attached documentation, please indicate).

List out project-specific POCs requiring treatment, based on coordination with the Port (if information is provided within attached documentation, please indicate).

Identify the BMPs selected to comply with this SWM Standard. Provide the following information.

BMP	Flow/Volume Based	Portion of Total WQ_F or WQ_V	Addressed POCs	Drawdown Time (Hours)

Identify any POCs requiring treatment that are not addressed by the above BMPs, as determined through coordination with the Port. If provided within an attached documentation, please indicate.

E.6 Source Controls

Designers shall complete the following portion of the Coordination Checklist to demonstrate compliance with this SWM Standard.

List below the POCs, based on coordination with the Port, that require source control (if provided within an attached documentation, please indicate).

List below any potential existing or new operational source control activities that may be appropriate for implementation, based on coordination with the Port (if provided within an attached documentation, please indicate).

Identify below applicable Activity Specific Source Control Requirements and if design complies with the requirements within Appendix M. If design does not comply, please confirm that a Variance Request has been submitted under the Variance Request portion of this checklist.

Activity	Applicable to Project	Design Complies with Appendix M Requirements
Solid Waste Storage Areas, Containers, and Trash Compactors	☐	☐
Material Transfer Areas/Loading Docks	☐	☐
Fuel Dispensing Facilities and Surrounding Traffic Areas	☐	☐
Aboveground Storage of Liquid Materials, Including Tank Farms	☐	☐
Equipment and Vehicle Washing Facilities	☐	☐
Covered and Uncovered Vehicle Parking Area	☐	☐
Exterior Storage and/or Processing of Bulk Materials	☐	☐
Water Reclaim and Reuse Systems	☐	☐

☐ Design does not expose any restricted material to stormwater.
☐ Check if the project site is within the Columbia South Shore Well Field WHPA.

Identify any POCs requiring source controls that are not addressed by the above source controls, as determined through coordination with the Port. If provided within an attached documentation, please indicate.

E.7 Hazardous Wildlife Attractants

Designers shall complete the following portion of the Coordination Checklist to demonstrate compliance with this SWM Standard, FAA requirements, and the WHMP.

Project design includes a BMP or potential hazardous wildlife attractant within the following Hazardous Wildlife Attractant Zone (please check one):

- ☐ Primary Zone
- ☐ Intermediate Zone
- ☐ Secondary Zone
- ☐ Five-Mile

☐ Project design is in compliance with this SWM Standard, FAA requirements, and the PDX WHMP.

Please describe the identified potential hazard(s) in the design and the measure(s) taken to reduce the attractiveness of the BMP or potential hazardous wildlife attractant (if demonstration is provided within an attached documentation, please indicate).

E.8 Floodway and Natural Resource Protection

Designers shall complete the following portion of the DSM Coordination Checklist to demonstrate compliance with this SWM Standard.

☐ Project design is in compliance with all applicable federal, state, regional, and City of Portland floodway and natural resource regulations.

Flood Hazard Areas

☐ Design avoids construction within flood hazard areas.
☐ Design includes construction within flood hazard areas.

- Identify applicable required reviews, approvals, and permits associated with construction within the identified flood hazard area(s).

Greenway Overlay Zones

☐ Design avoids construction within greenway overlay zones.
☐ Design includes construction within greenway overlay zones.

- Identify applicable required reviews, approvals, and permits associated with construction within the identified greenway overlay zone(s).

Environmental Overlay Zones

☐ Design avoids construction within environmental overlay zones.
☐ Design includes construction within environmental overlay zones.

- Identify applicable required reviews, approvals, and permits associated with construction within the identified greenway overlay zone(s).

E.9 Erosion and Sediment Control

Designers shall complete the following portion of the Coordination Checklist to demonstrate compliance with this SWM Standard.

☐ Stormwater management design is in compliance with City of Portland Code Title 10 and the *Erosion and Sediment Control Manual.*

☐ Designers have incorporated the Port's technical specification "015713 – Temporary Erosion, Sediment, & Pollution Control" into project design documents.

☐ A DEQ construction permit is applicable toward the project and coverage under a permit is either already completed or is being sought.

- ☐ 1200-CA is applicable toward the project and designers have coordinated with the Port on permit requirements
- ☐ 1200-C is applicable and designers are coordinating or have already coordinated with the Port on the required permit application

☐ The project consists of ground-disturbing activities 500 square feet or greater in area and is a permitted development project, or the site is located on steep slopes, in an environmental overlay zone, or in a greenway overlay zone

- ☐ The Erosion, Sediment, and Pollutant Control Plan (ESPCP) has been developed and submitted to the City.
- ☐ The ESPCP has been developed and submitted to DEQ as part of the 1200-C application, or if covered under the 1200-CA permit, a copy has been developed and will be retained on-site during construction.

Identify applicable required reviews, approvals, and permits associated with construction.

E.10 Design Criteria in Chapter 5 and Chapter 6

Designers shall complete the following portion of the DSM Coordination Checklist to demonstrate compliance with the design criteria for drainage system design (Chapter 5) and BMP design (Chapter 6 and BMP Fact Sheets).

☐ Design of the drainage system is in compliance with the design criteria within Chapter 5. Please provide a summary demonstrating compliance with design criteria for the drainage system design (if summary is provided within an attached documentation, please indicate). If design does not comply, please confirm that a Variance Request has been submitted under the Variance Request portion of this checklist.

☐ Design of the drainage system is in compliance with the design criteria within Chapter 6 and BMP Fact Sheets. Please provide a summary demonstrating compliance with design criteria for BMPs (if summary is provided within an attached documentation, please indicate). If design does not comply, please confirm that a Variance Request has been submitted under the Variance Request portion of this checklist.

E.11 Identification of Variance Requests

Designers are required to submit completed Variance Requests to the Port at the Preliminary Design Milestone(s), as applicable. This allows the Port to review discrepancies from DSM requirements, provide feedback to designers, and adjust project course as needed before proceeding to the Final Design phase. Designers are encouraged to discuss and submit Variance Requests to the Port earlier in the design process, as they are identified. This portion of the DSM Coordination Checklist is used to track the potential need for a Variance Request or to track any outstanding Variance Requests. Please see Appendix F for the Variance Request Application Form that must be submitted to the Port along with supporting documentation.

Variance Request	Brief Description of Variance Request	Submitted Variance Request
Off-Site mitigation to meet water quality SWM Standard (See Chapter 4)		☐
Implement of a new Underground Injection Control (UIC) system serving non-roof areas (See Chapter 4)		☐
Modify an activity-specific source control requirement (See Chapter 4 and Appendix M)		☐
Deviate from conveyance or BMP design criteria (See Chapter 5, Chapter 6, and the BMP Fact Sheets)		☐
Implement a BMP type other than those defined in the BMP Fact Sheets (BMPs must be certified under the Washington State Dept. of Ecology TAPE program)		☐

Appendix F

Variance Request Application Form

APPENDIX F: VARIANCE REQUEST APPLICATION FORM

This form shall be included as a cover sheet along with each Variance Request submitted to the Port at the Preliminary Design Milestone. Along with this form, the designer must submit required supporting documentation as described in Chapter 3 of the DSM. Designers shall inform the Port as soon as possible when the need for a Variance Request is first identified, and shall coordinate on the Port in advance of this submittal, if possible, to facilitate Port review.

Project Name and Number:

Port Facility / Project Location:

Designer Contact: (Name, Company, E-mail)

Date Submitted:

Total Area Disturbed (Acres):

Acres Treated onsite (if applicable):

	To be completed by the reviewing Port official	
Check One of the following:	Approved	Denied
☐ Off-site mitigation to meet water quality SWM standard	☐	☐
☐ Implement a new Underground Injection Control (UIC) system serving non-roof areas	☐	☐
☐ Modify an activity-specific source control requirement	☐	☐
☐ Deviate from conveyance or BMP design criteria in Chapters 5, 6, or the BMP Fact Sheets	☐	☐
☐ Implement a BMP type other than those defined in the BMP Fact Sheets (BMPs must be certified under the Washington State Department of Ecology Technology Assessment Protocol (TAPE) program).	☐	☐

Reason for making the variance request:

____

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____

____

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To be completed by the reviewing Port official

Port Comments:

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____

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Appendix G

Stormwater Management Submittal Content List

APPENDIX G: SWM SUBMITTAL CONTENT LIST

As detailed within Chapter 3 of the DSM, the SWM submittal is submitted at the final design milestone. The following list captures the required components to be submitted to the Port within the SWM submittal. The Port may require additional components within the SWM submittal on a project-by-project basis. Coordinate with the Port to determine if more information is required.

- Narrative
    - Overview of the Project Design
        - Project objectives
        - Industrial activities
        - Footprint size
        - Project phasing or planned future development (if applicable)
    - Overview of the Project Site
        - Soil characteristics and groundwater analysis, including infiltration capacity
        - Location relative to facility drainage system, catchment areas, and outfalls
        - Receiving waters and hydrology
        - Adjacent development
        - Operational constraints
    - Description of How Design Complies with Each SWM Standard
        - <u>LID</u> – Implement LID strategies, and elaborate on information described in the DSM coordination checklist.
        - <u>Infiltration</u> – Identify and justify the site-specific infiltration strategy and demonstrate how infiltration requirements are met by infiltration facilities.
        - <u>Water Quantity Control</u> – Demonstrate compliance with the water quantity objectives. Identify of any additional controls, and demonstrate how the selected BMPs address the water quantity objectives.
        - <u>Water Quality – Capture and Treat</u> – Calculate and assess the water quality design storm and describe water quality treatment BMPs designed to meet requirements.
        - <u>Source Controls</u> – Identification of industrial activities and anticipated pollutants of concern that require source controls, as determined through coordination with the Port. Identification of the selected source controls.
        - <u>Hazardous Wildlife Attractants</u> – Describe the project hazardous wildlife attractant zone and approach to meeting the zone-specific requirements, including BMP design criteria and features geared toward minimizing the attraction of wildlife.
        - <u>Floodway and Natural Resource Protection</u> – Demonstrate compliance with federal, state, regional, and City regulations. Identify any protected areas within the project development area, efforts taken to avoid or minimize conflicts with protected areas, and how applicable development standards or requirements were incorporated into the design.
        - <u>Erosion and Sediment Control</u> – Applicability and implementation of erosion and sediment control requirements, including permits and erosion, sediment and pollution control plans (ESPCP).
    - Description of SWM BMPs

- Description of Project Drainage System
  - Functions served by each BMP, and demonstration of how BMP designs meet required SWM standards in Chapter 4
  - Design basis to meet SWM standards
  - Reasoning for selecting the BMPs
  - Selected design features, including vegetation, major BMP components, pretreatment, and associated systems
  - Compliance with BMP design criteria in Chapter 6 and BMP fact sheets
  - Identification of drawings that illustrate BMP design and locations
- Description of Variance Requests
  - Deviations from DSM requirements
  - Justification for varying from DSM requirements, including project or site constraints
  - Status of variance requests and coordination of variances with the Port
  - Attach completed variance request forms
- Description of Required Regulatory Approvals
  - Anticipated regulatory reviews or approvals from FAA, City, Oregon DOT, DEQ, or other entities
  - Description and status of regulatory submittals and permit applications
  - History of coordinating regulatory approvals with regulator and the Port

- SWM Coordination Checklist
- Calculations
  - Calculations or analysis supporting the sizing/design of conveyance
  - Calculations or analysis supporting the sizing/design of BMPs
  - Calculations or analysis supporting the review of maximum ponding elevations
  - Stage versus discharge or outlet rating curves for volume-based facilities
  - Inflow and outflow calculations and hydrographs for BMPs (flow-based and volume-based, as described in Chapter 4)
  - Calculation of water quality volume or water quality flow, as detailed in Chapter 4 (SWM standard for Water Quality – Capture and Treat)
  - Calculation of infiltration volume corresponding to the applicable infiltration strategy, as detailed in Chapter 4 (SWM standard for Infiltration)
  - Additional design calculations not mentioned within this checklist but related specifically to the project.
- Model Reports (see Appendix H)
- Erosion, Sediment and Pollution Control Plan (if applicable)
- Soil and Groundwater Reports along with Geotechnical Reports
- Operations and Maintenance Plan (see Appendix I)
- Supporting Drawings: Provide figures illustrating site hydrology, conveyance, BMPs, and drainage features under pre- and post-development conditions. These drawings may be part of the design drawing set, or may be developed separately to fulfill SWM submittal requirements. The SWM submittal must include drawings conveying the following:
    - Drainage maps
    - Runoff assumptions for calculations
    - BMP reference numbers
    - Pipe and structure reference numbers
    - Plan and profile of conveyance features
    - BMP plan and sections

Appendix H

Modeling Report Content List

APPENDIX H: MODELING REPORT CONTENT LIST

The modeling report shall include a summary of hydrologic and hydraulic model input and output, as is typically included in standard stormwater modeling software. The Port may request additional items on a project-specific basis to account for any unique project analysis needs.

- Software description, including software developer, version, and engine or calculation basis.
- Description of model analysis performed (e.g., analysis of development for compliance with particular SWM standards, analysis of development for conveyance sizing, downstream analysis of watershed to review impacts of uncontrolled peak flows, etc.).
- Model network diagram (i.e., node-link diagram) showing connectivity of model elements.
- Model input (coordinate with Port for consistency with the existing PDX SWM model):
    - Drainage catchment characteristics (e.g., areas, slopes, and percent imperviousness, infiltration parameters or runoff coefficients, etc.)
    - Rainfall assumptions
    - Soil and infiltration assumptions
    - Hydraulic assumptions for conveyance including size, slope, roughness, invert elevations, flow restrictions, and connectivity
    - BMP characteristics, including capacity, shape, stage-storage curve, performance criteria, and inlet/outlet controls
- Model output for required design storms for compliance with SWM standards and design criteria within Chapter 5 and 6, including:
    - Runoff volumes
    - Peak flows
    - Analysis of system capacity including:
        - Identification of any surcharging.
        - Maximum water surface elevation and identification and explanation for any increases and/or decreases.
        - Demonstrate compliance with Water Quantity Control SWM standard.
        - Demonstration of compliance with design criteria in Chapters 5 and 6.
    - Peak storage volumes
    - Flow hydrographs downstream of BMPs and at the project discharge point(s)

Appendix I

Project O&M Form

APPENDIX I: PROJECT O&M FORM

Project Title:	
Project Number:	
Location: (Port Facility)	
Designer Contact: (Name, Company, E-mail)	

Summary Narrative – Required Components and Attachments

- Stormwater management facilities description
- Operational considerations, procedures, and schedule
- Maintenance considerations, procedures, and schedule
- Inspection and monitoring considerations, procedures, and schedule
- Decision tree(s) on trouble shooting operations
- Decision tree(s) for when to perform irregular maintenance and inspections
- Record-keeping recommendations
- Monitoring recommendations
- Equipment and personnel hours and expertise required to perform tasks
- Location map for each stormwater management facility
- Vendor information if applicable

Table 1: Summary of Stormwater Management Facilities

Stormwater management facilities include BMPs as well as major BMP components. The functions and locations of the stormwater management facilities shall be summarized in the table below and if needed or required by the Port additional information shall be provided within the narrative or attachments.

Facility Number/Descriptor	Description (Size, Source of SW, Discharge Point)	Function (Treatment Capabilities, either Flow or Volume, and Storage Capabilities)	Location	Drawing Number

Table 2: Summary of Stormwater Management Facilities Operations

The operations of the stormwater management facilities shall be summarized in the table below and if needed or required by the Port additional information shall be provided within the narrative or attachments.

Facility Number/Descriptor	Operation	Operation Frequency	Required Personnel and Equipment to Operate Facility	Attachment(s) or Subsequent Section(s)

Table 3: Summary of Stormwater Management Facility Maintenance Tasks

The maintenance tasks of the stormwater management facilities shall be summarized in the table below and if needed or required by the Port additional information shall be provided within the narrative or attachments.

Facility Number/Descriptor	Maintenance Task	Maintenance Triggers	Required Personnel and Equipment for Maintenance Task	Maintenance Task Frequency	Attachment(s) or Subsequent Section(s)

Table 4: Summary of Stormwater Management Facility Monitoring and Inspection Tasks

The monitoring and inspections tasks of the stormwater management facilities shall be summarized in the table below and if needed or required by the Port additional information shall be provided within the narrative or attachments.

Facility Number/Descriptor	Required Monitoring and/or Inspection Task	Monitoring and/or Inspection Task Frequency	Required Personnel and Equipment for Monitoring and/or Inspection Task	Attachment(s) or Subsequent Section(s)

Appendix J

City Draft Figure on the “Depth to Seasonally High Water (Table)

Depth to Seasonal High Water

BUILDABLE LANDS

March 24, 2010 City of Portland | Bureau of Planning and Sustainability | Geographic Information System

This work was supported, in part, by a grant from the Oregon Department of Land Conservation and Development.

Appendix K

Drainage System Design Reference

APPENDIX K: DRAINAGE SYSTEM DESIGN REFERENCES

K.1 Rational Method

Equation K-1: Rational Method

$$Q = CIA$$

Where:

Q	Peak runoff, cubic feet per second (cfs)
C	Runoff coefficient, Table K-1 and Table K-2.
I	Rainfall Intensity, inches per hour (in/hr) for a design storm duration equal to T_c
A	Drainage area contributing to the point of interest, acre

Table K-1: Rational Method Runoff Coefficients for Developed Areas[1]

Percent Impervious	Hydrologic Soil Group[2]	Runoff Coefficient, C by Slope		
		Drainage Area Slope		
		< 5%	5% to 10%	> 10%
0 - 10	A	0.19	0.24	0.29
	B	0.24	0.30	0.36
	C	0.29	0.36	0.44
	D	0.33	0.43	0.52
11 – 20	A	0.26	0.31	0.36
	B	0.30	0.37	0.43
	C	0.35	0.42	0.50
	D	0.39	0.48	0.57
21 – 30	A	0.34	0.39	0.44
	B	0.37	0.44	0.5
	C	0.41	0.49	0.56
	D	0.45	0.54	0.62
31 – 40	A	0.41	0.46	0.51
	B	0.44	0.50	0.56
	C	0.47	0.55	0.61
	D	0.51	0.59	0.67
41 – 50	A	0.49	0.54	0.59
	B	0.52	0.57	0.63
	C	0.55	0.61	0.67
	D	0.57	0.65	0.72
51 – 60	A	0.56	0.61	0.66
	B	0.58	0.64	0.70
	C	0.61	0.67	0.74
	D	0.63	0.70	0.77

[1] SDFDM, Chapter 6, Table 6.4.
[2] Refer to Chapter 6 for Hydraulic Soil Group descriptions.

Table K-1: Rational Method Runoff Coefficients for Developed Areas[1]

Percent Impervious	Hydrologic Soil Group[2]	Runoff Coefficient, C by Slope		
		Drainage Area Slope		
		< 5%	5% to 10%	> 10%
61 – 70	A	0.64	0.69	0.74
	B	0.66	0.72	0.77
	C	0.67	0.74	0.80
	D	0.69	0.76	0.92
71 – 80	A	0.71	0.76	0.81
	B	0.72	0.78	0.83
	C	0.73	0.80	0.85
	D	0.75	0.81	0.87
81 – 90	A	0.79	0.84	0.89
	B	0.80	0.85	0.90
	C	0.81	0.86	0.91
	D	0.81	0.87	0.92
91 - 99	A	0.86	0.91	0.98
	B	0.87	0.92	0.97
	C	0.87	0.92	0.97
	D	0.88	0.92	0.97
100	-	0.90	0.95	1.00

Table K-2: Rational Method Runoff Coefficients for Undeveloped Areas[3]

Surface Characteristics	Hydrologic Soil Group[4]	Runoff Coefficient, C by Slope		
		Drainage Area Slope		
		< 5%	5% to 10%	> 10%
Woodland	A	0.10	0.15	0.20
	B	0.14	0.20	0.25
	C	0.25	0.30	0.35
	D	0.30	0.35	0.40
Lawn, Pasture, and Meadow	A	0.15	0.20	0.25
	B	0.20	0.25	0.30
	C	0.25	0.35	0.45
	D	0.30	0.40	0.50
Cultivated Land	A	0.25	0.35	0.50
	B	0.30	0.45	0.60
	C	0.40	0.55	0.70
	D	0.50	0.65	0.80
Railroad Yard	-	0.25	0.30	0.40
Gravel Areas and Walks				
1. Loose	-	0.30	0.40	0.50
2. Packed	-	0.70	0.75	0.80
Pavement and Roof	-	0.90	0.95	1.00

[3] SDFDM, Chapter 6, Table 6.5.
[4] Refer to Chapter 6 for Hydraulic Soil Group descriptions

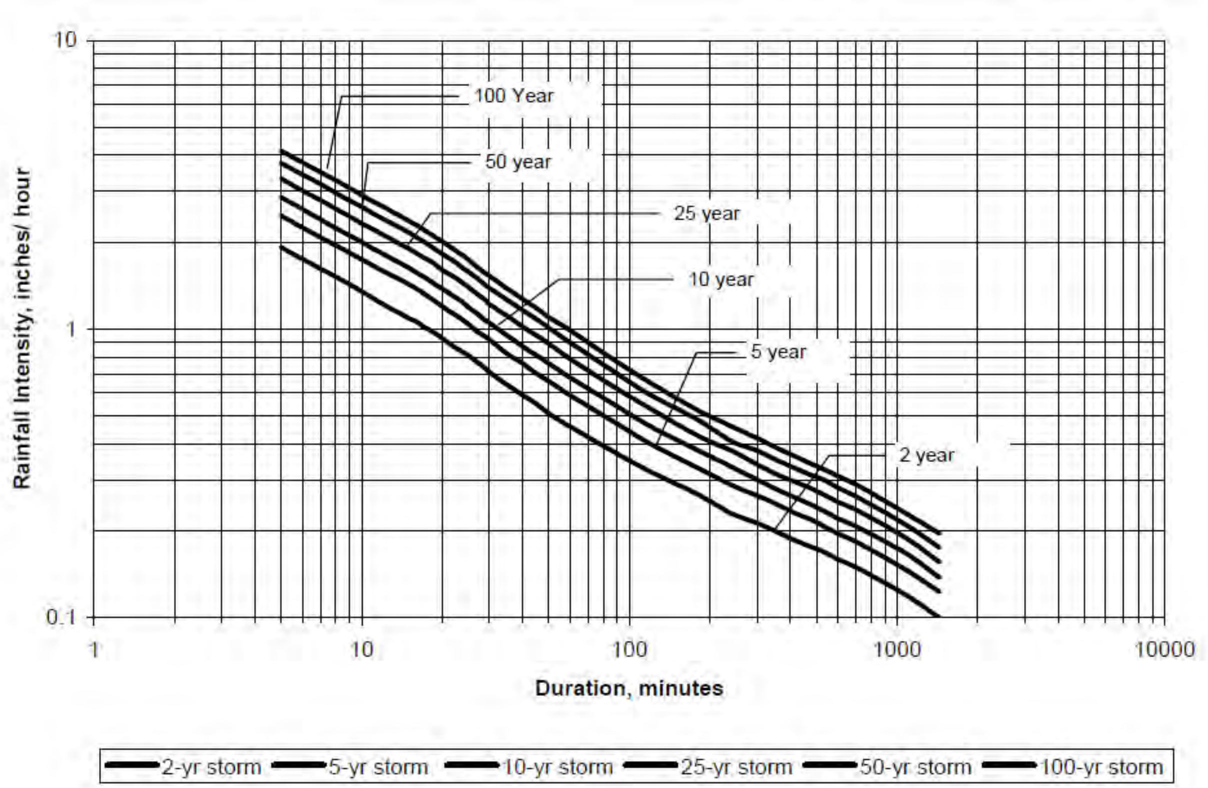

Exhibit K-1: Intensity – Duration – Frequency (IDF) Curves for Portland, OR[5]

[5] SDFDM, Chapter 6, Figure 6.1.

Table K-3: IDF Curve Data for Portland, OR[6]

Time, minutes	Rainfall Intensity, inches per hour					
	Return Interval, years					
	2	5	10	25	50	100
5	1.92	2.47	2.86	3.32	3.75	4.14
6	1.75	2.25	2.60	3.02	3.43	3.78
7	1.62	2.08	2.40	2.80	3.18	3.50
8	1.52	1.95	2.24	2.61	2.96	3.28
9	1.43	1.84	2.11	2.46	2.79	3.08
10	1.35	1.74	2.00	2.32	2.65	2.91
11	1.28	1.66	1.90	2.22	2.52	2.77
12	1.22	1.59	1.82	2.12	2.41	2.66
13	1.17	1.53	1.75	2.04	2.32	2.55
14	1.13	1.48	1.69	1.96	2.24	2.46
15	1.09	1.43	1.63	1.90	2.16	2.37
16	1.06	1.38	1.57	1.83	2.08	2.29
17	1.02	1.33	1.52	1.77	2.01	2.21
18	0.99	1.28	1.47	1.72	1.94	2.14
19	0.96	1.24	1.42	1.66	1.88	2.07
20	0.93	1.20	1.38	1.60	1.82	2.01
21	0.90	1.16	1.34	1.56	1.77	1.95
22	0.87	1.13	1.30	1.52	1.72	1.89
23	0.85	1.10	1.27	1.48	1.67	1.84
24	0.83	1.07	1.23	1.44	1.62	1.79
25	0.81	1.04	1.19	1.40	1.58	1.74
26	0.79	1.01	1.16	1.36	1.54	1.69
27	0.77	0.98	1.13	1.32	1.50	1.64
28	0.75	0.96	1.10	1.29	1.46	1.60
29	0.73	0.94	1.07	1.26	1.42	1.56
30	0.71	0.92	1.05	1.22	1.39	1.53
35	0.64	0.82	0.95	1.11	1.26	1.38
40	0.59	0.76	0.87	1.02	1.16	1.27
45	0.55	0.70	0.81	0.95	1.08	1.18
50	0.51	0.66	0.76	0.89	1.01	1.10
60	0.46	0.59	0.68	0.79	0.90	0.99
90	0.37	0.47	0.54	0.62	0.70	0.77
120	0.32	0.40	0.46	0.53	0.59	0.65
180	0.25	0.38	0.43	0.50	0.55	0.61
240	0.22	0.35	0.40	0.46	0.51	0.56
300	0.20	0.32	0.37	0.43	0.48	0.52
360	0.19	0.30	0.34	0.40	0.44	0.48
420	0.18	0.27	0.31	0.36	0.40	0.44
480	0.17	0.25	0.29	0.33	0.36	0.39
540	0.17	0.22	0.26	0.30	0.32	0.35
600	0.16	0.16	0.20	0.22	0.25	0.28
720	0.15	0.15	0.18	0.21	0.23	0.26
1080	0.12	0.12	0.15	0.17	0.19	0.21
1440	0.10	0.10	0.12	0.14	0.16	0.18

[6] SDFDM, Chapter 6, Table 6.11.

K.2 SCS Curve Numbers

Table K-4: SCS Runoff Curve Numbers[7]

Cover type and hydrologic condition	Average percent Impervious Area	Curve numbers for hydrologic soil group[8]			
		A	B	D	C
Runoff Curve Numbers for Urban Areas					
Open space (lawns, parks, golf courses, cemeteries, etc.):					
Poor condition (grass cover < 50%)		68	79	86	89
Fair condition (grass cover 50 to 75%)		49	69	79	84
Good condition (grass cover > 75%)		39	61	74	80
Impervious areas					
Paved parking lots, roofs, driveways, etc. (excluding right-of-way)		98	98	98	98
Streets and roads:					
Paved; curbs and storm sewers (excluding right-of-way)		98	98	98	98
Paved; open ditches (including right-of-way)		83	89	92	93
Gravel (including right-of-way)		76	85	89	91
Dirt (including right-of-way)		72	82	87	89
Urban districts:					
Commercial and business	85	89	92	94	95
Industrial	72	81	88	91	93
Residential districts by average lot size:					
1/8 acre or less (town houses)	65	77	85	90	92
1/4 acre	38	61	75	83	87
1/3 acre	30	57	72	81	86
1/2 acre	25	54	70	80	85
1 acre	20	51	68	79	84
2 acres	12	46	65	77	82
Runoff Curve Numbers for Agricultural Areas					
Pasture, grassland, or range-continuous forage for grazing	Poor	68	79	86	89
<50% ground cover or heavily grazed with no mulch	Fair	49	69	79	84
50 to 75% ground cover and not heavily grazed	Good	39	61	74	80
>75% ground cover and lightly or only occasionally grazed	Poor	68	79	86	89
Meadow-continuous grass, protected from grazing and generally mowed for hay	-	30	58	71	78
Brush--weed-grass mixture with brush as the major element					
<50% ground cover	Poor	48	67	77	83
50 to 75% ground cover	Fair	35	56	70	77
>75% ground cover	Good	30	48	65	73
Woods-grass combination (orchard or tree farm)	Poor	57	73	82	86
	Fair	43	65	76	82
	Good	32	58	72	79
Woods					
Forest litter, small trees, and brush are destroyed by heavy grazing or regular burning	Poor	45	66	77	83
Woods are grazed but not burned, and some forest litter cover the soil	Fair	36	60	73	79
Woods are protected from grazing, and litter and brush adequately cover the soil.	Good	30	55	70	77

7 City SWMM, Appendix C, Table C-2.
8 Consult the Natural Resource Conservation Service Soil Survey for hydrologic soils types.

K.3 Time of Concentration

Use the following equations to calculate the Time of Concentration, T_c, for various flow regimes.

Equation K-2: Time of Concentration

$$T_c = T_{t1} + T_{t2} + T_{t3} + \cdots + T_{tn}$$

Equation K-3: Conversion of Velocity to Travel Time (T_t)

$$T_t = L/(60V)$$

Equation K-4: Travel Time for Sheet Flow Less than 100 Feet (Manning Kinematic Equation)

$$T_t = 0.42(nL)^{0.8} / (\sqrt{P_2}(S^{0.4}))$$

Equation K-5: Velocity for Shallow Concentrated Flow on Unpaved Surfaces (slope less than 0.005 ft/ft)[9]

$$V = 16.1345\sqrt{S}$$

Equation K-6: Velocity for Shallow Concentrated Flow on Paved Surfaces (slope less than 0.005 ft/ft)[10]

$$V = 20.3282\sqrt{S}$$

Equation K-7: Velocity in a Channel (Manning's Equation)

$$V = \frac{1.49}{n} R_H^{2/3} \sqrt{S}$$

Equation K-8: Velocity in Full Capacity Pipe Flow (Manning's Equation)

$$V = \frac{0.59}{n} D^{2/3} \sqrt{S}$$

Where:

T_t	Travel time of consecutive segments along the flow path, minutes (min)
T_c	Total time of concentration, min
n	Manning's roughness coefficient, from Table K-5, Table K-6 or Table K-8
L	Flow length in feet (ft)
V	Average velocity of flow, feet per second (fps)
P_2	2-year, 24-hour rainfall (in.), generally 1.58 in. in Portland

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[9] City SWMM, Appendix C
[10] City SWMM, Appendix C.

S	Slope of the hydraulic grade line (land or watercourse slope), in feet per foot (ft/ft)
R_H	Hydraulic radius in feet (A / wetted perimeter)
D	Pipe diameter, ft.

K.4 Manning's Roughness coefficient

Table K-5: Manning's Surface Roughness Coefficient n for Sheet Flow Conditions[11]

Surface Description	n
Concrete or asphalt	0.011
Bare sand	0.010
Graveled surface	0.020
Bare clay- loam (eroded)	0.020
Grass	
Short grass prairie	0.15
Short grass prairie	0.24
Dense grass – lawn	0.41
Bermuda grass	
Woods	
Light underbrush	0.40
Dense underbrush	0.80
Paved Streets and Gutters	
Concrete gutter, trowel finished	0.012
Asphalt pavement	
Smooth texture	0.013
Rough texture	0.018
Concrete gutter with asphalt pavement	
Smooth	0.013
Rough	0.015
Concrete Pavement	
Float finish	0.014
Broom finish	0.016
For gutters with small slope where sediment may accumulate increase the n_s value by:	0.002

[11] SDFDM, Table 6-15

Table K-6: Manning's Roughness Coefficient n for Excavated and Natural Channels[12]

Channel Description	n
Open Channels-Natural	
Minor stream on plain (top width at flood stage < 100 feet)	
Clean straight, full stage, no pools	0.030
Same as above but more stones and weeds	0.035
Clean, winding, some pools and shallows	0.040
Same as above but some weeds and stones	0.045
Same as above, lower stages, more ineffective slopes and sections	0.048
Same as above but more stones	0.050
Sluggish reaches, dense vegetation, weedy, deep pools	0.070
Very sluggish, weedy, deep pools or floodways with heavy stand of timber or underbrush	0.100
Upland channels, no vegetation in channel, banks usually steep, trees and brush along banks	
Gravel bottom	0.025
Same as above but more cobbles and boulders	0.040
Earth bottom, clean	0.020
Same as above but more debris and litter	0.030
Open Channels – Excavated or Dredged	
Earth, straight, uniform clean, recently completed	
Same as above but clean, recently completed	0.018
Same as above after weathering	0.020
Same as above but short grass, few weeds	0.027
Earth, winding and sluggish	
Same as above no vegetation	0.025
Same as above but grass and some weed	0.030
Same as above but dense weeds in deep channels	0.035
Same as above but earth bottom and rubble sides	0.030
Same as above but stony bottom an weedy banks	0.035
Same as above but cobble bottom and clean sides	0.040
Gravel, straight, uniform section, clean	0.025
Unmaintained, clean bottom, brush on side slopes	0.050
Same as above highest flow stage	0.070
Unmaintained, dense weeds as high as flow depth	0.080
Unmaintained, dense brush, high stages	0.100

[12] SDFDM, Table 8-4

Table K-7: Manning's Roughness Coefficient n for Lined Channels[13,14]

Lining Category	Type	n for given flow depth ranges 0-0.5 ft	0.6 – 2.0 ft	>2.1 ft
Rigid	Concrete	0.015	0.013	0.013
	Grouted riprap	0.015	0.013	0.013
	Stone Masonry	0.040	0.030	0.028
	Soil Cement	0.042	0.032	0.030
	Asphalt	0.025	0.022	0.020
Unlined	Bare Soil	0.018	0.016	0.016
	Rock Cut	0.023	0.020	0.020
Temporary	Woven Paper net	0.045	0.035	0.025
	Jute net	0.016	0.015	0.015
	Fiberglass roving	0.028	0.022	0.019
	Straw with net	0.028	0.021	0.019
	Curled wood mat	0.065	0.033	0.025
	Synthetic mat	0.066	0.035	0.020
Gravel/Riprap	1-inch D_{50}	0.036	0.025	0.021
	2-inch D_{50}	0.044	0.033	0.030
	6-inch D_{50}	0.066	0.041	0.034
	12-inch D_{50}	0.104	0.069	0.035

Table K-8: Manning's Roughness Coefficient n Closed Conduits[15,16]

Channel Type	n
All sewer pipe materials including: concrete, polyvinylchloride (PVC), high density polyethylene (HDPE) and Cast Iron	0.013
All concrete culverts including circular and irregular shapes	0.013
Corrugated Metal Pipe	0.024

[13] SDFDM, Chapter 8, Table 8.5
[14] Values listed are representative values for the represented depth ranges. Manning's roughness coefficients vary with flow depth. Reference: HEC-15, 1988
[15] SDFDM, Chapter 8, Table 8.1
[16] Values listed are representative values for the represented depth ranges. Manning's roughness coefficients vary with flow depth. Reference: HEC-15, 1988

Curb and Gutter Design

Equation K-9: Gutter Flow Capacity (Manning's Equation Modified)[17]

$$Q = 0.56 \left(\frac{1/S_x}{n}\right)\sqrt{S} \times d^{2.67}\text{, or}$$

$$Q = \frac{0.56}{n} S_x^{1.67} T^{2.67} \sqrt{S}\text{, or}$$

$$V = \frac{1.12}{n} \times S_x^{0.67} T^{0.67} \sqrt{S}$$

Where:

Q	Flow rate in cfs
n	Manning's roughness coefficient in a gutter, usually 0.018
d	Depth of flow at the curb, ft
S	Roadway longitudinal slope, ft/ft
T	Total width of flow in the gutter, ft
S_x	Roadway Cross slope, ft/ft

[17] SDFDM, Appendix I, Chart 1 – Standard Equations

FORM 3

INLET DESIGN FORM

CONTINUOUS GRADE - UNIFORM CROSS SLOPE

Project No. Designed by Date Checked by Date

Project name:

Inlet standard plan No.→ ← Inlet standard plan No.

Inlet location or No. → ← Inlet location or No.

GRATE INLETS

STEP	SYMBOL	UNIT
1	W	ft
1	L	ft
1	a	ft
2	n	coeff
3	S	ft/ft
3	Sx	ft/ft
4	T	ft
5	an	cfs
6	a	cfs
7	Ts	ft
8	Osn	cfs
9	as	cfs
10	Ow	cfs
11	Eo	ratio
12	d	ft
13	A	sq ft
14	V	fps
15	Vo	fps
16	Rl	ratio
17	Rs	ratio
18	E	ratio
19	a,	cfs
20	Qb	cfs

CURB INLETS

UNIT	SYMBOL	STEP
ft	W	1
ft	L	1
ft	a	1
coeff	n	2
ft/ft	S	3
ft/ft	Sx	3
const.	K	4
ft	T	5
cfs	an	6
cfs	a	7
ft	d	8
ft	LT	9
ratio	LILT	10
ratio	E	11
cfs	0 1	12
cfs	0b	13

Exhibit K-2: Inlet Design Forms[18]

[18] SDFDM, Appendix I.

PROCEDURE for FORM 3
(Grate Inlet)

GRATE INLET CAPACITY PROCEDURES
CONTINUOUS GRADE· UNIFORM CROSS SLOPE

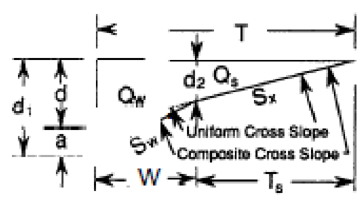
Using the **INLET DESIGN FORM (FORM 3)**:

1. Note inlet Standard Plan No., dimensions, (W, L & a) and location or No.
2. Note Manning's coefficient of roughness, n (normally 0.018).
3. Determine and note the street geometries (cross slope, Sx ; longitudinal slope, S) using the street design and / or survey (see **STREET GEOMETRICS, CHARTS 25 & 26**)

Determine the following from calculations or noted charts:

* 4. T (Use maximum allowable width of flow or other known width.)
* 5. a n (**CHART 30**)
* 6. a = an / n
7. T_s = T - W
8. as n (**CHART 30**)
9. as = as n / n
10. Q_w = a-as
11. E_o = Q_w / 0 (or **CHART 31** @ *Sw/S.* =1)
12. d = TS_x
13. A =(dT) / 2
14. V = a / A
15. Vo (**CHART 27**)
16. R_f = 1 - 0.09 (Vo - V) if V > Vo
    RI = 1 if V ≤ Vo
17. Rs = 1 / (1 + $\frac{0.15 \ V^{1.8}}{Sx \ L^{2.3}}$)
18. E = R_f Eo + R_s (1 - Eo)
19. 0_1 = EO
20. Ob = $0 - 0_1$

* To determine T from a known A, reverse the order of steps 4 through 6



a gutter depression, inches
A cross-sectional area of flow, sq ft
d depth of flow at the curb
E efficiency of a grate (interception efficiency of an inlet)
Eo ratio of frontal flow to total gutter flow
L length of the grate, ft
n Manning's coefficient of roughness
a total gutter flow, cfs
Ob the portion of total gutter flow which is not intercepted by an inlet (bypass or carryover flow), cfs
a_I the portion of total gutter flow which is intercepted by an inlet (intercepted flow), cfs
as side flow rate
Ow flow in width W, cfs
R_I ratio of frontal flow intercepted to total frontal flow (frontal flow interception efficiency)
R_s ratio of side flow intercepted to total side flow (side flow interception efficiency)
S pavement longitudinal slope, ft / ft
Sx pavement cross slope, ft / ft
T total spread of water in the gutter, ft
T_s spread of water outside depressed gutter
V velocity of flow in the gutter, fps
Vo gutter velocity where splash-over first occurs over a grate, fps
W width of depressed inlet, ft

Exhibit K-2 **(continued): Inlet Design Forms**

PROCEDURE for FORM 3
(Curb Inlet)

CURB INLET CAPACITY PROCEDURES
CONTINUOUS GRADE· UNIFORM CROSS SLOPE

Using the **INLET DESIGN FORM (FORM 3)**:

1. Note inlet Standard Plan No., dimensions, (W. L & a) and location or inlet No.
2. Note Manning's coefficient of roughness, n (normally 0.018).
3. Determine and note the street geometries (cross slope. Sx ; longitudinal slope. S) using the street design and / or survey (see **STREET GEOMETRICS. CHARTS 25 & 26**)

Determine the following from known quantities. calculations or noted charts:

4. K = 0.6 (0.076 if in S. I.)

* 5. T (Use maximum allowable width of flow or other known width)

* 6. a n (From **CHART 30**)

*7. $a = an/n$

8. $d = TS_x$

9. $L_T = KaO^{.42}\ S0.3\ (1 / nS_x)^{0.6}$

10. LI L_r

11. $E = 1 \cdot (1 - L / L_T)^{1.8}$

12. $a_i = E a$

13. $a_b = a - a,$

* To determine T from a known a . reverse the order of steps 5 through 7.

a gutter depression. inches
d depth of flow at the curb
E efficiency of a grate (interception efficiency of an inlet)
K constant (0.6 or 0.076 if in S. I.)
L length of the grate. ft
n Manning's coefficient of roughness
a total gutter flow, cfs
a_b the portion of total gutter flow which is not intercepted by an inlet (bypass or carryover flow). cfs
OJ the portion of total gutter flow which is intercepted by an inlet (intercepted flow). cfs
S pavement longitudinal slope. ft / ft
Sw depressed gutter cross slope
Sx pavement cross slope. ft / ft
T total spread of water in the gutter, ft
W width of depressed gutter or grate. ft

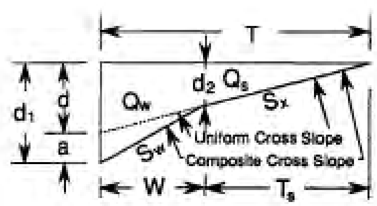


Exhibit K-2 (continued): Inlet Design Forms

FORM 4

INLET DESIGN FORM
CONTINUOUS GRADE · COMPOSITE CROSS SLOPE

Project No. Designed by Date Checked by Date
Project name:

Inlet standard plan No. → ← Inlet standard plan No.

Inlet location or No. → ← Inlet location or No.

GRATE INLETS			CURB INLETS		
STEP	SYMBOL	UNIT	UNIT	SYMBOL	STEP
1	W	ft	ft	W	1
1	L	ft	ft	L	1
1	a	ft	ft	a	1
2	n	coeff	coeff	n	2
3	S	ft/ft	ft/ft	S	3
3	Sx	ft/ft	ft/ft	Sx	3
4	Sw	ft/ft	ft/ft	S'_w	4
5	Sw/Sx	ratio	ft/ft	Sw	5
6	T	ft	ratio	Sw/Sx	6
7	T_s	ft	const.	K	7
8	Os n	cfs	ft	T	8
9	Os	cfs	ratio	T/W	9
10	WiT	ratio	cfs	On	10
11	Eo	ratio	cfs	0	11
12	0	cfs	ratio	WiT	12
13	Q_w	cfs	ratio	Eo	13
14	d1	ft	ft/ft	Se	14
15	d2	ft	ft	d1	15
16	A	sq ft	ft	L_T	16
17	V	fps	ratio	LILT	17
18	Vo	fps	ratio	E	18
19	R_t	ratio	cfs	OJ	19
20	Rs	ratio	cfs	0_b	20
21	E	ratio			
22	OJ	cfs			
23	Q_b	cfs			

Exhibit K-2 (continued): Inlet Design Forms

PROCEDURE for FORM 4

GRATE INLET CAPACITY PROCEDURES

(Grate Inlet)

CONTINUOUS GRADE- COMPOSITE CROSS SLOPE

Using the INLET DESIGN FORM (FORM 4):

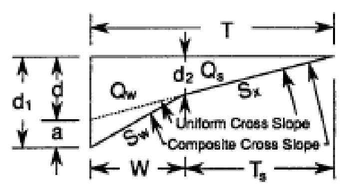
1. Note inlet Standard Plan No., dimensions, (W, L & a) and location or No.
2. Note Manning's coefficient of roughness, n (normally 0.018).
3. Determine and note the street geometries (cross slope, Sx ; longitudinal slope, S) using the street design and / or survey (see STREET GEOMETRICS, CHARTS 25 & 26)

Determine the following from known quantities, calculations or noted charts:

4. Sw = Sx + (a / W)
5. Sw *ISx*
- 6. T (Use maximum allowable width of flow or other known width.)
7. Ts = T-W
8. Osn (CHART 30)
9. as = Osn / n
10. *WIT*
11. Eo (CHART 31)
12. a = Os/(1-Eo)
13. Qw = a - as
14. d1 = TSx + a (for T > W)
    d1 = TSw (for T ≤ W)
15. d2 = (T-W) Sx
16. $A = \left(dl \frac{+}{2} d2\ W\right) + \left(\frac{d_2 T_s}{2}\right)$
17. V = a / A
18. Vo (CHART 27)
19. RI = 1-0.09 (Vo-V) if V>Vo
    RI = 1 if V ≤ V
20. $R^S = 1 / \left(1 + \frac{0.15\ V^{1.8}}{Sx\ L^{2.3}}\right)$
21. E = R_l Eo + Rs (1 - Eo)
22. OJ = EO
23. Ob = a -OJ

- To determine T from a known a, use CHART 32

a	gutter depression, inches
A	cross-sectional area of flow, sq ft
d1	depth of flow at the curb
d2	depth of flow at outside edge of depressed gutter
E	efficiency of a grate (interception efficiency of an inlet)
Eo	ratio of frontal flow to total gutter flow
L	length of the grate, ft
n	Manning's coefficient of roughness
a	total gutter flow, cfs
Ob	the portion of total gutter flow which is not intercepted by an inlet (bypass or carryover flow), cfs
OJ	the portion of total gutter flow which is intercepted by an inlet (intercepted flow), cfs
as	side flow rate
Ow	flow in width W, cfs
R_l	ratio of frontal flow intercepted to total frontal flow (frontal flow interception efficiency)
R_s	ratio of side flow intercepted to total side flow (side flow interception efficiency)
S	pavement longitudinal slope, ft / ft
SW	depressed gutter cross slope
Sx	pavement cross slope. ft / ft
T	total spread of water in the gutter, ft
T_s	spread of water outside depressed gutter
V	velocity of flow in the gutter, fps
Vo	gutter velocity where splash-over first occurs over a grate, fps
W	width of depressed gutter or grate, ft



(Grate Inlet)

Exhibit K-2 (continued): Inlet Design Forms

PROCEDURE for FORM 4
(Curb Inlet)

CURB INLET CAPACITY PROCEDURES
CONTINUOUS GRADE- COMPOSITE CROSS SLOPE

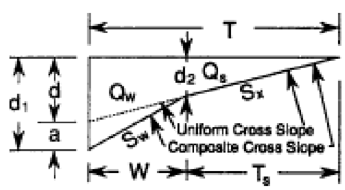
Using the INLET DESIGN FORM (FORM 4):

1. Note inlet Standard Plan No., dimensions, (W, L & a) and location or inlet No.
2. Note Manning's coefficient of roughness, n (normally 0.018).
3. Determine and note the street geometries (cross slope, Sx ; longitudinal slope, S) using the street design and / or survey (see STREET GEOMETRICS, CHARTS 25 & 26)

Determine the following from known quantities, calculations or noted charts:

4. $S'_w = a / W$ (a in feet)
5. $Sw = Sx + S'_w$
6. Sw/Sx
7. K = 0.6 (0.076 if in S. I.)
* 8. T (Use maximum allowable width of flow or other known width)
9. Ts = T-W
10. Osn (CHART 30)
11. as = Osn / n
12. W/T
13. Eo (CHART 31)
14. $Sa = Sx + S'_w E_o$
15. d1 = TSx + a (forT>W)
    d1 = TSw (for T≤W)
16. $L_T = KO^{0.42} S^{0.3} (1 / nS_a)^{0.6}$
17. L / L_T
18. $E = 1 - (1 - L / L_T)^{1.8}$
19. OJ = EO
20. Ob = a -OJ

* To determine T from a known a, use CHART 32



a gutter depression, inches
d1 depth of flow at the curb
E efficiency of a grate (interception efficiency of an inlet)
Eo ratio of frontal flow to total gutter flow
K constant (0.6 or 0.076 if in S. I.)
L length of the grate, ft
n Manning's coefficient of roughness
a total gutter flow, cfs
Ob the portion of total gutter flow which is not intercepted by an inlet (bypass or carryover flow), cfs
a i the portion of total gutter flow which is intercepted by an inlet (intercepted flow), cfs
S pavement longitudinal slope, ft / ft
Sw depressed gutter cross slope
Sx pavement cross slope, ft / ft
T total spread of water in the gutter, ft
W width of depressed gutter or grate, ft

(Curb Inlet)

Exhibit K-2 (continued): Inlet Design Forms

K.5 Vegetative LINING OPEN Channel Design Procedures

Use a two step procedure to design vegetative channels.[19] The permissible unit shear stress is provided in Table K-9 and the maximum velocities allowed are provided in Table K-10. Coordinate the selection of vegetation with the SWM Standard for Hazardous Wildlife Attractants in Chapter 4.

Table K-9. Permissible Unit Shear Stress for Lining Materials[20,21]

Lining Category	Type	Permissible Unit Shear Stress τ_p (lb/ft^2)
Temporary	Woven Paper Jute	0.15
	Jute net	0.45
	Fiberglass roving (single)	0.60
	Fiberglass roving (double)	0.85
	Straw with net	1.45
	Curled wood mat	1.55
	Synthetic mat	2.00
Vegetative	Class A: Excellent stand, 2 to 3 ft. tall	3.70
	Class B: Good stand of vegetation, no woody, average of 1 to 2 ft. tall	2.10
	Class C: Fair stand, mowed or uncut, average 0.5 to 4 ft. tall	1.00
	Class D: Good to excellent, mowed or uncut, average of 0.2 to 0.6 ft. tall	0.60
	Class E: Poor stand, mowed to 1 ½ inch stubble or damaged (e.g., burned)	0.35

Table K-10. Maximum Velocities for Vegetative Channel Linings[22]

Vegetative Type	Slope Range (%)[23]	Maximum Velocity[24] (feet per second, fps)
Bermuda Grass	0 to 10	5
Tall Fescue Grass mixtures	0 to 10	4
Kentucky Blue Grass	0 to 5	6
Grass Mixture	0 to 5	4
Annual[25]	0 to 5	3
Sod	-	4

[19] SDFDM, Chapter 8.
[20] SDFDM, Chapter 8, Table 8.8
[21] Values listed are representative values for the represented depth ranges. Manning's roughness coefficients vary with flow depth.
[22] Manual for Erosion and Sediment control in Georgia, 1996
[23] Do not use on slopes steeper than 10 percent except for a side slope in a combination channel.
[24] Use velocities exceeding 5 fps only where good stands of vegetation can be maintained.
[25] Annuals use on mile slopes or as temporary protection until permanent covers are established.

K.6 Stability

1. Calculate the design variables"
    a. Discharge Q, cfs
    b. Bottom slope S_H
    c. Cross-section geometry and
    d. Vegetation type
2. Assign a maximum velocity from Table K-10 based on vegetation and slope.

Assume a Manning's roughness coefficient n_{CH} (Exhibit K-9) and determine the corresponding value of vR from the n versus vR curves in Exhibit K-3 Use a retardance Class D for permanent vegetation or E for temporary Construction.

3. Calculate the Hydraulic Radius R_H using Equation K-10.

Equation K-10: Hydraulic Radius

$$R_H = (vR_H)/v_{max}$$

Where:

R_H	Hydraulic radius, ft.
vR_H	Value obtained from Exhibit K-3
v_{max}	Maximum velocity, obtained from Step 2

4. Use Equation K-11 to calculate the value of vR_H

Equation K-11: Manning's Equation for Stability Analysis

$$vR_H = \frac{1.49 R_H^{2/3} \sqrt{S}}{n_{CH}}$$

Where:

vR_H	Value obtained from Exhibit K-3
R_H	Hydraulic radius, ft.
S	Slope, ft/ft.
n_{CH}	Manning's roughness coefficient, assumed in Step 3.

5. Compare vR_H from Step 5 to the value assumed in Step 3. If the values are not reasonably close, return to Step 3 and repeat the calculations using a new assumed n_{CH}.
6. Determine the depth of flow using trial and error procedures.
7. If bends are considered, calculate the length of downstream protection, L_p for the bend using

Equation K-12: Downstream Protection

$$\left[\frac{L_p}{R_H}\right] = \frac{0.604 R_H^{1/6}}{n_b}$$

Where:

L_p	Protection length, ft.
R_H	Hydraulic radius, ft.
n_b	Manning's roughness coefficient in the bend

K.7 Capacity

Use the following procedures to calculate capacity of a vegetative channel.

1. Assume a depth of greater than the value from Step 7 in Stability (Page K-K-18) and compute the waterway area,A, and hydraulic radius, R_H.
2. Divide the design flow rate by the waterway area to determine the velocity.
3. Multiply velocity by R_H to determine the value of vR_H. Use Exhibit K-3 to find Manning's roughness coefficient n_{CH} for retardance Class C based on vR_H.
4. Use Manning's equation to find the velocity using R_H,n_{CH}, and channel slope.
5. Compare the velocity results from Step 2 to Step 5. If the values are not reasonably close, return to step 1 and repeat the calculations.
6. Add free-board according to Section 5.6 to the final depth from Step 6.
7. If bends are considered, calculate the super elevation of the water surface profile at the bend using Equation K-13.

Equation K-13: Water Surface Elevation Change in Bends

$$\Delta d = \frac{v^2 T}{g R_c}$$

Where:

Δd	Difference in water surface elevations between the inner and outer banks of the channel bend, ft.
v	Velocity, fps
g	Gravitational acceleration, 32.2 feet per square second (ft/s^2)
R_c	Radius of the centerline of the channel, ft.

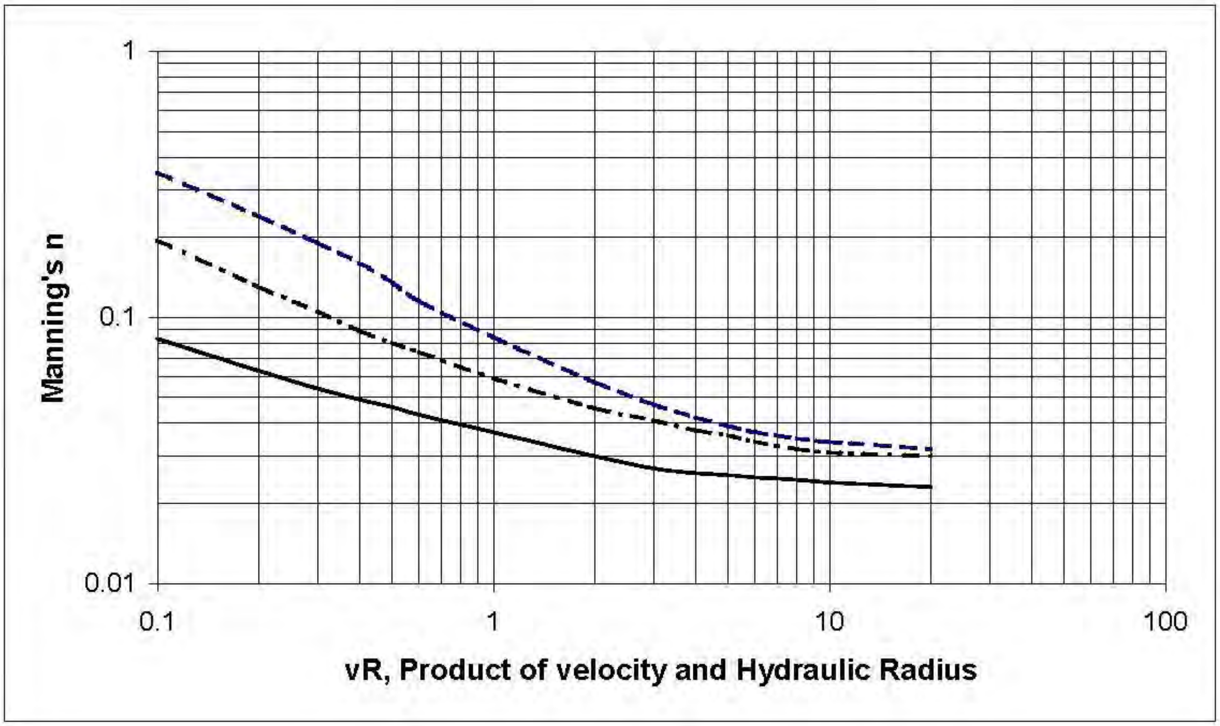


Exhibit K-3: Manning's Roughness Coefficient as a Function of Vegetative Flow Retardance[26]

[26] SDFDM, Chapter 8, Figure 8.2

K.8 Flexible Lining Open Channel Design Procedures[27]

Use the following procedures to design flexible channel linings with the following limitations:

- Minimum riprap thickness is equal to d_{100}
- The value of d_{85}/d_{15} must be less than 4.6
- The Froude number must be less than 1.2
- Slide slopes are equal to 2:1
- Assume a safety factor of 1.2
- The maximum velocity allowed is 15 fps.
- Specific weight of riprap is assumed to be 165 pounds per cubic foot (lb/ft^3)

Table K-11. Permissible Unit Shear Stress for Flexible Lining Materials[28,29]

Lining Category	Type	Permissible Unit Shear Stress τ_p (lb/ft^2)
Gravel Riprap	1-inch D_{50}	0.33
	2-inch D_{50}	0.67
Rock Riprap	6-inch D_{50}	2.00
	12-inch D_{50}	4.00

Table K-12. Maximum Velocities for Lining Materials[30]

Material Type	Maximum Velocity (feet per second)
Sand	2
Silt	3.5
Firm Loam	3.5
Fine Gravel	5
Stiff Clay Graded Loam or Silt to Cobbles	5
Coarse Gravel	5
Hard Pan	6

[27] SDFDM, Chapter 8, Section 8.5.8.
[28] SDFDM, Chapter 8, Table 8.8
[29] Values listed are representative values for the represented depth ranges. Manning's roughness coefficients vary with flow depth.
[30] AASHTO Model Drainage Material, 1991

1. Determine the average velocity of the main channel for the design return interval. Calculate the Manning's roughness coefficient for riprap using Equation K-14.

Equation K-14: Manning's Roughness Coefficient for Riprap

$$n = 0.0395 D_{50}^{1/6}$$

Where:

n	Manning's roughness coefficient for stone riprap
D_{50}	Diameter of stone for which 50%, by weight, of the gradation is finer, ft.

2. If the rock is to be placed at the outside of a bend, multiply the velocity determined in Step 1 by the bend correction coefficient, C_b using one of the following equations for either a natural (Equation K-15) or a prismatic channel Equation K-16). This requires determining the top width, T, upstream from a bend and the centerline bend radius, R_b.

Equation K-15: Natural Channel Velocity Correction Coefficient

$$C_b = 1.80 \left[\frac{R_b}{T}\right]^{-0.161099}$$

Equation K-16: Prismatic Channel Velocity Correction Coefficient

$$C_b = 1.65 \left[\frac{R_b}{T}\right]^{-0.251239}$$

Where:

C_b	Bend correction Coefficient used to correct velocity in a bend
T	Top width of stream, upstream of bend, ft.
R_b	Radius of the bend, ft.

3. Calculate the Froude Number using Equation K-17.

Equation K-17: Froude Number

$$F_r = \frac{v}{\sqrt{\frac{gA}{T}}}$$

Where:

F_r	Froude number
v	Average velocity, fps
g	Gravitational acceleration, 32.2 feet per square second (ft/s^2)
A	Cross-sectional flow area, ft^2
T	Top width of water surface, ft.

4. Determine the required minimum D_{30} from Equation K-18.

Equation K-18: Minimum d_{30} Riprap Sizing

$$\frac{D_{30}}{d} = 0.193F_R^{2.5}$$

Where:

D_{30}	Minimum riprap sizing, ft.
d	Depth of flow above channel lining, ft.
F_r	Froude number, calculated using Equation K-17

5. Determine available riprap gradations. A well-graded riprap is preferable to uniform size. The diameter of the largest stone,D_{100}, should be no more than 1.5 times the D_{50} size. Blanket thickness should be greater than or equal to D_{100} except as noted below. Sufficient fines (below D_{15}) should be available to fill the voids in the larger rock sizes. The stone weight for a selected stone size can be calculated by the equation:

Equation K-19: Riprap Stone Weight

$$W = 0.5236(SW_s)D$$

Where:

W	Riprap stone weight, lbs.
SW_s	Specific weight of stone, 165 lb/ft^3
D	Selected stone diameter, ft.

K.9 Culvert Design Equations

Equation K-20: Manning's Equation for Culverts[31]

$$Q = \frac{1.49}{n} AR_H^{2/3}\sqrt{S}$$

Where:

Q	Flow rate, cfs
n	Manning's roughness coefficient, 0.013 regardless of pipe material
A	Cross-sectional flow area, ft^2
R_H	Hydraulic radius, ft.
S	Friction slope, ft/ft

[31] City SWMM, Appendix A.4

K.10 Pipe Fill Height Requirements

HS 25 - 44 LIVE LOAD

PIPE DIAMETER (Inches)	NONREINFORCED CONCRETE PIPE				REINFORCED PIPE					
	CLASS 2		CLASS 3		CLASS III		CLASS IV		CLASS V	
	MINIMUM COVER (Feet)	MAXIMUM COVER (Feet)	MINIMUM COVER (Feet)	MAXIMUM COVER (Feet)	MINIMUM COVER (Feet)	MAXIMUM COVER (Feet)	MINIMUM COVER (Feet)	MAXIMUM COVER (Feet)	MINIMUM COVER (Feet)	MAXIMUM COVER (Feet)
4	2.0	19	2.0	23						
6	2.0	20	2.0	24						
8	2.0	21	2.0	23						
10	2.0	20	2.0	24						
12	2.0	22	2.0	24	1.5	17	1.0	27	0.5	41
15	2.0	25	2.0	28	1.5	18	1.0	27	0.5	42
18	2.0	29	2.0	31	1.5	18	1.0	27	0.5	42
21	2.0	31	2.0	35	1.5	17	1.0	27	0.5	42
24	2.0	32	2.0	39	1.5	17	1.0	27	0.5	42
27	2.0	34	2.0	41	1.5	17	1.0	27	0.5	41
30	2.0	37	2.0	41	1.5	17	1.0	27	0.5	41
33	2.0	38	2.0	43	1.5	17	1.0	27	0.5	41
36	2.0	39	2.0	44	1.5	17	1.0	26	0.5	41
42					1.5	17	1.0	26	0.5	41
48					1.5	16	1.0	26	0.5	41
54					1.5	16	1.0	26		
60					1.5	16	1.0	26		
66					1.5	16	1.0	26		
72					1.5	16	1.0	25		

Exhibit K-4: Fill Height Table for Circular Concrete Pipe[32]

[32] ODOT, Standard Drawing, RD386

PIPE	CORRUGATED HDPE	
DIAMETER (Inches)	MINIMUM COVER (Feet)	MAXIMUM COVER (Feet)
12	2.0	29
15	2.0	30
18	2.0	27
24	2.0	24
30	2.0	21
36	2.0	23
42	2.0	22
48	2.0	22
60	2.5	21

Exhibit K-5: Fill Height Table for Corrugated HDPE Pipe[33] [34]

PIPE	STEEL REINFORCED HDPE	
DIAMETER (Inches)	MINIMUM COVER (Feet)	MAXIMUM COVER (Feet)
24	1.0	50
30	1.0	50
36	1.0	50
42	1.0	50
48	1.0	30
60	1.0	30
66	1.5	30
72	1.5	30

Exhibit K-6: Fill Height Table for Steel Reinforced HDPE Pipe[35] [36]

[33] ODOT, Standard Drawing, RD390
[34] Heavy solid line denotes boundary between minimum cover requirements.
[35] ODOT, Standard Drawing, RD391
[36] Heavy solid line denotes boundary between minimum cover requirements.

PIPE	DUAL WALL POLYPROPYLENE		
DIAMETER (Inches)	MINIMUM COVER (Feet)	MAXIMUM COVER (Feet)	REMARKS
12	1.0	28	ASTM F 2736
15	1.0	30	
18	1.0	26	
24	1.0	22	
30	1.0	22	

Exhibit K-7: Fill Height Table for Dual Wall Polypropylene Pipe[37]

PIPE	TRIPLE WALL POLYPROPYLENE		
DIAMETER (Inches)	MINIMUM COVER (Feet)	MAXIMUM COVER (Feet)	REMARKS
30	1.0	22	ASTM F 2764
36	1.0	19	
48	1.0	16	
60	2.0	22	

Exhibit K-8: Fill Height Table for Triple Wall Polypropylene Pipe[38]

[37] ODOT, Standard Drawing, RD393
[38] ODOT, Standard Drawing, RD393

PIPE	SOLID WALL PVC		
DIAMETER (Inches)	MINIMUM COVER (Feet)	MAXIMUM COVER (Feet)	REMARKS
4	2.0	40	ASTM D 3034 SDR35 (46 psi stiffness)
6	2.0	40	
8	2.0	40	
10	2.0	40	
12	2.0	40	
15	2.0	40	
18	2.0	40	ASTM F 679 (46 psi stiffness)
21	2.0	40	
24	2.0	40	
27	2.0	40	
30	2.0	40	
33	2.0	40	
36	2.0	40	
42	2.0	40	
48	2.0	40	

PIPE	PROFILE WALL PVC		
DIAMETER (Inches)	MINIMUM COVER (Feet)	MAXIMUM COVER (Feet)	REMARKS
4	2.0	40	ASTM F 794 Series 46 (46 psi stiffness)
6	2.0	40	
8	2.0	40	
10	2.0	40	
12	2.0	40	
15	2.0	40	
18	2.0	40	
21	2.0	40	
24	2.0	40	
27	2.0	40	
30	2.0	40	
33	2.0	40	
36	2.0	40	
39	2.0	40	
42	2.0	40	
45	2.0	40	
48	2.0	40	

Exhibit K-9: Fill Height Table for PVC Pipe[39]

[39] ODOT, Standard Drawing, RD388

PIPE DIAMETER (Inches)	SOLID WALL PVC MINIMUM COVER (Feet)	SOLID WALL PVC MAXIMUM COVER (Feet)	SOLID WALL PVC REMARKS
14	2.0	41	AWWA C905 DR 32.5 (57 psi stiffness)
16	2.0	41	
18	2.0	41	
20	2.0	41	
24	2.0	41	
30	2.0	41	
36	2.0	41	
42	2.0	41	
48	2.0	41	

PIPE DIAMETER (Inches)	SOLID WALL PVC MINIMUM COVER (Feet)	SOLID WALL PVC MAXIMUM COVER (Feet)	SOLID WALL PVC REMARKS
14	1.0	46	AWWA C905 DR 26 (115 psi stiffness)
16	1.0	46	
18	1.0	46	
20	1.0	46	
24	1.0	46	
30	1.0	46	
36	1.0	46	

PIPE DIAMETER (Inches)	SOLID WALL PVC MINIMUM COVER (Feet)	SOLID WALL PVC MAXIMUM COVER (Feet)	SOLID WALL PVC REMARKS
14	1.0	48	AWWA C905 DR 25 (129 psi stiffness)
16	1.0	48	
18	1.0	48	
20	1.0	48	
24	1.0	48	
30	1.0	48	
36	1.0	48	
42	1.0	48	
48	1.0	48	

Exhibit K-10: Fill Height Table for Triple Wall Polypropylene Pipe[40]

[40] ODOT, Standard Drawing, RD393

PIPE	SOLID WALL PVC		
DIAMETER (Inches)	MINIMUM COVER (Feet)	MAXIMUM COVER (Feet)	REMARKS
14	1.0	61	AWWA C905 DR 21 (224 psi stiffness)
16	1.0	61	
18	1.0	61	
20	1.0	61	
24	1.0	61	
30	1.0	61	
36	1.0	61	

PIPE	SOLID WALL PVC		
DIAMETER (Inches)	MINIMUM COVER (Feet)	MAXIMUM COVER (Feet)	REMARKS
4	1.0	48	AWWA C900 DR 25 (129 psi stiffness)
6	1.0	48	
8	1.0	48	
10	1.0	48	
12	1.0	48	

PIPE	SOLID WALL PVC		
DIAMETER (Inches)	MINIMUM COVER (Feet)	MAXIMUM COVER (Feet)	REMARKS
4	1.0	69	AWWA C900 DR 18 (364 psi stiffness)
6	1.0	69	
8	1.0	69	
10	1.0	69	
12	1.0	69	

PIPE	SOLID WALL PVC		
DIAMETER (Inches)	MINIMUM COVER (Feet)	MAXIMUM COVER (Feet)	REMARKS
4	1.0	109	AWWA C900 DR 14 (814 psi stiffness)
6	1.0	109	
8	1.0	109	
10	1.0	109	
12	1.0	109	

Exhibit K-11: Fill Height Table for Triple Wall Polypropylene Pipe[41]

[41] ODOT, Standard Drawing, RD393

K.11 Manhole Geometry

Table K-13: Minimum Diameter Precast Manhole for Maximum Pipe Sizes[42]

Manhole Diameter, inches	Maximum pipe size (inches) for Deflection Angle		
	0° (through pipe)	45°	90°
48	30	15	--
60	36	18	--
72	48	24	--
84	60	30	12
96	72	42	15

[42] SDFDM, Chapter 4

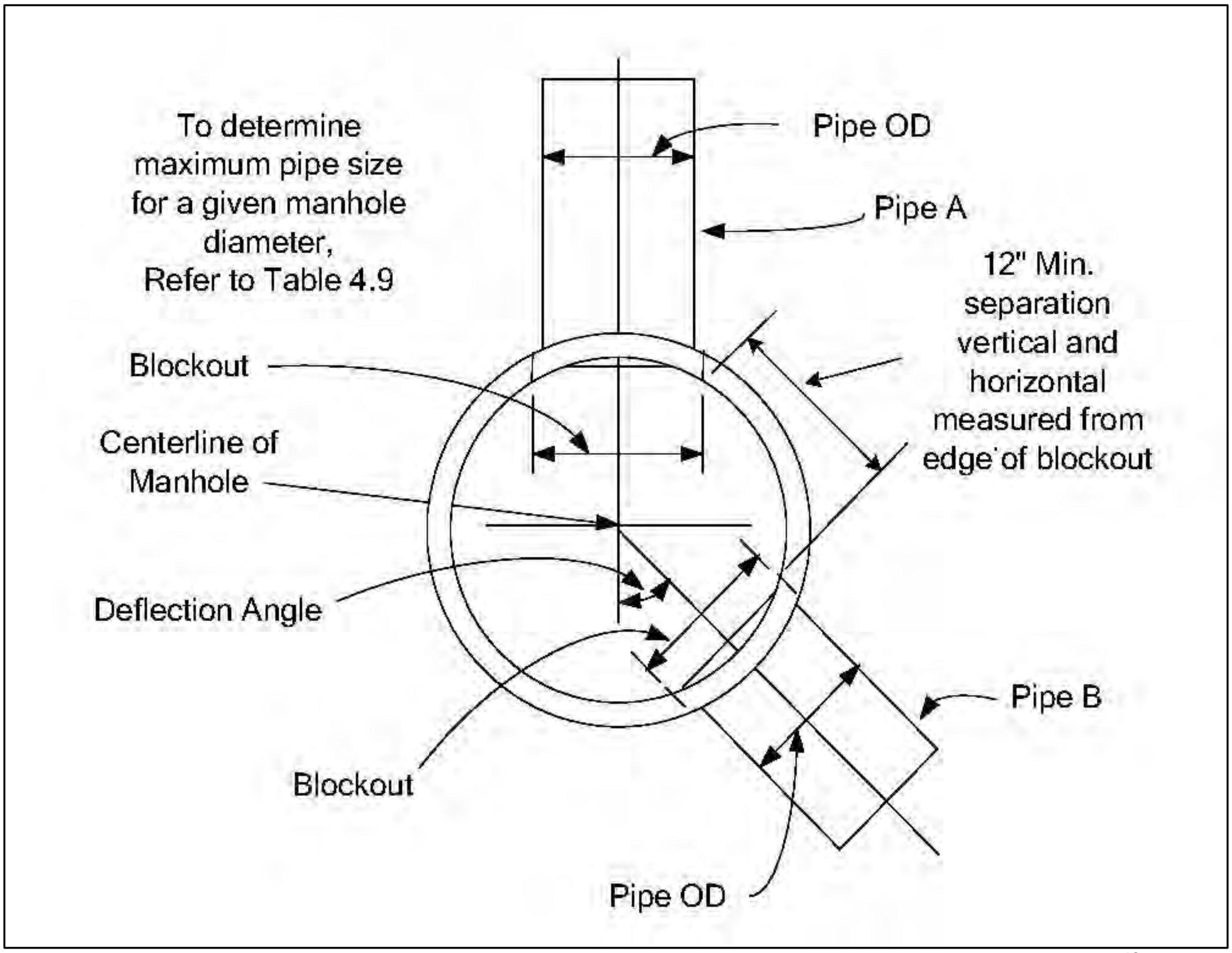


Exhibit K-12: Minimum Precast Manhole Diameter for Maximum Sewer Sizes[43]

[43] SDFDM, Chapter 4.

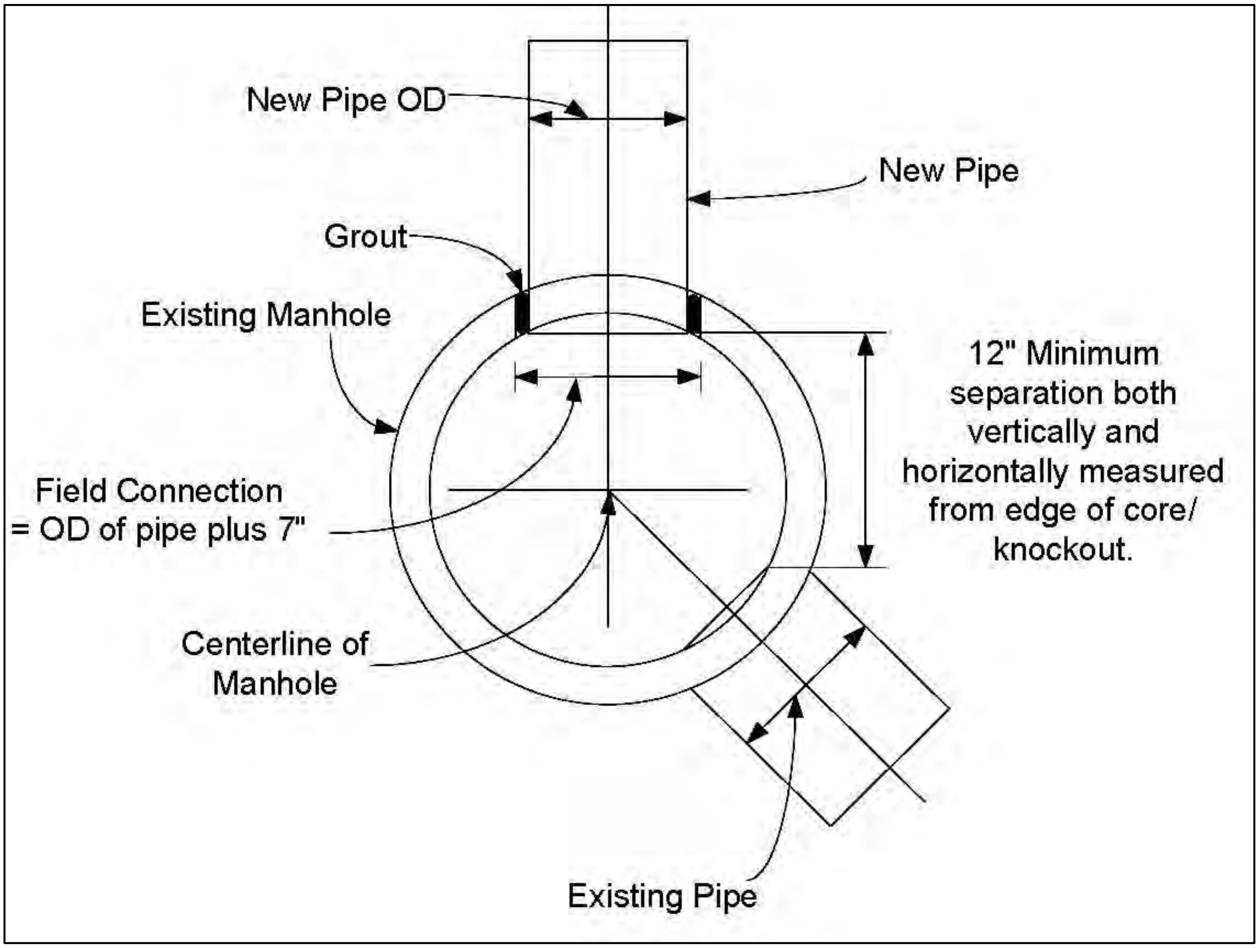


Exhibit K-13: New Pipe Connection to an Existing Manhole[44]

[44] SDFDM, Chapter 4.

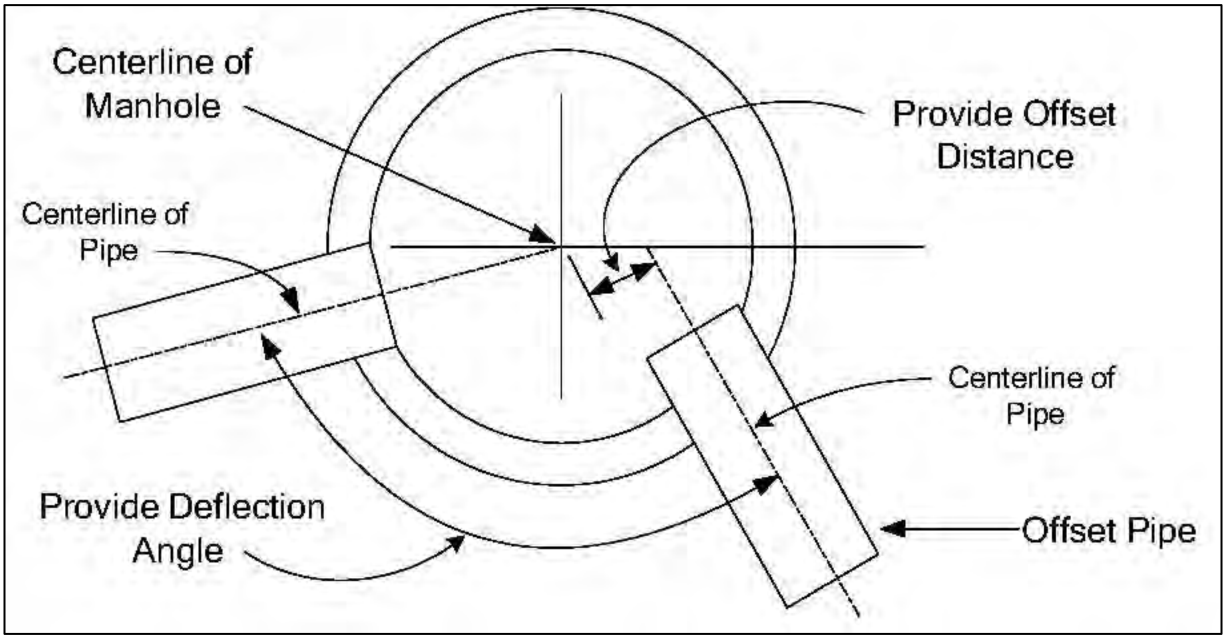


Exhibit K-14: Offset Pipe Connections to a Manhole[45]

[45] SDFDM, Chapter 4.

Appendix L

Nomographs for Water Quality BMP Sizing

APPENDIX L: NOMOGRAPHS FOR WATER QUALITY BMP SIZING

This appendix presents BMP sizing nomographs developed to identify a recommended design storm for sizing water quality BMPs for Port properties. Both volume-based and flow-based BMP sizing nomographs, as well as a nomograph specifically for sizing permanent wet pools, have been developed as described below. These nomographs supported the development of DSM minimum sizing criteria for water quality BMPs to meet the Port's MS4 permit capture and treat requirements, as described in Chapters 4 and 6 of the DSM.

L.1 Summary of Approach

Stormwater BMPs are most appropriately sized and evaluated using hydrograph routing techniques because both the storage and release dynamics of the system are considered. Long-term continuous hydrologic simulation can account for hydrograph routing, but also allows for an assessment of the volume captured and treated by a BMP under a wide variety of antecedent and storm event conditions. It is for this reason that continuous simulation is the industry-preferred method for stormwater BMP assessment and design. However, developing and implementing a continuous simulation model whenever a BMP is being considered can be a difficult and time-consuming task. Percent capture nomographs that summarize the results of continuous simulation provide a means for quickly estimating the size of a given BMP needed to achieve a target percent capture (e.g., 80 percent).

The USEPA Stormwater Management Model (version 5.0.022) was used to simulate the long-term, continuous hydraulic performance of volume-based BMPs and estimate the average annual percent capture for different unit sizes (e.g., storage volumes normalized by drainage area). Runoff from a fixed catchment size was simulated and routed through storage units with various volume capacities and drawdown times using a 60-year, hourly rainfall record. The amount of runoff that bypassed the facility over the entire period of record for each variation was recorded to determine the capture efficiency, or percent of runoff captured, for each facility. Thus, capture efficiency is defined here as the portion of total runoff captured and treated divided by the total runoff volume from the drainage area.

The percentage of total volume captured by flow-based BMPs for various design intensities and times of concentration was estimated by analyzing 5 minute, Automated Surface Observing System (ASOS) rainfall data from the gauge at PDX. To calculate this, the portion of the runoff greater than that produced by the specified design intensity was assumed to be bypassed by the BMP.

For BMPs with permanent wet pools (e.g., wet basins), an analysis of discrete storm events was conducted. Storm events were discretized from the 60-year, hourly rainfall record by defining a minimum inter-event time and minimum event depth expected to produce runoff. Assuming that the performance of wet pools is based on the volume of the wet pool relative to the incoming runoff volume, as well as the retention time between storms, the long-term average percent capture and treated by a wet pool can be estimated by comparing various design storm depths to the depths of discrete storm events. The inter-event times can be approximated as the minimum residence time of stormwater in the wet pool.

Additional details of the nomograph development methodology are provided below, followed by a sensitivity analysis to evaluate the accuracy of the recommended BMP sizing approach.

L.2 Methodology

L.2.1 Volume-Based BMPs

For the volume based BMPs (e.g., detention basins), the SWM model was used to perform a series of continuous simulations using a variety of detention storage configurations and drawdown times, with hourly rainfall data from the PDX rainfall gauge over a 60-year period. The tributary area was assumed to be 10 acres with 100 percent imperviousness. A fixed depth of 2.5 feet was assumed and the surface area was varied such that the storage volume was equivalent to a range of unit BMP volumes (expressed in watershed inches). Additionally, discharge rates were varied to represent a range of drawdown times (time it takes to completely drain the storage volume from a brimful condition).

General SWM modeling parameters and subcatchment properties assumed for the batch processing simulation modeling are included in Table 1. Table 2 summarizes the assumed BMP parameters. As indicated in Table 2, storage areas were computed for a range of design storm depths by assuming a long-term volumetric runoff coefficient of 0.84, which as discussed in Section 3.3 is the recommended runoff coefficient to use for a 100 percent impervious drainage area.

Table 1: SWM Model Parameters

Parameter	Assumption
Wet time step	15 min
Dry time step	4 hour
Routing time step	20 sec
Routing option	Kinematic wave
Infiltration option	*Not used as subcatchment; was 100% impervious*
Rainfall record	PDX (NCDC Gage #356751)
Period of record modeled	10/1/1951 – 10/1/2011
Evaporation data	See Table 2, below
Subcatchment area	10 ac
Subcatchment imperviousness	100%
Subcatchment flow path	250 ft
Subcatchment slope	3%
Impervious Manning’s n	0.012
Pervious Manning’s n	*Not used as subcatchment; was 100% impervious*
Impervious depression storage	0.05 inches
Pervious depression storage	*Not used as subcatchment; was 100% impervious*
Percent zero depression storage (within impervious area)	25%
Soil parameters	*Not used as subcatchment; was 100% impervious*

Table 2: BMP Parameters

BMP Parameter	Assumption
Depth of ponding (ft)	2.5 ft
Storage Area (ft^2)	(10 ac)*(43560 ft^2/ac)*(Design Storm Depth*0.84)*(1/12 ft/in)/2.5 feet
Design Storm Depths (watershed inches)	Varied from 0.05 to 2.0 in
Outlet Stage/Discharge Curve	(Storage Area*2.5 ft)/(Drawdown Time)
Drawdown Time (hours)	Varied from 1 to 2400 hrs

Evaporation inputs used in the SWM model are included in Table 3, below. The evaporation was based on pan evaporation data from North Willamette Experimental Station reported in the NOAA Technical Report NWS 34. A pan coefficient of 0.8 was multiplied by the monthly values to approximate actual evaporation occurring at Portland International Airport. This pan coefficient is slightly higher than the typical value used for Class A Evaporation Pans (0.7). The evaporation simulated in the model is from very impervious depression rather than from a waterbody or wet soil, so the rate of evaporation is expected to be higher.

Table 3: Evaporation Inputs

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Evaporation (in/day)	0.026	0.041	0.068	0.093	0.148	0.178	0.211	0.186	0.135	0.068	0.03	0.026

Using the above inputs, the SWM model was used to estimate the long-term volume treated and bypassed to estimate the percent capture for a variety of BMP sizes.

L.2.2 Flow-based BMPs

For flow-based BMPs (e.g., Stormfilter vaults, swales), 5-minute rainfall data from PDX was analyzed to estimate the volume captured and volume bypassed for different unit flow rates (design intensities) using a spreadsheet analysis. Both online and offline BMP configurations were considered. With the online configuration, no treatment was assumed to occur once the design flow rate has been exceeded. Flow is either 100 percent treated as long as flow is below the design flow rate, or no flow is treated if flow is above the design flow rate. This can occur in vegetated swales where they become significantly less effective at removing pollutants when they are conveying high flow rates. With the offline configuration, treatment up to the design flow rate was assumed to occur at all flow rates, while any additional flow exceeding the design flow is not treated. This can occur for Stormfilter vaults, which have an internal bypass mechanism to ensure treatment occurs even though the influent flow rate exceeds the design capacity.

In addition to online and offline configurations, various times of concentration for the tributary drainage area were considered by averaging the 5-minute intensities over different time periods and then using these averaged intensities to evaluate the volume captured over the period of record. This accounts for the fact that a higher percent capture is possible with a longer time of concentration because of the influence hydrologic routing has on peak flow rates. Table 4 summarizes the analysis parameter assumptions for developing the flow-based nomographs.

Table 4: Flow-Based Analysis Parameters

Parameter	Assumption
Rainfall Record	PDX (WBAN 24229)
Period of Record	01/1/2000 – 5/30/2013
Times of Concentration	5 to 60 minutes
Design Intensity Range	0.01 to 0.5 in/hr

L.2.3 Wet Pool Based BMPs

For wet pool based BMPs, such as wet basins, a discrete storm event analysis was conducted using the same rainfall record used for the volume-based BMPs summarized in Table 1. The statistics functions of EPA SWM model 5 were used to discretize the rainfall events by specifying 6-hour, 12-hour, and 24-hour minimum inter-event times with a minimum event depth of 0.1 inches. This resulted in three separate time series' of discrete storm events. Each time series was then used to assess the effective long-term treated volume for various unit wet pool volumes (i.e., expressed in watershed inches). For example, for a unit wet pool volume of 0.5 watershed inches, all events less than 0.5 inches were assumed 100 percent treated. For all other events, only the first 0.5 inches was assumed treated. By tabulating the cumulative treated volumes for each design storm for each discrete event time series, a relationship between percent treated and wet pool size was developed and summarized into a sizing nomograph as described below.

L.2.4 Runoff Coefficient for BMP Sizing

Sizing BMPs using the nomographs requires an estimate of the long-term volumetric runoff coefficient for the watershed. The most accurate estimate of the runoff coefficient is one based on the actual SWM model simulations since the SWM model was used to develop the nomographs and will reflect the long-term series of rainfall-runoff for Port facilities. Therefore, the SWM model was run using the same time series as used to develop the volume-based nomographs for a variety of impervious areas while holding the other watershed parameters constant. A conservative hydraulic conductivity of 0.12 in/hr was used along with a pervious depression storage coefficient of 0.1 in. Results of this analysis are provided in Section 3.

L.2.5 Sensitivity Analysis

To evaluate the accuracy of the recommended simple BMP sizing procedure based on the percent capture nomographs, a simple sensitivity analysis was completed. BMPs were sized by assuming a target percent capture and then using the design storm depth (volume-based BMPs) or design storm intensity (flow-based BMPs) to investigate the differences in the assumed percent capture and the modeled percent capture by varying drainage area imperviousness, hydraulic conductivity, and slope. A SWM model was created with a single drainage area draining to either a storage unit to simulate volume-based BMPs or a flow divider to simulate flow-based BMPs. Offline flow-based BMPs were simulated by using a cutoff divider where all portions of the flows above the design flow rate are diverted. Online flow-based BMPs were simulated by using a tabular divider where all flows are diverted once the design flow rate is exceeded. For volume-based BMPs, two different drawdown rates, 24 hour and 48 hour, were evaluated by sizing a single orifice to drain the entire design volume in the specified time; overflows were simulated using a wide, transverse weir. Evaporation rates were not considered in this analysis. Twenty minute rainfall data from the Automated Surface Observing System (ASOS) gauge was used for the flow-based BMP simulations, while hourly rainfall data from the National Climatic Data Center (NCDC) gauge was used for the volume-based simulation. Table 5 shows the common parameters used in the analysis for all simulations.

Table 5: SWM Model Parameters

Parameter	Assumption
Wet time step (volume-based)	10 min
Wet time step (flow-based)	1 min
Dry time step	1 hour
Routing time step	30 sec
Routing option	Kinematic wave
Evaporation data	See Table 6, below
Subcatchment area	10 acres
Subcatchment flow path	250 feet
Impervious Manning's n	0.012
Pervious Manning's n	0.10
Impervious depression storage	0.05 inches
Pervious depression storage	0.15
Percent zero depression storage (within impervious area)	25%
Soil parameters	Green Ampt

Using a batch processing tool, 64 volume-based simulations and 64 flow-based simulations were completed for the sensitivity analysis. Table 6 shows which parameters were varied to complete the volume-based simulations and Table 7 shows which parameters were varied to complete the flow-based simulations.

Table 6: Volume-Based Simulation Parameters

Parameter	Assumption
Imperviousness	20, 40, 80, and 100 (%)
Hydraulic Conductivity (K_{sat})	0.05 and 0.5 (in/hr)
Suction Head , K_{sat}=0.05	8 (in)
Suction Head , K_{sat}=0.5	3 (in)
Initial Moisture Deficit, K_{sat}=0.05	0.2
Initial Moisture Deficit , K_{sat}=0.5	0.3
Slope	2 and 8 (%)
BMP Percent Capture	40 and 80 (%)
Drawdown Rate	24 and 48 (hrs)
Orifice Diameter	Sized according to drawdown rate
Rainfall Record	PDX (NCDC Gage #356751)
Period of Record Modeled	10/1/1951 – 10/1/2011

Table 7: Flow-Based Simulation Parameters

Parameter	Assumption
Imperviousness	20, 40, 80, and 100 (%)
Hydraulic Conductivity (K_{sat})	0.05 and 0.5 (in/hr)
Suction Head , K_{sat}=0.05	8 (in)
Suction Head , K_{sat}=0.5	3 (in)
Initial Moisture Deficit, K_{sat}=0.05	0.2
Initial Moisture Deficit , K_{sat}=0.5	0.3
Slope	2 and 8 (%)
BMP Percent Capture	40 and 80 (%)
Configuration	Online and Offline
Rainfall Record	PDX (ASOS Gage #KPDX)
Period of Record Modeled	1/1/2000 – 06/26/2013

The results of this analysis were compared to BMP sizes from volume-based and flow-based nomographs. Assumed percent captures from the nomographs were compared to simulated percent captures from the simple BMP size modeling. Results are presented and discussed below.

L.3 Results

L.3.1 Volume-based BMP Results

The resulting volume-based BMP nomograph is included as Figure 1. Each point on the nomograph reflects the percent of runoff captured by a single BMP scenario, assuming a BMP that is sized for a particular design storm depth and a discharge rate that corresponds to a particular BMP drawdown time. Each curve on the nomograph reflects a specific drawdown time and each point reflects the percent capture achieved by various BMP sizes (design storm depths) when sized to that drawdown time.

The required design storm to achieve 80 percent capture with a BMP that drains in 48 hours is approximately 0.65 inches. A 90 percent capture would require a design storm of approximately 0.91 inches.

L.3.2 Flow-based BMP Results

The resulting flow-based nomograph for an online configuration is included below as Figure 2 and for an offline configuration as Figure 3. Similar to the volume-based nomograph, each point on the flow-based nomographs reflects the percent of runoff captured by a single BMP scenario, assuming a particular time of concentration and design intensity. Each curve on the nomograph reflects the percent capture achieved by various BMP sizes (corresponding to design intensity and flow rate), each having a common time of concentration. The required design intensity required to achieve 80 percent capture, assuming a 10-minute time of concentration (corresponds to highly impervious areas with an established drainage network), is approximately 0.21 in/hr for an online configuration and approximately 0.12 in/hr for an offline configuration. As shown in the figure, higher percent capture may be achieved by choosing a higher design intensity.

L.3.3 Wet Pool Results

The resulting nomograph for wet pools are provided in Figure 4. The minimum residence times indicated in the figure are related to the minimum inter-event times used to discretize the storm events. As shown in the figure, a wet pool volume sized using a design storm of 1 inch would be expected to treat approximately 80 percent of the long-term runoff volume with a minimum residence time of 12 hours. Shorter residence times require smaller design storm depths and longer residence times require larger design storm depths to achieve an equivalent level of treatment.

L.3.4 Runoff Coefficient Results and BMP Sizing

Figure 5 summarizes the results of the SWM model simulations using PDX rainfall, variable imperviousness, and a conservative saturated hydraulic conductivity of 0.12 in/hr to estimate infiltration in pervious areas. The rational formula can be used to size BMPs given a runoff coefficient and a design storm depth. The runoff coefficient for a watershed with a particular imperviousness can be computed using the linear regression line. BMP sizes would be conservative (i.e., larger) for areas with conveyance storage and with higher infiltration rates than have been assumed, but could be non-conservative (i.e., smaller) for watersheds with no conveyance storage and lower infiltration rates. While most drainage areas have some conveyance storage and lower infiltration rates than what have been assumed are not likely, the recommended runoff coefficient formula as a function of imperviousness would be to just round up the linear regression parameters as follows:

$$R_v = 0.82 \cdot IMP + 0.02$$

Where R_v is the volumetric runoff coefficient and IMP is the impervious fraction. This coefficient can be applied to both volume and flow based BMP sizing calculations and was used in the sensitivity analysis as described below by using the following rational formulas for sizing:

Volume-based BMPs:

$$WQ_v = R_v \cdot P \cdot A \cdot$$

Where WQ_v is the water quality design volume, P is the design storm depth, and A is the drainage area to the BMP.

Flow-based BMPs:

$$WQ_f = R_v \cdot I \cdot A \cdot$$

Where WQ_f is the water quality design flow rate, I is the design storm intensity, and A is the drainage area to the BMP.

L.3.5 Sensitivity Analysis Results

The sensitivity analysis shows that hydraulic conductivity affects volume based BMP sizing performance more than other factors. The analysis also shows that the simple BMP sizing procedure using the derived runoff coefficient equation under-predicted BMP performance (i.e., conservatism) when imperviousness was greater than 40 percent and over-predicted BMP performance when imperviousness was near 20 percent. Imperviousness also affected performance when hydraulic conductivity was low. Slope minimally affected capture efficiency. Figure 6 shows the results of this analysis for a 24 hour drawdown time; Figure 7 shows a 48 hour drawdown time.

For flow based BMPs, the analysis shows that hydraulic conductivity had the greatest influence on BMP sizing performance for both online and offline configurations. Nonetheless, the BMP sizing nomographs presented in this appendix effectively predict flow-based BMP performance. Based on the sensitivity tests, performance was only over predicted in the extreme case when imperviousness was 20 percent, hydraulic conductivity was 0.05 in/hr, and the target capture efficiency was 80 percent. Imperviousness had greater influence when hydraulic conductivity was low. Slope had greater influence when both imperviousness and hydraulic conductivity were low. Figure 8 and Figure 9 show the results for online and offline configurations, respectively.

L.4 Summary and Conclusion

The nomographs presented in this memo are based on long-term continuous rainfall analysis and runoff simulation and are useful for evaluating different design storm depths and intensities for sizing volume and flow-based BMPs to achieve a variety of long-term percent capture volumes. The implications of selecting design storms capable of achieving percent capture volumes of 80 percent or greater can be assessed with some additional analyses. For example, the design storm depths can be converted to a design volume using the rational formula, which can be used to estimate the required footprint area given a typical design depth and factor of safety for a BMP (while considering freeboard and setbacks).

Detention BMPs designed for both water quality and flood control would require additional storage volume and potentially different outlet controls to convey the target flood control design storm. These additional features would likely require a slightly larger footprint. In addition, facilities that have a permanent pool, such as wetland basins and wet ponds, where treatment is more a function of residence time require a different type of analysis. For these facilities, a synoptic analysis of discrete rainfall events was conducted where the inter-event time used to define discrete events was varied. The discrete events were then analyzed to determine the percent capture given a permanent pool volume normalized to watershed inches. Figure 4 is a wet pond sizing nomograph with 6, 12, and 24 minimum residence times.

For flow-based BMPs, such as Stormfilter cartridge vaults, design intensities can be converted to design flow rates by using the rational formula. The number of cartridges needed per acre of impervious drainage area could then be estimated to evaluate the sensitivity of design intensity on vault size. The size of flow-through swales may also be evaluated by making assumptions on cross-sectional and longitudinal profiles and desired contact time (typically > 5 min). The DSM can provide a series of minimum design intensities for a variety of times of concentration, allowing the designer to select an appropriate intensity for their application.

The results of the sensitivity analysis show that BMPs are oversized except for highly pervious areas with low hydraulic conductivity. While this condition could be encountered at Port facilities, if the hydraulic conductivity is estimated to be below 0.1 in/hr for the pervious areas, then the area should be considered impervious when sizing the BMP. Also, drainage areas with only 20 percent imperviousness would likely be subject to future development and it may be in the

Port's best interest to size these BMPs for full build-out conditions (while still ensuring adequate residence times are provided). In addition, the nomographs presented in this appendix are expected to be conservative because no conveyance routing was assumed in their development. Conveyance routing would tend to smooth out storm event hydrographs resulting in lower peaks and higher percent capture of runoff volumes.

In summary, the nomographs provide a useful tool for sizing BMPs and providing guidance on target design storm characteristics. The use of nomographs for BMP sizing provides the benefits and flexibility of sizing BMPs based on continuous simulation. Designers can select a BMP that meets the percent capture requirements and performance goals without being restricted to a single design storm event. The recommended runoff coefficient along with the use of the nomographs is expected to result in a conservative BMP size. However, a designer may wish to use an additional factor of safety when sizing BMPs.

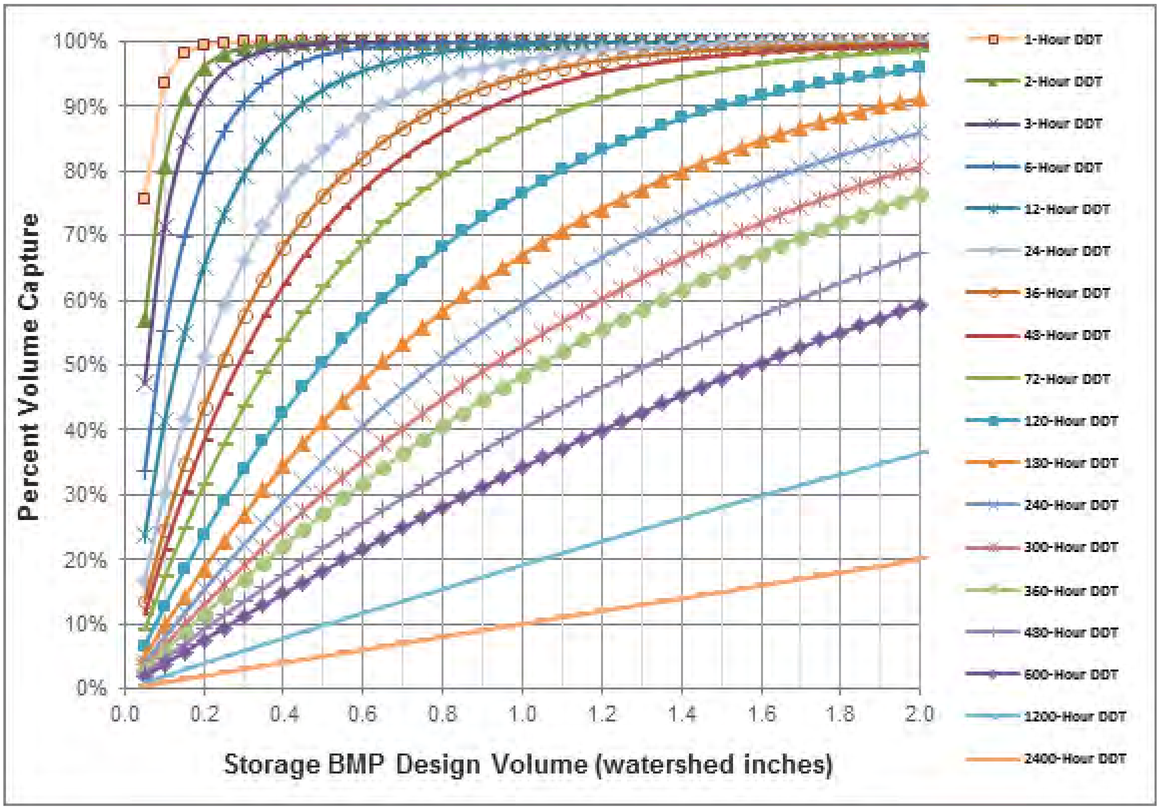


Figure 1: Volume-based BMP Sizing Nomograph

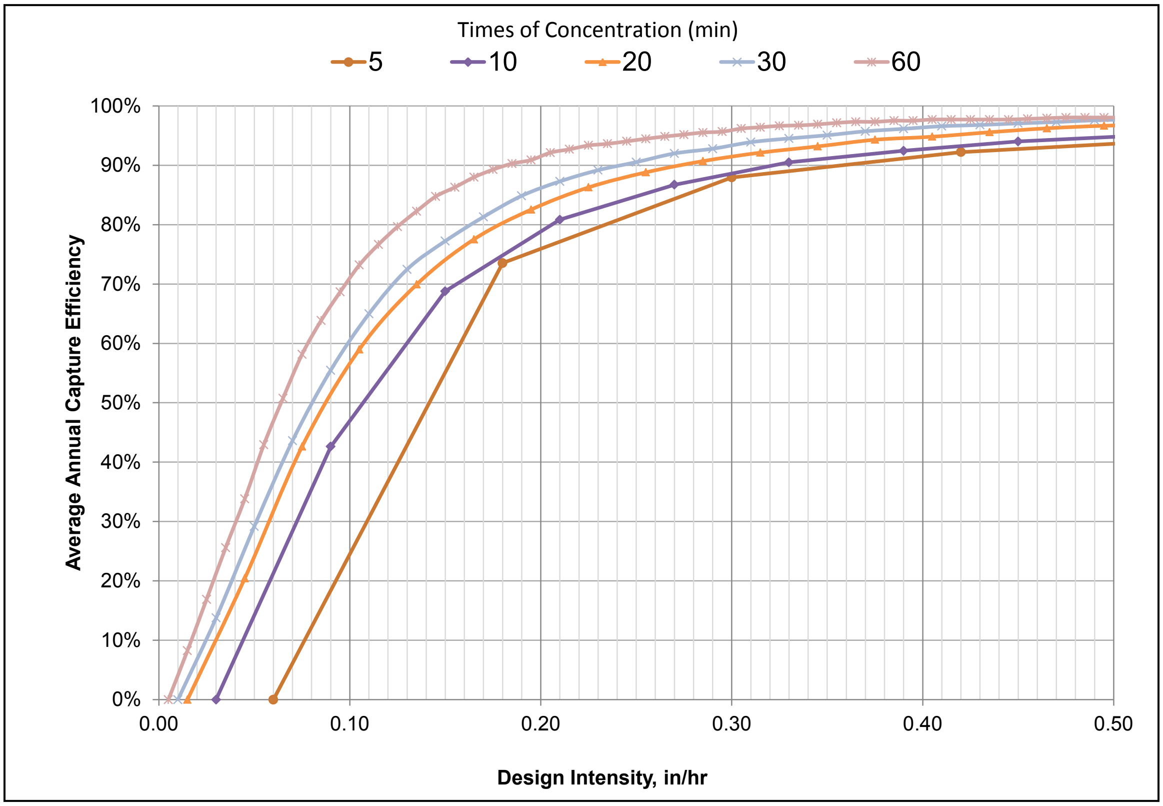


Figure 2: Flow-based Sizing Nomograph – Online Configuration

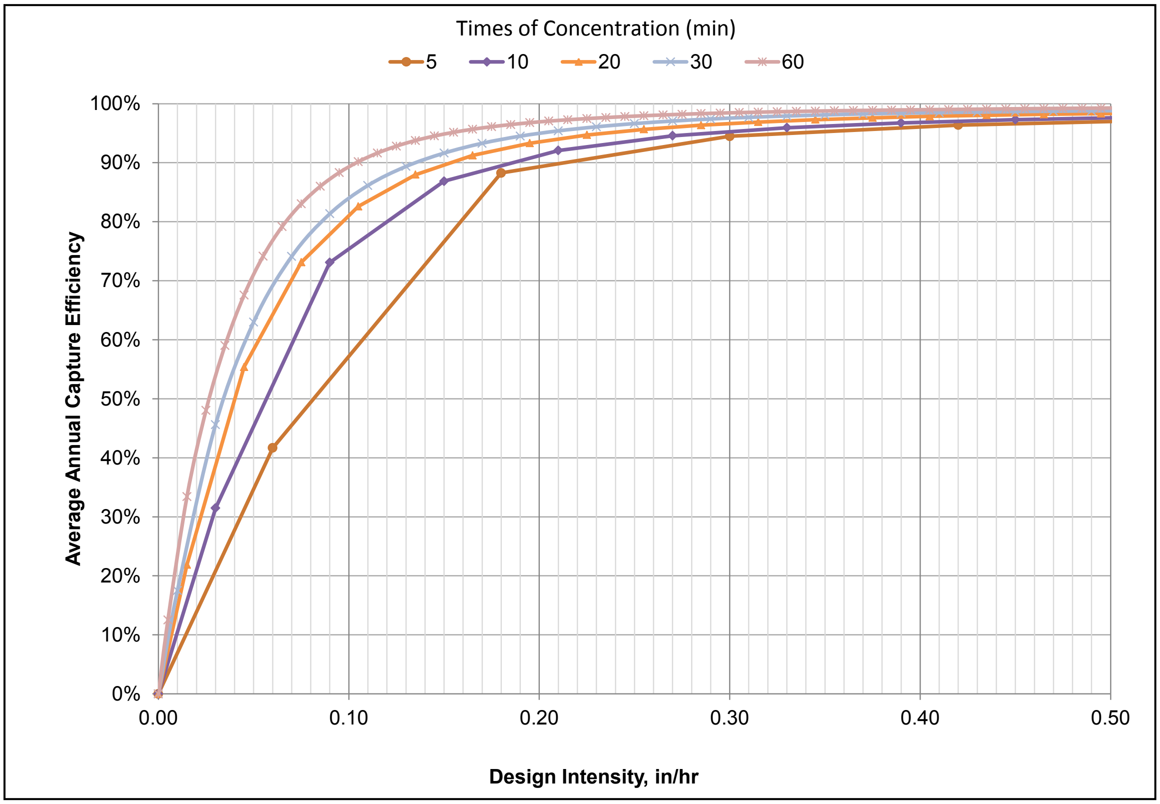


Figure 3: Flow-based Sizing Nomograph – Offline Configuration

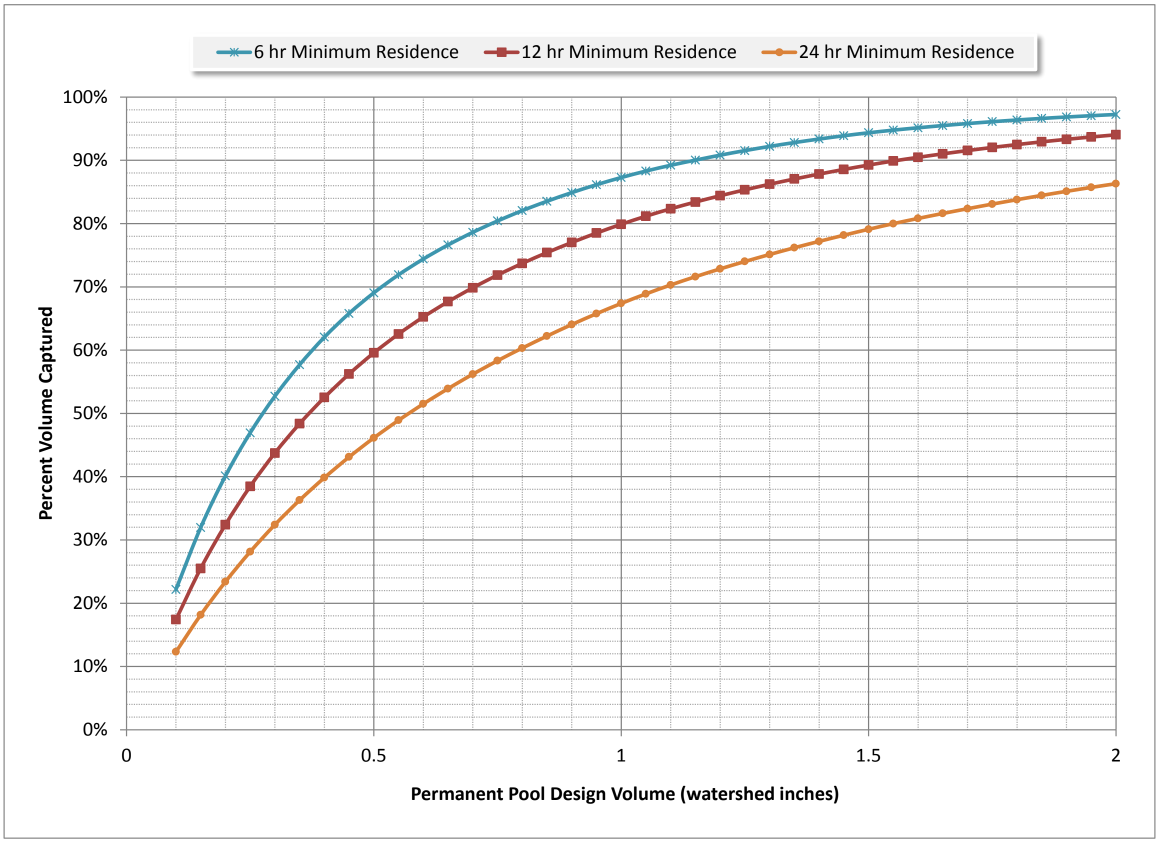


Figure 4: Wet Pond Sizing Nomograph

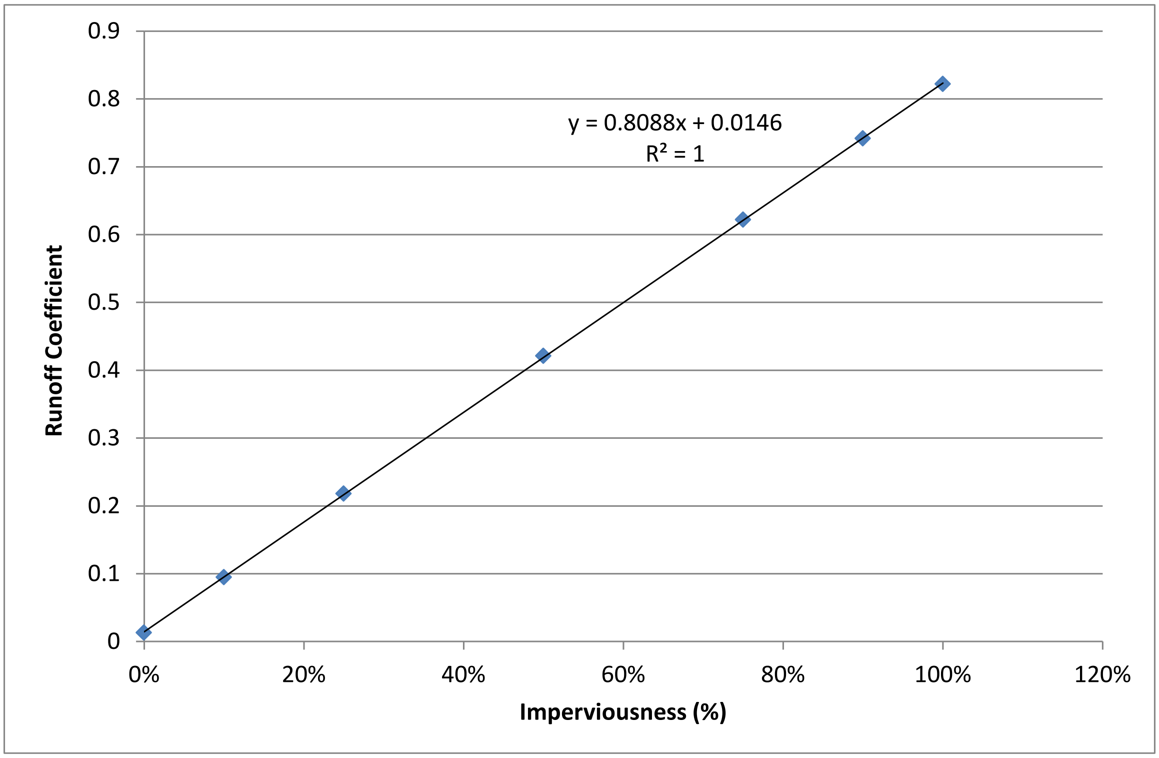


Figure 5: Long-term Runoff Coefficient Estimates

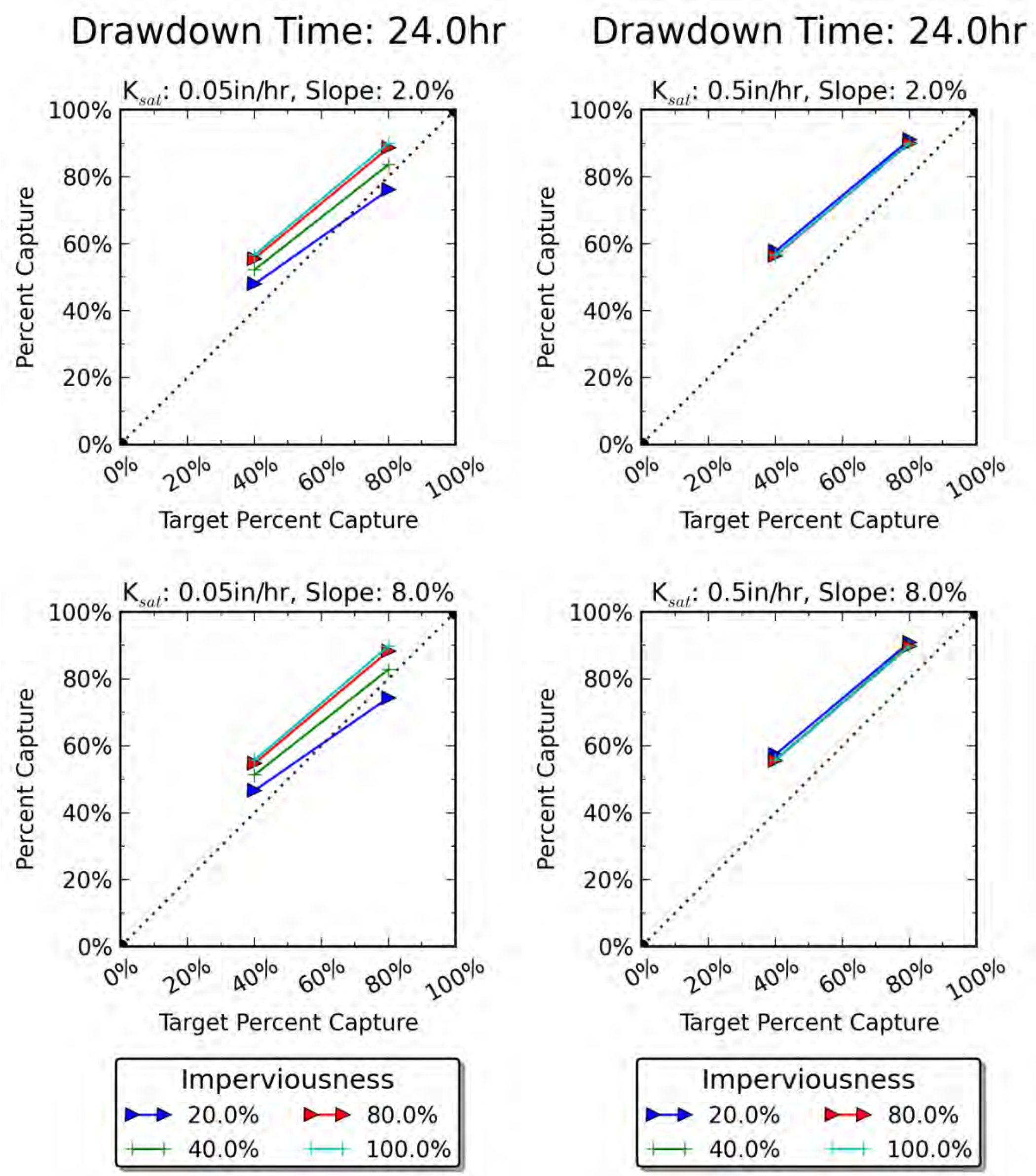


Figure 6: Sensitivity Analysis of Volume-based BMPs – 24 Hour Drawdown Times

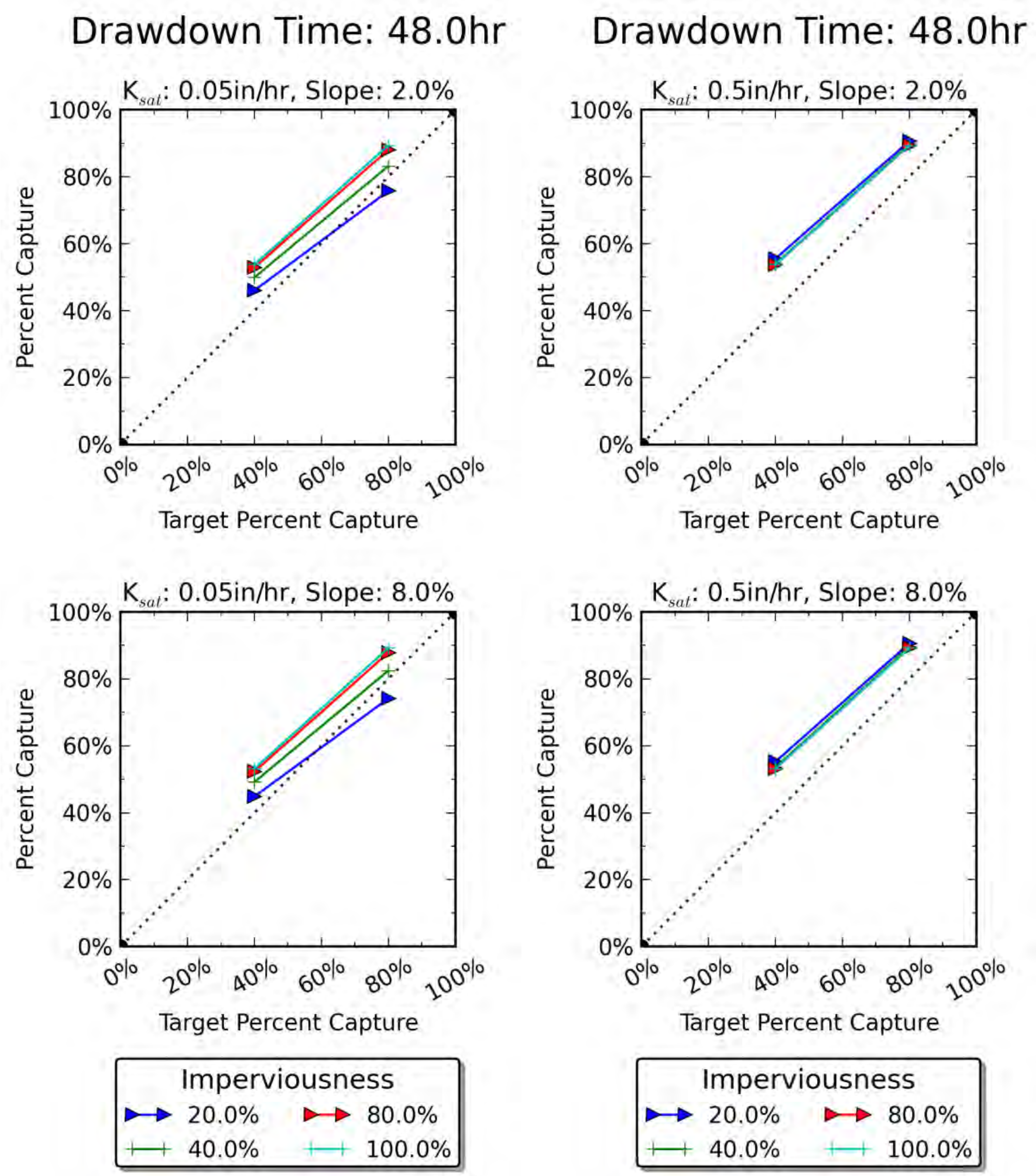


Figure 7: Sensitivity Analysis of Volume-based BMPs – 48 Hour Drawdown Times

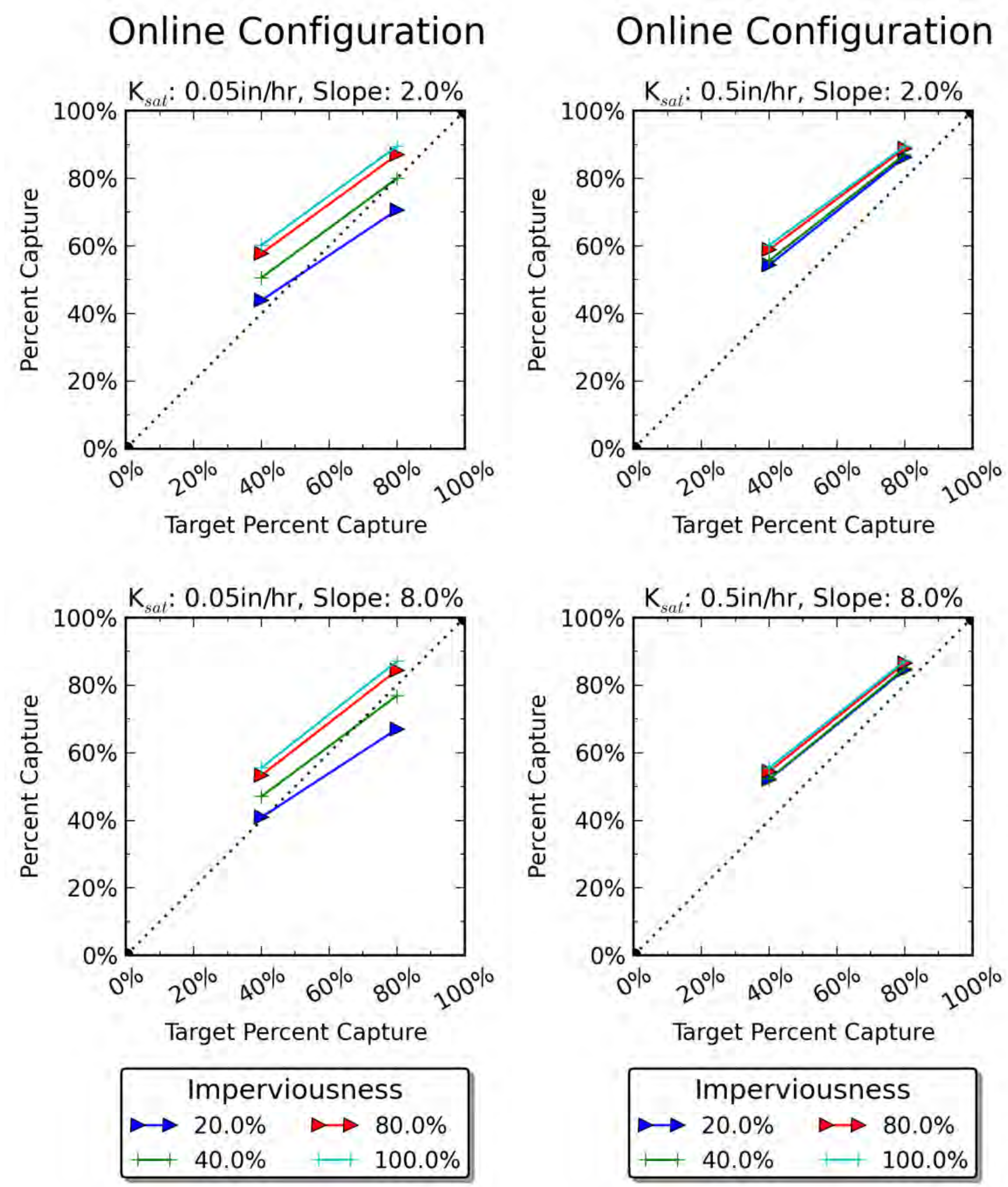


Figure 8: Sensitivity Analysis of Flow-based BMPs – Online Configuration

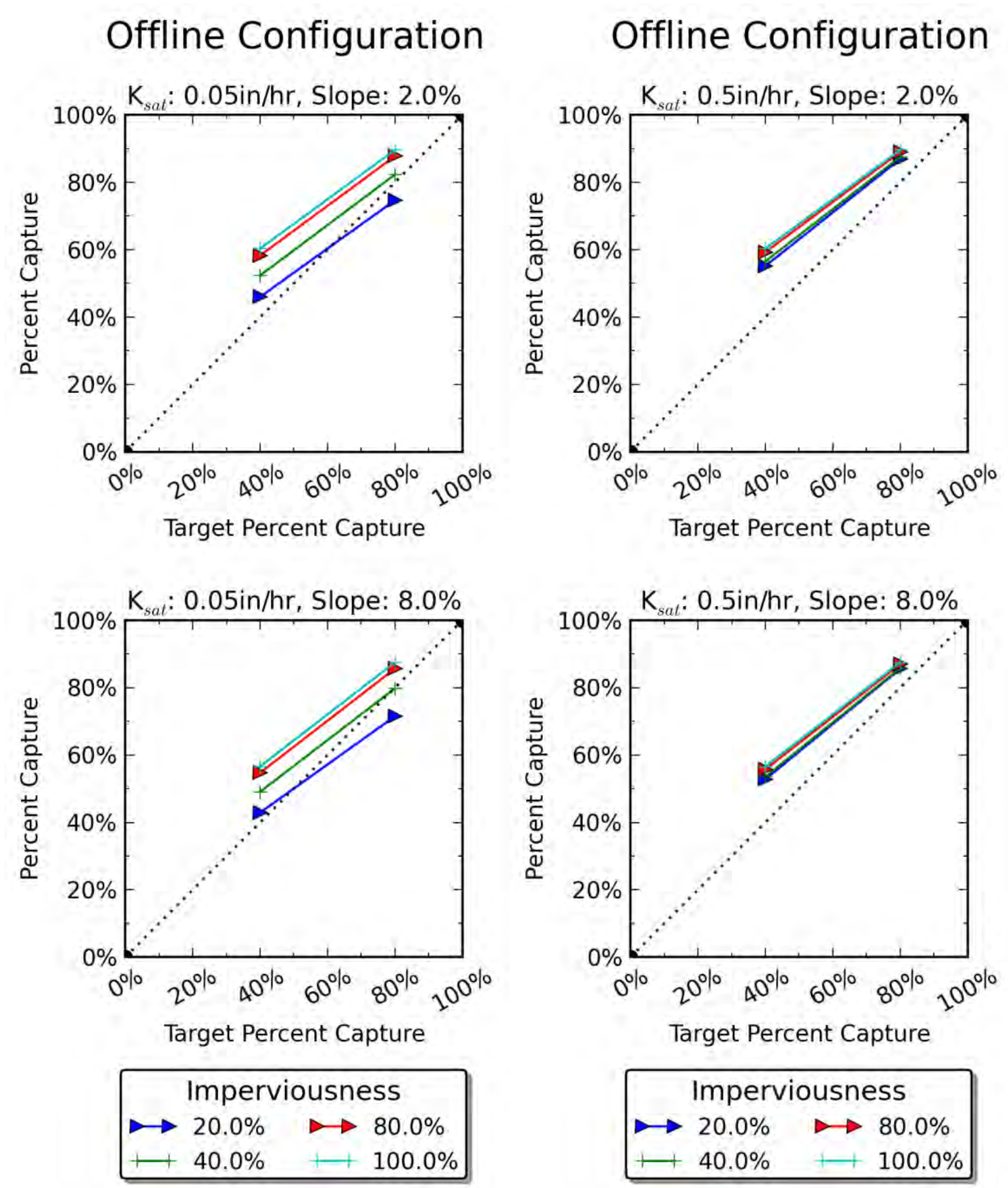


Figure 9: Sensitivity Analysis of Flow-based BMPs – Offline Configuration

Appendix N

Best Management Practices Capital Cost Estimation Methods

APPENDIX N: BMP CAPITAL COST ESTIMATION METHODS

N.1 BMP Cost Data Sources

The BMP cost estimates used in this DSM are intended for high-level planning purposes to evaluate the relative potential capital costs for different BMP types. The BMP costs for non-proprietary BMPs are generally based on engineer's estimates supported by available unit cost information from 2010 RSMeans© data and confidential vendor quotes. The relative cost ranking for proprietary BMPs was developed from cost information provided by a local vendor. The vendor-provided cost was increased by 75 percent to include cost of installation, per the vendor's recommendation. Cost estimates assume a redevelopment scenario (rather than new development) to take into account current infrastructure at the Port facilities.

Cost estimates have been developed based on generic BMP designs representing a "typical" range of design criteria and site conditions influencing cost. The distinct differences between BMP types that influence differential cost (e.g., materials, geometry, typical scale of installation) are accounted for in developing unit costs (e.g., \$ per ft^3) for the physical BMP size and/or water quality volume. This approach was selected instead of using empirically-developed unit cost equations to better isolate the differences between BMP types and how they affect overall costs and to consider only incremental costs over baseline conditions in a redevelopment scenario.

While the line items vary between BMP types, they all include the costs for the BMP itself (e.g., retaining walls, vegetation, cisterns, pond liners) which are described in the individual BMP Fact Sheets. In addition these estimates include, where relevant, costs for excavation, hauling, backfill and compaction, and fencing, and they include a 10 percent contingency to account for site-specific design considerations.

Capital redevelopment costs account for incremental costs associated with constructing BMPs in developed commercial and industrial areas. This includes soil decompaction, demolition and disposal of existing impervious area, and an increase in haul distance for excavated fill for relevant BMPs. Land costs are not included as a component of the BMP unit costs[1]. Engineering and planning and mobilization costs are not included in unit costs, except for specialized BMP types, as they are not considered to be an incremental cost for redevelopment projects. In addition, the BMP unit costs do not include the costs for supporting infrastructure, which would need to be evaluated on a site-specific basis (e.g., drainage conveyance modifications, pump stations, etc.)

N.2 BMP Sizing Methods

The BMPs are sized for the water quality design volume or water quality design flow required to meet the 80 percent mean annual runoff capture standard (see Chapter 4, Stormwater Management Standard Water Quality-Capture and Treat) using generic nomographs developed for the Port (refer to Appendix L, Nomographs for Water Quality BMP Sizing). Nomographs were developed for (1) volume-based BMPs, (2) flow-based BMPs and (3) wet pool BMPs. Per

[1] Land costs are not included as a component of BMP unit costs as they can be highly variable and the availability of otherwise unused land within the development footprint will vary across project types. In cases where the otherwise unused land area is not sufficient to site a BMP, additional costs should be added to the BMP unit costs to account for land acquisition and/or the opportunity cost associated with loss of developable area.

the nomographs, for volume-based BMPs, the design storm depth for a 48-hour drawdown time is 0.65 inches. For flow-based BMPs, the design storm intensity used to size BMPs is 0.13 in/hr, which is the intensity for a 5-minute time of concentration for an offline system. For wet pool BMPs, the design storm depth for a minimum residence time of 12 hours is 1 inch. Because the costs would scale for all sites with an increase in impervious area and this value is heterogeneous across the Port, the costs here reflect the cost for a 100 percent impervious area. With this impervious area, a runoff coefficient of 0.84 is used for BMP sizing, which was calculated using the volumetric runoff coefficient in Chapter 4, Stormwater Management Standard Water Quality-Capture and Treat.

The above characteristics are used to determine the water quality volume and water quality flow rates used for the cost estimation methodology. Because the cost equations are not linear, cost estimates are developed for a BMP treating runoff from a 1-acre site and a 10-acre site. The design water quality design volumes for volume-based BMPs are 1,982 and 19,820 ft^3, respectively, and for wet pools are 3,049 and 30,492 ft^3, respectively. For flow-based BMPs, the water quality design flow rates are 0.11 and 1.07 cfs, respectively.

N.2.1 Cost Estimations

Cost rankings are based on the average per-acre cost for each BMP which is the average of the 1-acre cost and the per-acre cost for the 10-acre option; this method uses both sizes to account for the effect on cost from scaling some of the BMPs to larger sizes. The cost category breakdown used to rank relative costs are shown in Table 1.

Table 1: Relative Cost Rankings

Cost Ranking Category	Range ($/impervious acre treated)
$	< $10,000
$$	$10,000 - $25,000
$$$	$25,000 - $100,000
$$$$	> $100,000

The BMP costs for treating both the 1- and 10-acre impervious areas, rounded to the nearest $1,000, are shown in Table 2 and Table 3.

Table 2: Relative Capital Cost Estimates for Non-Proprietary BMPs (2010 $)

BMP Category	Specific BMP	1-Acre Cost ($K)	10-Acre Cost ($K)	Avg Per-Acre Cost ($K)	Cost Ranking Category
DSM-1: Extended dry detention basins	Extended dry detention basin	$24	$66	$15	$$
DSM-2: Wet basins	Wet pond	$28	$119	$20	$$
DSM-2: Wet basins	Wetland basin	$23	$91	$16	$$
DSM-2: Wet basins	Pocket wetland	$23	$108	$17	$$
DSM-3: Subsurface flow wetlands	Subsurface flow wetland*	$46	$182	$32	$$$
DSM-4: Bioretention	Bioretention basin without underdrain	$19	$157	$17	$$
DSM-4: Bioretention	Bioretention basin with underdrain	$23	$197	$21	$$
DSM-5: Infiltration trenches	Infiltration trench	$22	$204	$21	$$
DSM-6: Vegetated swales	Vegetated swale without underdrain	$10	$15	$6	$
DSM-6: Vegetated swales	Vegetated swale with underdrain	$11	$17	$6	$
DSM-7: Vegetated filter strips	Vegetated filter strip	$2	$16	$2	$
DSM-8: Media bed filters	Media bed filter	$18	$136	$16	$$
DSM-9: Underground stormwater control facilities	Detention USCF	$46	$389	$42	$$$
DSM-9: Underground stormwater control facilities	Infiltration USCF	$46	$389	$42	$$$
DSM-9: Underground stormwater control facilities	Wet USCF	$46	$389	$42	$$$
DSM-10: Pervious pavement	Pervious pavement	$20	$189	$19	$$
DSM-11: Building BMPs	Planter box filter	$33	$274	$30	$$$
DSM-11: Building BMPs	Green roof	$212	$2,102	$211	$$$$
DSM-11: Building BMPs	Cistern	$67	$477	$57	$$$
DSM-11: Building BMPs	Dry well	$55	$546	$55	$$$

**Note: USEPA reported that subsurface flow wetlands are between 1.8 and 2.3 times the cost of free water surface wetlands for 0.1 MGD wastewater treatment depending on liner type[2,3], so the cost estimate used here is double the cost of that for a wetland basin.*

[2] United States Environmental Protection Agency, Office of Water (2000). *Wastewater technology fact sheet: Free water surface wetlands* (EPA Publication No.832-F-00-024). Washington, DC: US EPA.
[3] United States Environmental Protection Agency, Office of Water (2000). *Wastewater technology fact sheet: Wetlands: Subsurface flow* (EPA Publication No.832-F-00-023). Washington, DC: US EPA.

Table 3: Relative Capital Cost Estimates for Proprietary BMPs

BMP Category	Specific BMP (basis for Local Vendor Cost Estimate)	1-Acre Cost ($K)	10-Acre Cost ($K)	Avg Per-Acre Cost ($K)	Cost Ranking Category
DSM-12: Cartridge Filter	1 acre: 4-Cartridge Catch Basin StormFilter 10 acres: 8x14 StormFilter with 33 Cartridges (15 gpm cartridges and perlite media for both)	$29	$121	$21	$$
DSM-13: Oil/Water Separator	1 acre: Vortclarex VCL30 10 acres: Vortclarex VCL80-2	$20	$59	$13	$$
DSM-14: Hydrodynamic Separator	1 acre: CDS2015-4 10 acres: CDS2020	$13	$23	$8	$

NOTE: The relative cost ranking for proprietary BMPs was developed from cost information provided by a local vendor. The vendor-provided cost was increased by 75 percent to include cost of installation, per the vendor's recommendation.

Appendix O

BMP Operations and Maintenance Level of Effort

APPENDIX O: BMP OPERATIONS AND MAINTENANCE LEVEL OF EFFORT

O.1 BMP Operations and Maintenance Data Sources

This section presents planning level operations and maintenance (O&M) estimates, which are reported in terms of average annual hourly requirement (level of effort (LOE)). Scaling and ranking BMPs by level of effort enables comparison of annual labor intensity, but cannot capture the costs associated with varied hourly rates, repair and replacement of machinery, pumps, use of specialized equipment, or other site specific attributes that affect the annual operations and maintenance costs. This O&M comparison was intended to be consistent with the planning-level capital cost estimates presented in the BMP Capital Cost Appendix; therefore the O&M LOE estimates were made assuming a comparable tributary drainage area. Two primary sources were used for the analysis: the National Cooperative Highway Research Program Current Practice of Post-Construction Structural Stormwater Control Implementation for Highways (NCHRP 2013), and the Water Environment Research Foundation BMP and LID Whole Life Cost Models (WERF 2009). The data sources used for each BMP are indicated in Table 1.

O.1.1 NCHRP & WERF Methodologies and Limitations

The NCHRP provided O&M spreadsheets that report the number of maintenance hours and cost calculations for a 2 acre drainage area and a 7 acre drainage area. NCHRP cautions against using the estimates for a drainage area larger than 7 acres. Consequently, the estimates are not appropriate for regional BMPs that would treat a larger drainage area (e.g., 100 acres). In addition, NCHRP states that site-specific influences such as local hydrology, soils, drainage area, BMP design constraints and local regulatory requirements will influence the estimates for both cost and annual hourly LOE.

WERF included annual hourly requirements in its O&M cost analysis spreadsheet model. The estimates assume a 'Medium' level of maintenance activity. For most BMPs, the LOE estimates could not be scaled based on tributary drainage area. The only exceptions were bioretention, green roofs, planter boxes, and cisterns. For the other BMPs, WERF's LOE estimates were based on a default tributary area. WERF indicates that these default hours and tributary drainage area were taken from data collected from agencies across the U.S. when available, and based on the survey data, it was generally not possible to see the influence of system size on LOE. Instead, the data showed that there are likely to be a range of other often more significant factors that may influence the level of maintenance inputs at a particular site. This is why the O&M LOE for very few BMPs was based on a relationship between BMP size and maintenance costs. In addition, WERF noted that maintenance activities, site needs, and actual cost of maintenance are all highly variable from site to site and that O&M estimation must take the needs of the specific project into consideration. Based on the drainage areas used, only the wet basin LOE estimate is considered for a regional BMP (default drainage area of 50 acres). The other estimates are not considered appropriate for regional BMPs.

Table 1: Data Sources for O&M Level of Effort Estimates

BMP	Data Sources Used
DSM-1: Extended Dry Detention Basins	NCHRP 2013[1], WERF 2009[2]
DSM-2: Wet Basins	NCHRP 2013, WERF 2009
DSM-3: Subsurface Flow Wetlands	NCHRP Wet Basin[3]
DSM-4: Bioretention	NCHRP 2013, WERF 2009
DSM-5: Infiltration Trenches[4]	NCHRP 2013
DSM-6: Vegetated Swales	NCHRP 2013, WERF 2009
DSM-7: Vegetated Filter Strips	NCHRP 2013
DSM-8: Media Bed Filters	NCHRP 2013
DSM-9: Underground Detention (lined)	NCHRP 2013[5]
DSM-9: Underground Detention (open bottom)	NCHRP 2013[5]
DSM-10: Pervious Pavement	WERF 2009
DSM-11: Building BMPs:	
Planter Box Filters	WERF 2009
Green Roofs	WERF 2009
Cisterns	WERF 2009
Dry Wells	WERF 2009[5]
DSM-12: Cartridge Filter Vaults	NCHRP 2013
DSM-13: Oil/Water Separators	NCHRP 2013
DSM-14: Hydrodynamic Separators	NCHRP 2013

Notes:
[1] NCHRP 25-25/83: Current Practice of Post-Construction Structural Stormwater Control Implementation for Highways.
[2] WERF SW2R08: BMP and LID Whole Life Cost Models 2009.
[3] The LOE for sub-surface flow wetlands was assumed to be the same as the NCHRP wet basin LOE, based on EPA1 information, which reported comparable O&M costs for surface flow wetlands and sub-surface flow wetlands. Although both NCHRP and WERF estimates were used for wet basins, the higher LOE estimate reported by NCHRP was judged to be more appropriate for subsurface flow wetlands.
[4] Information provided for infiltration trenches was adapted from NCHRP infiltration basins.
[5] Because LOE estimates were not available for the BMP, O&M line items for other BMPs requiring similar O&M activities were used based on engineering judgment to develop the LOE estimate.

[1] USEPA. Wastewater Technology Fact Sheet Free Water Surface Wetlands, EPA 832-F-00-024 (September 2000) and Wastewater Technology Fact Sheet Wetlands: Subsurface Flow, EPA 832F-00-023 (September 2000).

Table 2 summarizes the tributary area used for each BMP to estimate the O&M LOE, including whether it was a default or user-input value for the WERF reference, and whether 2 acres or 7 acres was used for the NCHRP estimate. Due to the limitations of the data sources, the O&M LOE estimates for each BMP could not be normalized based on the tributary drainage area.

Table 2: Summary of Tributary Drainage Assumptions for O&M Level of Effort Analysis

BMP	Units	WERF Default Tributary Drainage Area	WERF User-Input Tributary Drainage Area	NCHRP Default Tributary Area
DSM-1: Extended Dry Detention Basins	Acres	10	Default[1]	7
DSM-2: Wet Basins	Acres	50	Default[1]	7
DSM-3: Subsurface Flow Wetlands[2]	Acres	--	--	7
DSM-4: Bioretention Basins	Acres	1	2	2
DSM-5: Infiltration Trenches	--	--	--	2
DSM-6: Vegetated Swales	Acres	2	Default[1]	2
DSM-7: Vegetated Filter Strips	--	--	--	2
DSM-8: Media Bed Filters	--	--	--	2
DSM-9: Underground Detention (lined)	--	--	--	2
DSM-9: Underground Detention (open bottom)	--	--	--	2
DSM-10: Pervious Pavement	ft^2	21,780	Default[1]	--
DSM-11: Building BMPs:				
Planter Box Filters[3]	ft^2	1,000	10,000	--
Green Roofs	ft^2	10,000	10,000	--
Cisterns	ft^2	5,000	10,000	--
Dry Wells	--	--	--	--
DSM-12: Cartridge Filter Vaults	--	--	--	2
DSM-13: Oil/Water Separators	--	--	--	2
DSM-14: Hydrodynamic Separators	--	--	--	2

Notes:
-- indicates no data available
[1]The default value could not be changed.
[2]Subsurface flow wetland LOE is based on NCHRP estimates for wet basins.
[3]The estimates for Planter Box Filters were made using WERF's Rain Garden tool.

O.2 BMP Operations & Maintenance Level of Effort Summary

Table 3 summarizes the O&M LOE for each BMP, provides a ranking (i.e., low, medium, high), and lists the major and specialized equipment required. The LOE ranking process was based on the annual hourly requirement for each BMP as determined by the NCHRP and WERF references. For BMPs using both data sources, the LOE was the average of the two estimates. Information on required equipment was acquired directly from the NCHRP source, from Western Washington LID O&M Guidance document (Herrera Environmental Consultants, Inc. and Washington Stormwater Center 2013), or assumed using engineering judgment. The LOE ranking criteria were developed by qualitatively evaluating the estimates and designating ranges for High, Medium, and Low LOE. A 'Low' LOE was assigned to BMPs with 15 or less annual hours of maintenance needed; a 'Medium' (Med) LOE was assigned to BMPs requiring greater than 15 hours and less than or equal to 25 annual hours of O&M; and 'High' LOW was assigned to BMPs requiring more than 25 annual hours of O&M.

Table 3: BMP O&M Level of Effort and Major Equipment

BMP	Annual O&M Hours Required[1, 2]	L.O.E.[3]	Major and Specialized Equipment Required
DSM-1: Extended Dry Detention Basins	27	High	Utility Truck, 10-15 yd Truck, Backhoe
DSM-2: Wet Basins	34	High	Utility Truck, 10-15 yd Truck, Backhoe, Flame Weeder or Hot Water Weeder,
DSM-3: Subsurface Flow Wetlands	50	High	Utility Truck, Vactor, Flame Weeder or Hot Water Weeder,
DSM-4: Bioretention Basins	25	Med	Utility Truck, 10-15 yd Truck, Backhoe or Mini Excavator, Vactor Truck, Flame Weeder or Hot Water Weeder, Water Jet or root Saw (Vactor truck tools for clearing roots from underdrains)
DSM-5: Infiltration Trenches	16	Med	Utility Truck, 10-15 yd Truck, Backhoe or Mini Excavator
DSM-6: Vegetated Swales	17	Med	Utility Truck, 10-15 yd Truck, Backhoe or Mini Excavator, Flame Weeder or Hot Water Weeder,
DSM-7: Vegetated Filter Strips	14	Low	Utility Truck, Flame Weeder or Hot Water Weeder,
DSM-8: Media Bed Filters	15	Low	Utility Truck, 10-15 yd Truck, Backhoe or Mini Excavator
DSM-9: Underground Detention (lined)	20	Med	Utility Truck, 10-15 yd Truck, Vactor Truck
DSM-9: Underground Detention (open bottom)	21	Med	Utility Truck, 10-15 yd Truck, Vactor Truck

BMP	Annual O&M Hours Required[1, 2]	L.O.E.[3]	Major and Specialized Equipment Required
DSM-10: Permeable Pavement	7	Low	Utility Truck, Hand Held Pressure Washer, Street Sweeper/Regenerative Air Sweeper, Paving Equipment
DSM-11: Building BMPs:			
Planter Box Filters	18	Med	Utility Truck, Rototiller, Line Trimmer
Green Roofs	82	High	Utility Truck, Line Trimmer, Fall Prevention
Cisterns	31	High	Utility Truck, Fall Prevention
Dry Wells	6	Low	Utility Truck
DSM-12: Cartridge Filter Vaults	24	Med	Utility Truck, 10-15 yd Truck
DSM-13: Oil/Water Separators	16	Med	Utility Truck, 10-15 yd Truck, Vactor Truck
DSM-14: Hydrodynamic Separators	15	Low	Utility Truck, Vactor Truck

Notes:

[1] *Hours were computed by averaging NCHRP and WERF level of effort estimates where both were available.*

[2] *The estimate is for the BMP tributary drainage area shown in Table 2.*

[3] *Level of Effort Ranking Criteria (Annual Hours): Low = ≤15; Med = 15< X ≤25; High = >25*

O.3 BMP Level of Effort Summary Tables

The following tables include the O&M line items for each BMP from the NCHRP and WERF data sources, a description of the prescribed maintenance activities, and the estimated LOE. In some cases, engineering judgment was used to adjust the frequency or number of hours for a given maintenance requirement; deviations from original source material have been noted at the end of each table.

Table 4: Extended Dry Detention Basin (DSM-1)

NCHRP (7 acres)						WERF (10 acres)				
Maintenance	**Action Required**	**# Per Year**	**Hours**	**Crew**	**Total Hours**	**Maintenance**	**# Per Year**	**Hours**	**Crew**	**Total Hours**
Minor						*Routine*				
Vegetation Management for Aesthetics	Cut vegetation to an average height of 6-inches and remove trimmings. Remove any trees, or woody vegetation.	2	2	2	8	Inspection, Reporting & Information Management	0.3	2	1	0.7
Trash and Debris	Remove and dispose of trash and debris	1	2	2	4	Vegetation Management with Trash & Minor Debris Removal	1	4	2	8
General Maintenance Inspection	Corrective action prior to wet season. Consult engineers if immediate solution is not evident.	1	2	2	4	Vector Control	0.3	4	1	1.3
Reporting		1	3	1	3					
Major						*Infrequent*				
Slope Stability	Reseed/revegetate barren spots prior to wet season.	1	4	2	8	Intermittent Facility Maintenance (Excluding Sediment Removal)[1]	1	3	3	9
Standing Water	Drain facility. Corrective action prior to wet season. Consult engineers if immediate solution is not evident.	1	1	2	2	Sediment Removal[2]	0.1	16	3	4
Sediment Management	Remove and properly dispose of sediment. Regrade if necessary. (expected every 50 years)	0.02	16	3	1		**Annual Man Hours**			**23**
				Annual Hours	**30**					

Notes:
[1] *Intermittent maintenance hours set to 3; crew set to 1*
[2] *Sediment removal hours set to 16; crew set to 3*

Table 5: Wet Basins (DSM-2 & DSM-3)

NCHRP (7 acres)						WERF (50 acres)				
Maintenance	**Action Required**	**# Per Year**	**Hours**	**Crew**	**Total Hours**	**Maintenance**	**# Per Year**	**Hours**	**Crew**	**Total Hours**
Minor						*Routine*				
24-hour draw down measured between the rim of the outlet structure and invert of the WQ orifice in the outlet structure.	If greater than 24 hours then discharge water to permanent pool elevation, clear outlet of debris. Notify engineer if needed.	1	2	2	4	Inspection, Reporting & Information Management	0.3	2	1	0.7
Trash and Debris	Remove and dispose of trash and debris	1	2	2	4	Vegetation Management with Trash & Minor Debris Removal	1	4	2	8
General Maintenance Inspection	Corrective action prior to wet season. Consult engineers if immediate solution is not evident.	1	1	2	4	Vector Control	0.3	4[1]	1	1.3
Reporting		1	3	1	3					
Major						*Infrequent*				
Vegetation Management[2]	1. Have a biologist survey the wet pond to determine if any birds are nesting or other sensitive animals are present. If birds are nesting, with advice from the biologist, proceed with the maintenance. 2. Lower and maintain the water level to expose the area to be maintained, do not completely drain basin. 3. Mechanically remove all plants vegetation. 4. Dispose of the vegetation material in a landfill or other appropriate disposal area. 5. Restock mosquito fish as recommended by vector control agency.	0.1	40	4	16	Intermittent Facility Maintenance (Excluding Sediment Removal)[3]	1	3	1	3

NCHRP (7 acres)						WERF (50 acres)				
Maintenance	**Action Required**	**# Per Year**	**Hours**	**Crew**	**Total Hours**	**Maintenance**	**# Per Year**	**Hours**	**Crew**	**Total Hours**
Sediment Management	Remove and properly dispose of sediment. Prior to start of wet season, restore vegetation to the plan shown on the as-built drawings. (expected every 5 years)	0.2	24	4	19	Sediment Dewatering & Removal: Forebay[4]	0.13	4	3	1.5
			Annual Hours		**50[6]**	Sediment Dewatering & Removal: Main Pool[5]	0.05	16	3	2.4
							Annual Hours			**17**

Notes:

[1] *Vector control included for parity with NCHRP.*
[2] *Frequency adjusted from 1 to .1 occurrences per year.*
[3] *Intermittent maintenance hours set to 3; crew set to 1*
[4] *Sediment dewatering – Forebay hours set to 4; crew set to 3*
[5] *Sediment dewatering – Main Pool hours set to 16; crew set to 3*
[6] *This value was assumed to be the LOE for DSM-3: Subsurface Flow Wetlands*

Table 6: Bioretention Basins (DSM-4)

NCHRP (2 acres)					
Maintenance	**Action Required**	**# Per Year**	**Hours**	**Crew**	**Total Hours**
Minor					
Vegetation Management for Aesthetics (optional)	Cut vegetation to an average height of 6-inches and remove trimmings. Remove any trees, or woody vegetation.	1	2	2	4
Soil Repair	Reseed/revegetate barren spots prior to wet season.	1	4	2	8
Trash and Debris	Remove and dispose of trash and debris	1	2	2	4
General Maintenance Inspection	Corrective action prior to wet season. Consult engineers if immediate solution is not evident.	1	1	2	2
Reporting		1	3	1	3
Major					
Standing Water	Drain facility. Corrective action prior to wet season. Consult engineers if immediate solution is not evident.	1	1	2	2
Sediment Management[1]	Remove and properly dispose of sediment. Regrade if necessary. (expected every 20 years)	0.05	8	2	1
Underdrains	Corrective action prior to wet season. Consult engineers if immediate solution is not evident.	1	0.5	2	1
			Annual Hours		**25**

WERF (2 acres)				
Maintenance	**# Per Year**	**Hours**	**Crew**	**Total Hours**
Routine				
Inspection, Reporting & Information Management	0.5	4	1	2
Vegetation Management with Trash & Minor Debris Removal	2	4	2	16
Infrequent				
Till Soil	0.25	4	2	2
Unclog Drain	0.5	2	1	1
Replace Mulch	0.5	4	2	4
		Annual Hours		**25**

Note:
[1] Frequency adjusted from 0.025 to 0.05 occurrences per year.

Table 7: Infiltration Trench[1] (DSM-5)

NCHRP (2 acres)					
Maintenance	**Action Required**	**# Per Year**	**Hours**	**Crew**	**Total Hours**
Minor					
Trash and Debris, & Sediment[2]	Remove and dispose of trash and debris	1	4	2	8
General Maintenance Inspection	Corrective action prior to wet season. Consult engineers if immediate solution is not evident.	1	1	2	2
Reporting		1	3	1	3
Major					
Sediment Management[3]	Remove and properly dispose of sediment. Regrade if necessary. (expected every 25 years)	0.04	24	3	3
			Annual Hours		**16**

Notes:
[1] *Minor vegetation maintenance has been removed from this table as per design recommendations in the Infiltration Trench Fact Sheet (no vegetation).*
[2] *Hours increased from 2 to 4 to account for additional routine sediment removal.*
[3] *Frequency adjusted from 0.025 to 0.04 occurrences per year.*

Table 8: Vegetated Swale (DSM-6)

NCHRP (2 acres)					
Maintenance	**Action Required**	**# Per Year**	**Hours**	**Crew**	**Total Hours**
Minor					
Vegetation Management for Aesthetics (optional)	Cut vegetation to an average height of 6-inches and remove trimmings. Remove any trees, or woody vegetation.	2	1	2	4
Trash and Debris	Remove and dispose of trash and debris	1	1	2	2
General Maintenance Inspection	Corrective action prior to wet season. Consult engineers if immediate solution is not evident.	1	1	2	2
Reporting		1	3	1	3
Major					
Vegetation Repair	Reseed/revegetate barren spots prior to wet season.	1	2	2	4
Sediment Management[1]	Remove and properly dispose of sediment. If flow is channeled regrade as necessary. (expected every 15 years)	0.07	4	2	1
Underdrains[2]	Corrective action prior to wet season. Consult engineers if immediate solution is not evident.	1	0.5	2	1
		Annual Hours			**17**

WERF (2 acres)				
Maintenance	**# Per Year**	**Hours**	**Crew**	**Total Hours**
Routine				
Inspection, Reporting & Information Management	0.3	2	1	0.67
Vegetation Management with Trash & Minor Debris Removal	1	4	2	8
Infrequent				
Corrective Maintenance	0.3	8	4	8
		Annual Hours		**17**

Notes:

[1] *Frequency adjusted from 0.033 to 0.066 occurrences per year.*

[2] *Underdrain maintenance included as per design recommendations in the Vegetated Swale Fact Sheet. Values sourced from NCHRP Media Bed Filter.*

Table 9: Vegetated Filter Strips (DSM-7)

NCHRP (2 acres)					
Maintenance	**Action Required**	**# Per Year**	**Hours**	**Crew**	**Total Hours**
Minor					
Vegetation Management for Aesthetics (optional)	Cut vegetation to an average height of 6-inches and remove trimmings. Remove any trees, or woody vegetation.	2	1	2	4
Trash and Debris	Remove and dispose of trash and debris	1	1	2	2
General Maintenance Inspection	Corrective action prior to wet season. Consult engineers if immediate solution is not evident.	1	1	2	2
Reporting		1	3	1	3
Major					
Vegetation Repair	Reseed/revegetate barren spots prior to wet season. (expected every 3 years)	0.3	4	2	3
			Annual Hours		**14**

Table 10: Media Bed Filters (DSM-8)

NCHRP (2 acres)					
Maintenance	**Action Required**	**# Per Year**	**Hours**	**Crew**	**Total Hours**
Minor					
Trash and Debris	Remove and dispose of trash and debris	1	2	2	4
General Maintenance Inspection	Corrective action prior to wet season. Consult engineers if immediate solution is not evident.	1	1	2	2
Reporting		1	3	1	3
Major					
Drain time	Drain facility. Remove and dispose of sediment, trash and debris. Check orifice. Notify engineer to consider removing top 2 inches of media and dispose of sediment. Restore media depth to 18 inches when overall media depth drops to 12 inches. Complete prior to wet season. (expected every 6 years)	0.2	8	3	4
Sediment Management[1]	Remove and properly dispose of sediment. Regrade if necessary. (expected every 25 years)	0.04	8	3	1
Underdrains	Corrective action prior to wet season. Consult engineers if immediate solution is not evident.	1	0.5	2	1
			Annual Hours		**15**

Note:

[1] *Frequency adjusted from 0.029 to 0.04 occurrences per year.*

Table 11 Underground Detention (Lined)[1] (DSM-9)

NCHRP (2 acres)						
Maintenance	**NCHRP Line Item Source**	**Action Required**	**# Per Year**	**Hours**	**Crew**	**Total Hours**
Minor						
24-hour draw down measured between the rim of the outlet structure and invert of the WQ orifice in the outlet structure.	Wet Pond	If greater than 24 hours then discharge water to permanent pool elevation, clear outlet of debris. Notify engineer if needed.	1	2	2	4
Inspect sump for accumulation of material	Hydrodynamic Separator	Empty unit	1	4	2	8
General Maintenance Inspection	Extended Dry Detention	Corrective action prior to wet season. Consult engineers if immediate solution is not evident.	1	1	2	2
Reporting	Std. NCHRP		1	3	1	3
Major						
Standing Water	Extended Dry Detention (2ac)	Drain facility. Corrective action prior to wet season. Consult engineers if immediate solution is not evident.	1	2	2	2
Sediment Management[2]	Infiltration Basin	Remove and properly dispose of sediment. (expected every 25 years)	0.04	8	3	1
				Annual Hours		**20**

Notes:

[1] *This table is formed from a composite of NCRHP maintenance recommendations for related BMP's for comparison purposes only. NCHRP 2013 does not provide specific guidance on O&M for lined underground detention.*

[2] *Frequency adjusted from 0.03 to 0.04 years.*

Table 12 Underground Detention (Open Bottom)[1] (DSM-9)

NCHRP (2 acres)						
Maintenance	**NCHRP Line Item Source**	**Action Required**	**# Per Year**	**Hours**	**Crew**	**Total Hours**
Minor						
24-hour draw down measured between the rim of the outlet structure and invert of the WQ orifice in the outlet structure.	Wet Pond	If greater than 24 hours then discharge water to permanent pool elevation, clear outlet of debris. Notify engineer if needed.	1	2	2	4
Inspect sump for accumulation of material	Hydrodynamic Separator	Empty unit	1	4	2	8
General Maintenance Inspection	Extended Dry Detention	Corrective action prior to wet season. Consult engineers if immediate solution is not evident.	1	1	2	2
Reporting	Std. NCHRP		1	3	1	3
Major						
Standing Water	Extended Dry Detention (2ac)	Drain facility. Corrective action prior to wet season. Consult engineers if immediate solution is not evident.	1	1	2	2
Sediment Management[2]	Infiltration Basin	Remove and properly dispose of sediment. (expected every 10 years)	0.1	8	3	2.4
				Annual Hours		**21**

Notes:

[1] *This table is formed from a composite of NCRHP maintenance recommendations for related BMP's for comparison purposes only. NCHRP 2013 does not provide specific guidance on O&M for lined underground detention.*

[2] *Frequency adjusted from 0.03 to 0.1 years*

Table 13: Pervious Pavement (DSM-10)

WERF (1/2 acre)				
Maintenance	**# Per Year**	**Hours**	**Crew**	**Total Hours**
Routine				
Inspection, Reporting & Information Management[1]	1	2	1	2
Litter & Minor Debris Removal	1	2	1	2
Permeable pavement vacuum sweeping[2]	1	2	1	2
Infrequent Maintenance				
Reestablish infiltration capacity by removing sediment in the upper layers with a vactor truck[3]	0.1	8	1	0.8
	Annual Man Hours			**7**

Notes:
[1] *Frequency adjusted from 0.033 to 1 occurrence per year.*
[2] *Hours adjusted from 1 to 2.*
[3] *The infrequent maintenance required is based on professional judgment and not from the WERF reference.*

Table 14: Building BMP's – Planter Box Filters[1] (DSM-11)

WERF (10,000 sq ft)				
Maintenance	**# Per Year**	**Hours**	**Crew**	**Total Hours**
Routine				
Vegetation Management[2]	1	7	2	14
Infrequent Maintenance				
Replace mulch[3]	0.3	3	2	2
Till Soil[4]	0.2	6	2	2.4
	Annual Man Hours			**18**

Notes:
[1] *Used WERF guidance for rain gardens for drainage area of 10,000 sq ft.*
[2] *Hours adjusted from 2 to 7, Crew adjusted from 10 to 2.*
[3] *Hours adjusted from 30 to 3.*
[4] *Hours adjusted from 20 to 6.*

Table 15: Building BMP's – Green Roofs[1] (DSM-11)

WERF (10,000 sq ft)				
Maintenance	**# Per Year**	**Hours**	**Crew**	**Total Hours**
Routine				
Inspection, Reporting & Information Management	2	4	1	8
Vegetation Management[2]	2	7	2	28
Irrigation Repair[3]	2	6	2	24
Infrequent Maintenance				
Corrective Maintenance (membrane patching, re-vegetation, component failure (e.g., clogging)	0.5	8	4	16
Soil Replacement[4]	0.2	8	4	6.4
	Annual Hours			**82**

Notes:
[1] *Used WERF guidance for drainage area of 10,000 sq ft.*
[2] *Hours adjusted from 10 to 7.*
[3] *Hours adjusted from 10 to 6.*
[4] *Frequency adjusted from 0.5 to 0.2 occurrences per year.*

Table 16: Building BMP's – Cisterns[1] (DSM-11)

WERF (10,000 sq ft)				
Maintenance	**# Per Year**	**Hours**	**Crew**	**Total Hours**
Routine				
Inspection, Reporting & Information Management	2	2	1	4
Roof Washing, Cleaning Inflow Filters	2	4	2	16
Tank Inspection and Disinfection	1	4	2	8
Infrequent Maintenance				
Intermittent System Maintenance (System flush, debris & sediment removal from tank)	0.3	3	2	2
Pump Replacement	0.2	3	2	1.2
	Annual Hours			**31**

Note:
[1] *Used WERF guidance for drainage area of 10,000 sq ft.*

Table 17: Building BMP's – Dry Wells[1] (DSM-11)

WERF					
Maintenance	**WERF Line Item Source**	**# Per Year**	**Hours**	**Crew**	**Total Hours**
Routine					
Inspection, Reporting & Information Management[2]	Bioretention.	1	1	1	1
Litter & Minor Debris Removal	Pervious pavement	1	2	1	2
Infrequent Maintenance					
Corrective Maintenance (unclogging, drainage)	Bioretention underdrains	0.5	2	1	1
Well Replacement (expected every 10 years)	Engineering Judgment	0.1	8	2	1.6
		Annual Hours			**6**

Notes:

[1] *This table is formed from a composite of WERF maintenance recommendations for related BMP's for comparison purposes only. WERF 2009 does not provide specific guidance on O&M for dry wells.*

[2] *Frequency adjusted from 0.5 to 1; hours adjusted from 4 to 1*

Table 18: Cartridge Filter Vaults (DSM-12)

NCHRP (2 acres)					
Maintenance	**Action Required**	**# Per Year**	**Hours**	**Crew**	**Total Hours**
Minor					
Standing Water	Drain facility. Corrective action prior to wet season. Consult engineers if immediate solution is not evident.	1	1	2	2
Trash and Debris	Remove and dispose of trash and debris	1	2	2	4
General Maintenance Inspection	Corrective action prior to wet season. Consult engineers if immediate solution is not evident.	1	1	2	2
Reporting		1	3	1	3
Major					
Sediment Management	Remove and properly dispose of sediment.(expected every 5 years)	0.2	8	3	5
Manufacturer’s recommended major maintenance	Consult with manufacturer regarding need for replacement of canisters. If manufacturer confirms need, replace canisters. Prior to wet season (expected every 3 years)	0.3	8	3	8
			Annual Hours		**24**

Table 19: Oil & Water Separator (DSM-13)

NCHRP (2 acres)					
Maintenance	**Action Required**	**# Per Year**	**Hours**	**Crew**	**Total Hours**
Minor					
Trash and Debris	Remove and dispose of trash and debris	1	3	2	6
General Maintenance Inspection	Corrective action prior to wet season. Consult engineers if immediate solution is not evident.	1	1	2	2
Reporting		1	3	1	3
Major					
Standing Water	Drain facility. Corrective action prior to wet season. Consult engineers if immediate solution is not evident.	1	2	2	4
Sediment Management	Remove and properly dispose of sediment. Regrade if necessary. (expected every 35 years)	0.03	8	3	1
			Annual Hours		**16**

Table 20: Hydrodynamic Separator (DSM-14)

NCHRP (2 acres)					
Maintenance	**Action Required**	**# Per Year**	**Hours**	**Crew**	**Total Hours**
Minor					
Inspect sump for accumulation of material	Empty unit	1	4	2	8
Inspect for standing water	If standing water cannot be removed or remains through the wet season notify VCD.	1	1	2	2
Reporting		1	3	1	3
Major					
Inspection for structural integrity	Immediately consult with engineer and manufacturer's representative to develop a course of action, effect repairs prior to the wet season.	1	1	2	2
			Annual Hours		**15**

O.4 References

National Cooperative Highway Research Program (NCHRP)

2013 Current Practice of Post-Construction Structural Stormwater Control Implementation for Highways, 2013. Appendix C - Unit Costs and Quantitative Assumptions for Maintenance Cost Estimates

Herrera Environmental Consultants, Inc. and Washington Stormwater Center

2013 Western Washington Low Impact Development Operations & Maintenance, 2013. Prepared by Herrera Environmental Consultants, Inc., Seattle, WA. and Washington Stormwater Center, Puyallup, WA.

Water Environment Research Foundation (WERF)

2009 Water Environment Research Foundation BMP and LID Whole Life Cost Models, Version 2.0, 2009. SW2R08

Appendix P

Sustainability Considerations For BMPs

APPENDIX P: SUSTAINABILITY CONSIDERATIONS FOR BMPS

P.1 Introduction

This section provides sustainability considerations for the selection, design, and implementation of stormwater management BMPs in the form of a Sustainability Attribute Checklist, which is provided in the Section M.4.2. The considerations in this section and checklist shall be coordinated with the design requirements and guidance provided for BMPs in Chapter 6 as well as the BMP Fact Sheets. The BMPs described in the DSM inherently have direct sustainability benefits related to water quality and flow control at both the site and watershed scales, therefore consideration of those benefits is not incorporated into the checklist.

The sustainability attributes described in this section shall be reviewed by designers for applicability to potential project BMPs, and discussed with the Port to determine if implementation of these attributes shall be pursued. Identifying and considering the sustainability attributes of a stormwater management BMP is an essential element in the Port's efforts to embed sustainability into its day-to-day operations and infrastructure. Incorporating the sustainability attributes during the design phase allows for better anticipation of risks, costs and potential opportunities throughout a project's full life cycle.

Designs that broaden the spectrum of benefits to the Port, community and watershed will ultimately be the most successful, as measured by overall effectiveness, social and environmental impact, and fulfillment of the Port's mission.

P.1.1 Objectives

The objective of this chapter is to:

- Provide the Port and its partners a tool with which to review the sustainability performance of stormwater BMPs before final design and construction, including potential financial, environmental and social opportunities, risks and externalized impacts.

P.1.2 Chapter Contents

This chapter provides information related to the development of the Sustainability Attribute Checklist for the stormwater management BMPs described in the DSM, including the following:

- Methodology: A description of the process and documents consulted in the development of the Sustainability Attribute Checklist, along with an explanation of how to use the checklist.
- Description of Sustainability Attribute Considerations: An overview of each sustainability element and aspect, their relevance to financial, environmental and social criteria, and the key considerations for assessing the individual attributes in the checklist.
- Key Takeaways: A summary review of results and the checklist in table format.

P.2 Methodology

P.2.1 Development of the Sustainability Attributes Checklist

The Sustainability Attribute Checklist was developed by reviewing policies and guiding documents from the Port as well as other sustainability frameworks and resources. The checklist is built to evaluate multiple contexts, but also provide a comprehensive filter to triple bottom line elements (i.e., financial, environmental and social). Each of the resources we examined identifies attributes or best practices used for stormwater management or more general sustainability efforts.

The following documents were reviewed:

- Port of Portland
  - 2010 Sustainability Report
  - Sustainable Natural Resources document
  - Environmental Policy document
  - Greenside Projects – sustainability best practices in action port-wide
- US Environmental Protection Agency
  - Green Infrastructure and Low Impact Development[1]
  - “Cool Pavements” – Reducing Urban Heat Island Effects[2]
- Global Reporting Initiative
  - Sustainability Reporting Guidelines Version 3.1[3]
- Stormwater management manuals
  - City of Portland, Oregon; Bureau of Environmental Services
  - Western Washington; Washington Department of Ecology
  - City of San Francisco; Public Utilities Commission
  - City of Charlotte and Mecklenburg County, North Carolina; Storm Water Services

P.2.2 How to Use the Sustainability Attribute Checklist

Designers should refer to this checklist as a prompt during pre-design alternatives analysis and throughout the design process to evaluate and consider the sustainability performance of various BMPs.

P.3 Description of Sustainability Attribute Considerations

The Sustainability Attribute Checklist was developed to include both benefits and costs associated with financial, environmental and social elements, and is organized in three tiers. Within each of the three elements are a series of aspects (each listed below). Nested under each aspect is a list of more detailed individual sustainability attributes (e.g., prepares for long-

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[1] Environmental Protection Agency, 2013. “Case Studies Analyzing the Economic Benefits of Low Impact Development and Green Infrastructure Programs” http://water.epa.gov/polwaste/green/upload/lid-gi-programs_report_8-6-13_combined.pdf

[2] Environmental Protection Agency, 2005. “Reducing Urban Heat Islands: Compendium of Strategies” http://www.epa.gov/hiri/resources/pdf/CoolPavesCompendium.pdf

[3] Global Reporting Initiative, 2013. G4 Sustainability Reporting Guidelines. https://www.globalreporting.org/resourcelibrary/GRIG4-Part1-Reporting-Principles-and-Standard-Disclosures.pdf

term climate adaptability, enhances native vegetation, improves community quality of life, etc.). The complete list of attributes can be found in the table in Section 4.2.

The sections below describe the relevance and importance of each aspect and the considerations that will help determine if the BMP incorporates the attributes in the checklist.

P.3.1 Financial

P.3.1.1 Life-Cycle Costs

- Why it matters
  - The total cost of building and maintaining a project has implications for current and future budgets. While initial capital costs are typically considered in project design, it is also important to take into account on-going operation and maintenance, decommissioning, and replacement expenses. An accounting of costs across the full life cycle of a project (known as "total cost of ownership") provides a more holistic view and better comparison of design alternatives.
- Considerations
  - When evaluating alternatives, examine the total cost of ownership and normalize the alternatives to the same time interval.

P.3.1.2 Financial Risk and Climate Adaptability

- Why it matters
  - A BMP could lead to additional costs not initially identified in construction or O&M. This evaluation will help to identify levels of risk and potential complications at the outset, such as potential for expensive and unexpected repairs, project or permitting delays, public relations problems, or that the facility could be under-engineered for future conditions or regulations.
  - For stormwater BMPs in particular, future climatic conditions are anticipated to include higher variability and intensity of precipitation, as well as more frequent flood events, which will lead to increased stress on stormwater systems.
  - Green infrastructure takes pressure off of existing traditional stormwater infrastructure (e.g., stormwater pipes). The increase in variability of precipitation that is anticipated in the Pacific Northwest can be managed more effectively through an integrated and flexible stormwater approach in comparison to traditional hardscape stormwater infrastructure.

- Considerations
  - If the BMP involves special permitting from regulators, consider the additional complexity in project implementation, both in terms of securing the original permit and demonstrating ongoing compliance.
  - The design of some BMPs may trigger concerns among community stakeholders. Designers shall identify, understand and resolve potential issues early on to ensure the project is suitable to the context and avoid unnecessary conflict.
  - Some BMPs involve systems that, in the event of an unexpected failure or routine maintenance, would require repairs or servicing that could be disruptive to Port users; therefore, identify potential financial risks and design considerations that mitigate those risks.

- Evaluate whether stormwater facilities are sized for present as well as future conditions.
- If the BMP involves vegetation establishment, select plants adapted to current and future site conditions. For example, a local tree planting organization, Friends of Trees – a partner of the Port, plants native species that are anticipated to be more resilient or acclimated to climate change.

P.3.1.3 Regional Economic Stimulus

- Why it matters
  - One of the Port's purposes is to support the local and regional economy.
  - A prosperous local economy results in consumption of goods that are often brought through the Port.
  - Local and regional procurement further supports a stable local economy.

- Considerations
  - When procuring good and services seek out local and regional firms, where offers are equal in price, quality, and availability.
  - Track the proportion of goods and services procured from locally based firms.

P.3.2 Environmental

P.3.2.1 Habitat and Ecosystem Services

- Why it matters
  - Human communities, and all living organisms, depend on the healthy functioning of biological systems. While Port operations can constrain the opportunity to realize "natural" systems, there are still measures that can restore, enhance, support or mimic these systems.

- Considerations
  - When possible, choose BMPs that transition from grey, impermeable systems to green, dynamic systems that mimic natural processes of peak volume reduction, pollutant removal and groundwater recharge through infiltration and filtration.
  - As described in each of the BMPs, wildlife, particularly avian species, pose a threat to aircraft safety at PDX. Special precautions must be taken to limit the attractiveness of hazardous wildlife to BMPs within the wildlife hazard zones described in Chapter 4.
  - At sites outside of wildlife hazard zones, prioritize and identify opportunities to improve wildlife habitat and ecosystem function. In particular, consider opportunities to utilize native plant species, increase tree canopy cover, and provide safe harbor for native and migrating species.
  - Habitat value can be more difficult to design for than other sustainability attributes, consequently a designer must engage this topic thoughtfully to provide for an effective outcome.

P.3.2.2 Materials Management

- Why it matters
  - Managing and reducing material consumption results in the extraction of fewer raw materials and reduces energy consumption, leading to less waste and pollution.

- Considerations
    - o Source environmentally responsible materials (e.g., concrete with high fly ash content) as well as materials that are recyclable at the end-of-life or can be repurposed for similar or other applications.
    - o Some BMPs may not seem material intensive at initial construction, but are material intensive over the course of the life cycle, due to O&M inputs. Designers shall identify factors that may increase life-cycle costs and identify options to reduce life-cycle material intensity.
    - o Consider use of non-traditional materials that still achieve project functionality and performance. As an example, rubblized, recycled concrete, in certain contexts, can be used in place of virgin gravel.
    - o Material and design selection should consider the public education and reputational value of using innovative materials.
    - o All non-traditional materials must be vetted through the Port for potentially unintended water quality impacts that may affect Port compliance with regulatory permits.

P.3.2.3 Energy and Greenhouse Gas Emissions

- Why it matters
    - o The global and regional climate is changing—primarily due to human caused emissions of greenhouse gases (GHGs). These changes present serious environmental, economic and social risk to the Port.
    - o The Port has established a goal of reducing direct and indirect GHGs by 15% below 1990 baseline levels by 2020.

- Considerations
    - o Generally speaking, in capital construction projects the GHG impacts of transporting materials and equipment operation tend to be insignificant compared to the GHGs embodied in building materials. Therefore, projects that utilize materials from energy intense manufacturing (e.g., steel) or from GHG intense manufacturing (e.g., cement) will tend to have greater GHG impacts than those that utilize "natural" materials.
    - o Many GHG intense building materials can be manufactured in a way to minimize their GHG impacts (e.g., concrete with high fly ash content). Explore design specifications that allow for the use of these materials.
    - o Preferentially select BMPs that do not require ongoing energy-intense maintenance, such as periodic or continuous pumping, which can be a source of GHG emissions.
    - o Some BMPs result in stormwater volume reductions, thereby reducing need for new stormwater infrastructure (e.g., pipe capacity) or additional conventional treatment, and as a result, displacing both direct and indirect GHGs. Designers shall identify opportunities to reduce GHGs by using BMPs that optimize flow control rather than conventional treatment.

P.3.3 Social

P.3.3.1 Quality of Life, Spaces and Culture

- Why it matters
  - Urban environments that blend and offer natural habitat improve quality of life, whether that is through aesthetic enhancement or improved air quality.
  - There is a limit to the available land that can be allocated for public spaces. Therefore, utilizing Port lands for stormwater functionality but that also public space enhancement is highly desired.

- Considerations
  - In the design stage, consider the ability for BMPs to provide multiple benefits, first and foremost as a stormwater management design, but also serving as public spaces for staff or the public at large.

P.3.3.2 Public Education and Engagement

- Why it matters
  - The Port has chosen to prioritize and incorporate sustainability into its mission. Moreover, the Port is highly visible in the community and its actions are subject to special scrutiny. Implementing projects that further advance sustainability and engage the public enhance the Port's reputation and important relationships in the community.

- Considerations
  - Where possible, designers shall seek to implement innovative stormwater BMPs.
  - Recognize the capacity of local and neighboring stakeholders to participate in the implementation, monitoring and educational opportunities associated with stormwater BMPs. Potential partners include the West Multnomah Soil and Water Conservation District, City Nature Division of Portland Parks and Recreation, the Columbia Land Trust, Xerces Society, and BES.

P.4 Key Takeaways

P.4.1 Results Summary

- **Use the Sustainability Attribute Checklist as a guide, rather than basing decisions on the results table:** The summary table is a generalization of how certain sustainability attributes apply to an idealized implementation of a given BMP. The sustainability results may be different in the context of a specific project. Many BMPs assessed in the Sustainability Attribute Checklist are identified as "design for sustainability", that the BMPs have potential to contribute to sustainability performance outcomes but require designers to address these attributes. There is no guarantee that a BMP, as applied in a given context, is an accurate indicator of sustainability performance because the specific implementation of a BMP will have unique characteristics based on site context. The best use of the checklist is as a prompt for the designer to consider how the identified sustainability attributes can be incorporated into the design of the BMP and maximize the value of the project.

- **Prioritize function and context:** Each site will have unique characteristics and functional requirements and not all BMPs will be appropriate for each site. A designer should not simply implement the BMPs that meet the greatest number of sustainability attributes, but rather seek to implement BMPs that meet the functional need and site context while maximizing sustainability value.
- **Prioritize habitat and social value when possible:** Most of the BMPs address at least some of the sustainability attributes. However, "Habitat and Ecosystem Services" and "Quality of Life, Spaces and Culture" are two aspects with distinct sustainability outcomes among BMPs. The BMPs that perform across the full spectrum of sustainability attributes are those that tend to be more visible, and those that are closer to habitat or public spaces including: bioretention basins, vegetated swales, planter box filters, green roofs and cisterns.
- **Integration of BMPs:** Tradeoffs exist and no single BMP can provide all the needed functionality for stormwater management. When possible, integrating BMPs can blend benefits, particularly environmental and social benefits, and integration should be part of a designer's strategy. Therefore, BMPs should not simply be assessed individually, but also in coordination with one another. In order to develop solutions to engage the complexity of environmental relationships more effectively, the designer must go beyond the individual site scale to assess how the site relates to, and is nested in, the entire watershed.
- **Innovation and emerging technologies:** The Port has demonstrated innovation with respect to projects across its operations, including the installation of a Living Machine at its building headquarters. The DSM furthers the Port's commitment to identifying and implementing a broad spectrum of designs; but in order to continue its trajectory of fostering a Port-wide culture of sustainability, the Port will continue to pursue BMPs, technologies and process innovations that continue to meet functional needs as well as positive sustainability outcomes, particularly as it relates to climate adaptation.

P.4.2 Sustainability Attribute Checklist

Sustainability Attribute Checklist

Designers should refer to this checklist as a prompt during pre-design alternatives analysis and again during final design to evaluate and consider the sustainability performance of various BMPs.

- (gray) **Not Applicable:** The attribute is not relevant to this BMP and there are no potential positive or negative performance outcomes.
- (green) **Threat/Barriers to Performance:** The BMP inherently has good performance outcomes without any special design considerations.
- (orange) **Design Dependent Performance:** The opportunity for good performance outcomes where certain design elements are incorporated.
- (red) **Threat/Barrier(s) to Performance:** The BMP may be problematic for this attribute.

	Dry Extended Detention Basin	Wet Basin	Subsurface Flow Wetland	Bioretention Basin	Infiltration Trench	Vegetated Swale	Vegetated Filter Strip	Media Filter	USCFs	Pervious Pavement	Planter Box Filters	Green Roofs	Cisterns	Dry Wells	Cartridge Filter Vaults	Oil-Water Separators	Hydrodynamic Separators
Financial																	
Life-Cycle Costs																	
Low to moderate life-cycle capital costs	green	green	orange	green	green	green	green	green	orange	green	orange	red	orange	orange	orange	green	green
Low to moderate life-cycle O&M costs	orange	orange	orange	green	green	green	green	green	green	green	green	orange	orange	green	green	green	green
Financial Risk and Climate Adaptability																	
Low complexity, lower risk	green	orange	orange	orange	red	green	green	orange	red	orange	orange	red	orange	red	red	red	red
Adaptable to long-term climate trends	orange	green	green	orange	orange	green	green	gray	orange	orange	orange	green	green	orange	orange	gray	gray
Regional Economic Stimulus																	
Uses regional materials	Implementation of each of the BMPs could incorporate locally or regionally sourced materials and expertise																
Hire local or regional small businesses																	
Environmental																	
Habitat and Ecosystem Services																	
Naturalizes industrial hardscapes	orange	green	green	green	green	green	green	orange	gray	orange	green	green	gray	gray	gray	gray	gray
Mimics natural processes	green	green	green	orange	orange	green	green	green	gray	orange	green	green	gray	gray	gray	gray	gray
Enhances native vegetation	orange	orange	orange	orange	gray	orange	orange	orange	gray	gray	orange	orange	gray	gray	gray	gray	gray
Increases urban tree canopy	gray	orange	gray	orange	gray	orange	orange	gray	gray	gray	orange	orange	gray	gray	gray	gray	gray
Improves pollinator and insect habitat	gray	orange	orange	orange	gray	orange	orange	orange	gray	gray	orange	orange	gray	gray	gray	gray	gray
Materials Management																	
Uses environmentally responsible materials	orange	orange	orange	orange	orange	gray	gray	orange	orange	orange	orange	orange	orange	orange	orange	orange	orange
Materials have potential for end of life use	orange	gray	gray	orange	orange	gray	gray	orange	orange	orange	orange	orange	orange	orange	orange	orange	orange
Energy and GHGs																	
Low energy and GHG intensity	orange	green	green	orange	orange	green	green	red	orange	orange	orange	orange	red	orange	red	red	red
Social																	
Quality of Life																	
Enhances public spaces	orange	green	green	green	orange	green	orange	orange	gray	green	green	green	orange	gray	gray	gray	gray
Public Education and Engagement																	
High public visibility	orange	green	orange	green	orange	green	orange	orange	gray	green	green	green	orange	gray	gray	gray	gray
Demonstrates leadership and innovation	orange	orange	green	orange	orange	orange	orange	orange	gray	green	orange	green	green	gray	gray	gray	gray
Opportunity for community partnerships	orange	green	orange	green	orange	green	orange	orange	gray	green	green	green	green	gray	gray	gray	gray

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