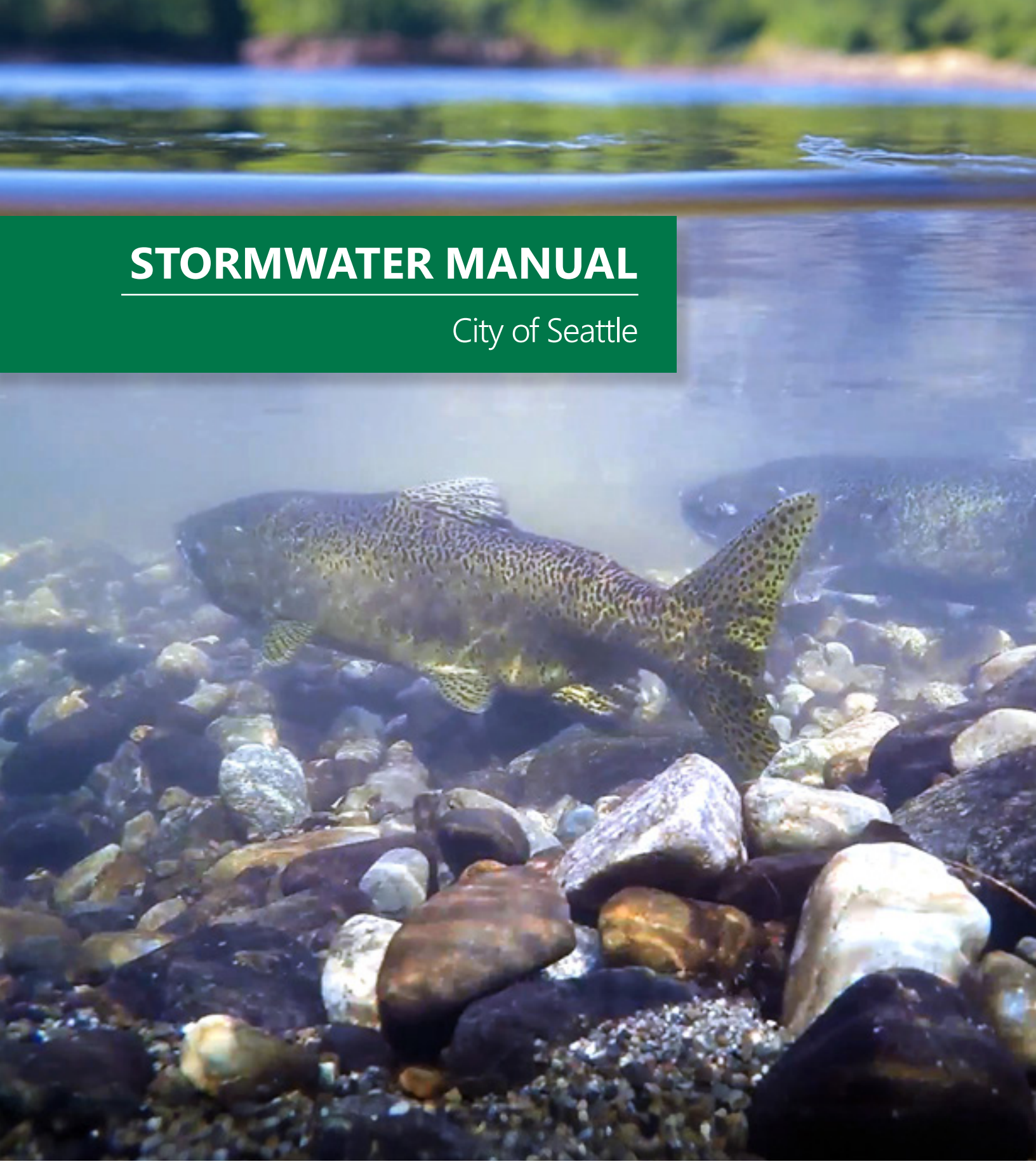
STORMWATER MANUAL

City of Seattle



July 2026

City of Seattle

City of Seattle

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Approved

/s/ Andrew Lee (signature on file)	June 4, 2026
Andrew Lee, SPU General Manager/CEO	Date
/s/ Sam Steele (signature on file)	June 4, 2026
Sam Steele, SDCI Interim Director	Date

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With a publication of this size and complexity there will inevitably be errors that must be corrected and clarifications that are needed. There will also be new information and technological updates. The City intends to publish corrections, updates, and new technical information on our Stormwater Code website (http://www.seattle.gov/sdci/codes/codes-weenforce-(a-z)/stormwater-code). The City will not use the website to make revisions in key policy areas – such as the thresholds and minimum requirements in Volume 1. Please check this site periodically for corrections and updates.

VOLUME 1

PROJECT MINIMUM REQUIREMENTS

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City of Seattle Core Team

Name	Affiliation	Role
Sherell Ehlers	SPU	Code Update Lead, Program Manager
Matthew Bateman	SDCI	Volumes 1, 2, & 3 Co-Lead, Core Team
Mary Weber	SPU	Volume 3 Co-Lead, Core Team
Jessica Huybregts	SPU	Volume 4 Lead, Core Team
Elizabeth Dent	SPU	Project Manager
Shanti Colwell	SPU	Core Team
Kevin Burrell	SPU	Core Team
Matt Recker	SPU	Core Team
Kristin Ramey	SPU	Core Team
Jessica Avila	SPU	Core Team
Susie Walson	SPU	Core Team
Cris Horbelt	SPU	Core Team
Nicole Kistler	SPU	Core Team
Eric Lust	SPU	Core Team
Ede Courtenay	SDCI	Core Team
Scott Stevens	Parks / SPU	Core Team
Eduardo Aban	Parks	Core Team
Amanda Barnett	Parks	Core Team
Farhat Kohistani	Parks	Core Team
David Graves	Parks	Core Team
Michael Cawrse	SDOT	Core Team
Nick Shrope	SDOT	Core Team
Jens Norman	SDOT	Core Team
Andy Perny	Law	Core Team
Dean Huber	SPU	Technical Support
David Shin	SPU	Technical Support
Moon Callison	SDCI	Communication Support
Wendy Shark	SDCI	Communication Support

Consultant Team

Name	Affiliation	Role
Brian Busiek	Herrera Environmental Consultants	Contract Project Manager
Olivia Wright	Herrera Environmental Consultants	Project Lead, Volumes 2 & 3 Co-Lead
Margot Walker	Lotus Water	Project Management
Julianne Chechanover	Herrera Environmental Consultants	Modeling Lead
Alice Lancaster	Herrera Environmental Consultants	Senior Technical Advisor
Rebecca Dugopolski	Herrera Environmental Consultants	Technical Advisor
Neil Schaner	Herrera Environmental Consultants	Technical Support
Dylan Ahearn	Herrera Environmental Consultants	Technical Support
Kate Forester	Herrera Environmental Consultants	Technical Support
Meghan Mullen	Herrera Environmental Consultants	Modeling Support
Whitney Packard	Herrera Environmental Consultants	Technical Support
Citlali Ramirez	Herrera Environmental Consultants	Technical Support
Katie Rodriguez	Herrera Environmental Consultants	Technical Support
Michelle Fox	Herrera Environmental Consultants	Publication Support
Kristine McGowan	Herrera Environmental Consultants	Publication Support
Cory Zanker	Herrera Environmental Consultants	Publication Support
Nicole Trolio	Herrera Environmental Consultants	Publication Support
Kristen Matsumura	Lotus Water	Implementation Tools Support
Tina Loucks-Jaret	Petals to Protons	Technical Editor
Robin Kirschbaum	RKI	Technical Support

Ecology Reviewers

Name	Affiliation
Colleen Griffith	Department of Ecology
Doug Howie	Department of Ecology

CHAPTER 1 – Introduction

1.1. Purpose of This Manual (Volumes 1 through 5 and Appendices)

In addition to meeting the specific stormwater needs of the City of Seattle (City), the Stormwater Code meets certain requirements that apply to the City from the 2024–2029 Phase I National Pollutant Discharge Elimination System (NPDES) and State Waste Discharge General Permit for Discharges from Large and Medium Municipal Separate Storm Sewer Systems, effective August 1, 2024 (referred to as the Phase I NPDES Municipal Stormwater Permit). Coverage under the general permit is issued to the City by the Washington State Department of Ecology (Ecology) pursuant to the federal Clean Water Act and state law. One of the conditions of this permit requires the City to adopt and make effective a local program to prevent and control the impacts of stormwater runoff from new development, redevelopment, and construction activities. This is accomplished, in large measure, through the Seattle Stormwater Code and its associated Directors' Rule (this Manual), which Ecology has determined meets the requirements contained in the Phase I NPDES Municipal Stormwater Permit, with reference to the *Stormwater Management Manual for Western Washington* (SWMMWW) (Ecology 2024).

Excerpts from the Stormwater Code (in *italics*) are presented throughout the manual as a reference. In cases where there is conflict between the Stormwater Manual and the Stormwater Code, the Stormwater Code governs. The City's Stormwater Code is contained in the Seattle Municipal Code (SMC), Chapters 22.800 through 22.808. The Stormwater Code contains regulatory requirements that provide for and promote the health, safety, and welfare of the general public.

Stormwater Code Language

SMC, Section 22.800.020 — *Purpose*

A. The provisions of this subtitle shall be liberally construed to accomplish its remedial purposes, which are:

1. To protect, to the greatest extent practicable, life, property and the environment from loss, injury and damage by pollution, erosion, flooding, landslides, strong ground motion, soil liquefaction, accelerated soil creep, settlement and subsidence, and other potential hazards, whether from natural causes or from human activity;

2. To protect the public interest in drainage and related functions of drainage basins, watercourses and shoreline areas;

3. To protect receiving waters from pollution, mechanical damage, excessive flows and other conditions in their drainage basins which will increase the rate of downcutting, streambank erosion, and/or the degree of turbidity, siltation and other forms of pollution, or which will reduce their low flows or low levels to levels which degrade the environment, reduce recharging of groundwater, or endanger aquatic and benthic life within these receiving waters and receiving waters of the state;

4. To meet the requirements of state and federal law and the City's municipal stormwater National Pollutant Discharge Elimination System (NPDES) permit;

5. To protect the functions and values of environmentally critical areas as required under the state's Growth Management Act and Shoreline Management Act;

6. To protect the public drainage system from loss, injury and damage by pollution, erosion, flooding, landslides, strong ground motion, soil liquefaction, accelerated soil creep, settlement and subsidence, and other potential hazards, whether from natural causes or from human activity; and

7. To fulfill the responsibilities of the City as trustee of the environment for future generations.

B. It is expressly the purpose of this subtitle to provide for and promote the health, safety and welfare of the general public. This subtitle is not intended to create or otherwise establish or designate any particular class or group of persons who will or should be especially protected or benefited by its terms.

C. It is expressly acknowledged that water quality degradation can result either directly from one discharge or through the collective impact of many small discharges. Therefore, the water quality protection measures in this subtitle are necessary to protect the health, safety and welfare of the residents of Seattle and the integrity of natural resources for the benefit of all and for the purposes of this subtitle. Such water quality protection measures are required under the federal Clean Water Act, 33 U.S.C. Section 1251, et seq., and in response to the obligations of the City's municipal stormwater discharge permit, issued by the State of Washington under the federal NPDES program.

To support implementation of the Stormwater Code, the Director of Seattle Public Utilities (SPU) and the Director of the Seattle Department of Construction and Inspection (SDCI) adopt rules that provide specific technical requirements, criteria, guidelines, and additional information. This Directors' Rule consists of a five-volume City Stormwater Manual and ten appendices.

1.2. How to Use this Manual (Volumes 1 through 5 and Appendices)

The City's Stormwater Manual includes the following five volumes:

- *Volume 1: Project Minimum Requirements* provides information about how to apply the minimum requirements contained in the Stormwater Code. It also provides site assessment and planning steps and requirements for drainage control review submittals.
- *Volume 2: Construction Stormwater Control* contains temporary erosion and sediment control technical requirements, which are required to minimize downstream impacts and to prevent contaminants from leaving the project site during construction.
- *Volume 3: Project Stormwater Control* presents approved methods, criteria, and details for analysis and design of on-site stormwater management, flow control, and water quality treatment best management practices (BMPs).
- *Volume 4: Source Control* provides information to individuals, businesses, and public agencies in Seattle to implement BMPs for controlling pollutants at their source and preventing contamination of stormwater runoff.
- *Volume 5: Enforcement* provides standards, guidelines, and requirements for enforcing the Stormwater Code.

The City's Stormwater Manual includes the following ten appendices:

- *Appendix A: Definitions* provides terminology from the Stormwater Code for all five volumes of the Stormwater Manual and other definitions as adopted in the Manual.
- *Appendix B: Drainage Control Report and Additional Submittal Requirements* provides supplemental information for Volume 1 (Project Minimum Requirements) related to submittal requirements including required drainage control report elements.
- *Appendix C: On-site List Infeasibility Criteria* provides a list of criteria to be evaluated for on-site stormwater management.
- *Appendix D: Subsurface Investigation and Infiltration Testing for Infiltration BMPs* describes subsurface report requirements, geotechnical explorations, four infiltration testing methods (Simple Test, Small Pilot Infiltration Test (PIT), Large PIT, and Deep Infiltration Test), infiltration rate correction factors, groundwater monitoring, and groundwater mounding analysis.
- *Appendix E: Additional BMP Design Requirements* includes additional design requirements for flow control structures, flow splitters, flow spreaders, level spreaders, pipe slope drains, outlet protection, facility liners, and geotextiles.
- *Appendix F: Hydrologic Analysis and Design* includes descriptions of acceptable methods for estimating the quantity and hydrologic characteristics of stormwater runoff, and the assumptions and data requirements of these methods.
- *Appendix G: Stormwater Control Operations and Maintenance Requirements* contains maintenance requirements for typical stormwater BMPs and components.

- *Appendix H: Financial Feasibility Documentation for Vegetated Roofs and Rainwater Harvesting* provides additional guidance on the required documentation to prove financial infeasibility of vegetated roofs or rainwater harvesting.
- *Appendix I*: *Landscape Management Plans and Integrated Pest Management Plans* provides supplemental information for Volume 1 (Project Minimum Requirements) and Volume 4 (Source Control).
- Appendix J: *Plant and Tree Lists for Stormwater BMPs* provides a guide for appropriate plants and trees to be in bioretention (infiltrating and non-infiltrating), biofiltration swales, sand filters, and wet ponds.

1.3. Purpose of Volume 1

Volume 1 — Project Minimum Requirements describes minimum requirements for all types of land development and redevelopment. It also provides site assessment and planning steps and drainage control review requirements.

1.4. How to Use This Volume

- *Chapter 1* outlines the purpose and content of the entire Stormwater Manual.
- *Chapter 2* outlines steps to determine a project's minimum requirements.
- *Chapter 3* describes the minimum requirements for all projects.
- *Chapter 4* describes the minimum requirements for specific project types.
- *Chapter 5* describes the minimum standards for on-site stormwater management, flow control, and water quality treatment.
- *Chapter 6* describes the options for alternative compliance.
- *Chapter 7* describes exemptions, adjustments, and exceptions.

CHAPTER 2 – Determining Minimum Requirements

There are eight basic steps used to determine which minimum requirements for on-site stormwater management, flow control, and water quality treatment apply to a project:

- **Step 1** — Define the boundaries of the project site.
- **Step 2** — Identify the type of project.
- **Step 3** — Identify the receiving water and downstream conveyance.
- **Step 4** — Perform site assessment and planning.
- **Step 5** — Calculate new plus replaced hard surface and native vegetation conversion.
- **Step 6** — Calculate new plus replaced pollution generating surface.
- **Step 7** — Determine which minimum requirements apply.
- **Step 8** — Determine drainage control review and application requirements.

Details of each of the eight steps are provided in the following subsections.

In addition to determining the applicable minimum requirements, all projects must comply with all other Stormwater Code requirements, in particular the Minimum Requirements for All Discharges and All Real Property (SMC, Chapter 22.803) and the Minimum Requirements for All Projects (SMC, Chapter 22.805).

2.1. Step 1 – Define the Boundaries of the Project Site

The boundaries of the project site must include all development activities as defined by "development" SMC, Section 22.801.050. The boundary of the public right-of-way typically forms the boundary between project types if more than one project type exists.

The project site may also include contiguous areas that are subject to the addition or replacement of hard surface or the undertaking of land-disturbing activity.

In the case of a subdivision, short plat, or closely related projects, including common plan of development or sale, the boundary of the project site is the full area included in the subdivision, short plat, or closely related projects. See SMC, Section 22.805.010 and *Appendix B* for specific requirements for subdivisions and short plats.

All projects, even if implemented in incremental stages or phases, must consider the total combined development at full build-out when determining Stormwater Code requirements.

Stormwater Code Language
SMC, Subsection 22.808.010.A.1—*Civil violations* *g. Piecemeal of projects. It is a violation for any person to knowingly divide a larger project into a set of smaller projects specifically for the purpose of avoiding minimum requirements;*

2.1.1. Definitions Related to the Project Site

For definitions related to the project site such as “development”, “hard surface”, “project”, “project site” or “site”, refer to SMC, Chapter 22.801 and *Appendix A*.

Defining project boundaries will help identify the project type(s) in Step 2.

2.1.2. Closely Related Projects

Stormwater Code Language
SMC, Subsection 22.805.010.B –*Closely related projects, projects under a common plan of development or sale, subdivisions, and short plats are considered as one project for purposes of applying the Stormwater Code, including but not limited to determining whether the thresholds for applicability of particular Stormwater Code minimum requirements are met.*
SMC, Subsection 22.801.040.C – *“Closely related projects” means two or more projects that are concurrently under review, under issued permits not yet approved for final construction, or both, and share any of the following physical or functional interdependencies:* 1. *A feature physically spans the property lines between lots or the project sites, such as shared structures, shared driveways, shared pedestrian access (including easements to rights-of-way), shared drainage and utility designs, foundation footings, or retaining walls. For purposes of this subsection, abutting driveways or pedestrian accesses are not considered to span the property lines if the required driveway or pedestrian access width for each project independently meets development standards;* 2. *A shared driveway is proposed to access a parking area for more than one project, regardless of whether the parking is required;* 3. *Parking, including maneuvering, aisle requirements, or other parking related easements, regardless of whether the parking is required, is proposed to be provided (or partially provided) on the site of another project, even if the project sites do not abut each other;* 4. *Proposed structures are joined or share a common wall;* 5. *Proposed projects share required open space, amenity area, or both;* 6. *The design of two or more project sites are dependent on grading, construction of retaining walls or foundations, or both across the lot lines or project sites;* 7. *One site is required to permanently access, construct, and maintain the structures or development features on an abutting or adjacent site; or* 8. *Other features that create physical or functional interdependence between the projects.*

Projects submitted for review are considered “under review” once a complete project application has been made, until the applicable construction permits for the project are issued, or the permit application is withdrawn by the applicant. Final construction approval means that all final inspections are conducted and passed, all fees are paid, and the permit status is “completed.”

2.1.3. Common Plan of Development or Sale

Stormwater Code Language
SMC, Subsection 22.801.040.C – *"Common plan of development or sale" means a site where multiple separate and distinct construction activities may be taking place at different times on different schedules and/or by different contractors, but still under a single plan. Examples of "common plan of development or sale" include:* 1. *Phased projects and projects with multiple filings/lots, even if the separate phases or filings/lots will be constructed under separate contract or by separate owners (e.g., a development where lots are sold to separate builders);* 2. *A development plan that may be phased over multiple years, but is still under a consistent plan for long-term development;* 3. *Projects in a contiguous area that may be unrelated but still under the same contract, such as construction of a building extension and a new parking lot at the same facility; and* 4. *Linear projects such as roads, pipelines, or utilities.*

A single plan means coordinated development across one or more adjacent or abutting project sites that are planned, designed, permitted, or implemented as parts of a unified development project or phased buildout whether constructed concurrently or in phases or under separate permits.

For purposes of this section, development activities that are separate in time, ownership, permitting, or construction may nevertheless be considered part of a single plan when there is objective evidence that the activities are related or integrated, including but not limited to:

1. Shared or related planning documents;
2. Coordinated or sequential phasing intended to implement an overall development concept;
3. Common ownership or control together with coordinated timing, design, permitting, financing, marketing, or construction; or
4. Other evidence demonstrating that the activities function as components of a unified development project.

In determining whether development remains under a single plan, the Director may consider the totality of the circumstances. The Director may determine that separate actions fall within a single plan where the division of land, sequencing of permits, modification of project boundaries, or changes in ownership have the purpose or effect of avoiding applicable stormwater thresholds, minimum requirements, or review obligations.

2.2. Step 2 – Identify the Type of Project

For the purpose of determining applicable minimum requirements, there are nine general classifications of projects:

1. Parcel-based (*Section 2.2.1*)
2. Sidewalk (*Section 2.2.2*)

3. Trail (*Section 2.2.3*)
4. Roadway (*Section 2.2.4*)
5. Utility (*Section 2.2.5*)
6. Pavement maintenance (*Section 2.2.6*)
7. Remediation (*Section 2.2.7*)
8. Retrofit (*Section 2.2.8*)
9. Washington State Department of Transportation (WSDOT) (*Section 2.2.9*)

Each project type is described in the following subsections (*Section 2.2.1* through *2.2.9*).

In addition to the general classifications listed above, some projects are more complex than others (e.g., bridges, closed depressions, rail yards, rail stations, light rail guideways and tracks (both elevated and non-elevated), and other rail lines and railways) or include more than one project type, making it difficult to determine the applicable minimum requirements. Refer to *Section 2.7.1.* Special Circumstances for additional guidance on determining applicable minimum requirements.

2.2.1. Parcel-based Project

A **parcel-based project** (Figure 2.1) is defined in SMC, Section 22.801.170.

Stormwater Code Language
SMC, Section 22.801.170 - *"Parcel-based project" means any project that is not a roadway project, sidewalk project, or trail project. The boundary of the public right-of-way shall form the boundary between the parcel and roadway portions of a project.*

Examples of parcel-based projects include, but are not limited to, commercial developments, multifamily developments, apartments, carriage houses, cottage housing development, rowhouse developments, townhouse development, institutions, industrial buildings and sites, parking lots, parks and playgrounds, commercial use development, public facilities, live-work units, manufacturing facilities, storage facilities, transportation facilities, utility use facilities, subdivisions, short plats, building additions, and single-family and all other residential developments. Utility work on the parcel that is integral with and contiguous to the project area is part of the parcel-based project.

In addition, the following specific pollution-generating activities or projects are considered parcel-based projects and require drainage review. Specifically, source control BMPs must be implemented as specified in *Volume 4*, to the extent necessary to prevent prohibited discharges and to prevent contaminants from coming in contact with drainage water or being discharged to the drainage system, public combined sewer, or directly into receiving waters.

Stormwater Code Language
SMC, Section 22.807.020.A.2.j — *Applications for approvals for activities or projects for:* 1. *Fueling at dedicated stations, for new or substantially altered fueling stations.* 2. *In-water and over-water fueling.* 3. *Maintenance and repair of vehicles and equipment.* 4. *Concrete and asphalt mixing and production.* 5. *Recycling, wrecking yard, and scrap yard operations.* 6. *Storage of liquids in aboveground tanks.* 7. *Other projects that the Director determines pose a hazard to public health, safety, or welfare; endanger any property; adversely affect the safety and operation of City right-of-way, utilities, or other property owned or maintained by the City; or adversely affect the functions and values of an environmentally critical area or buffer.*

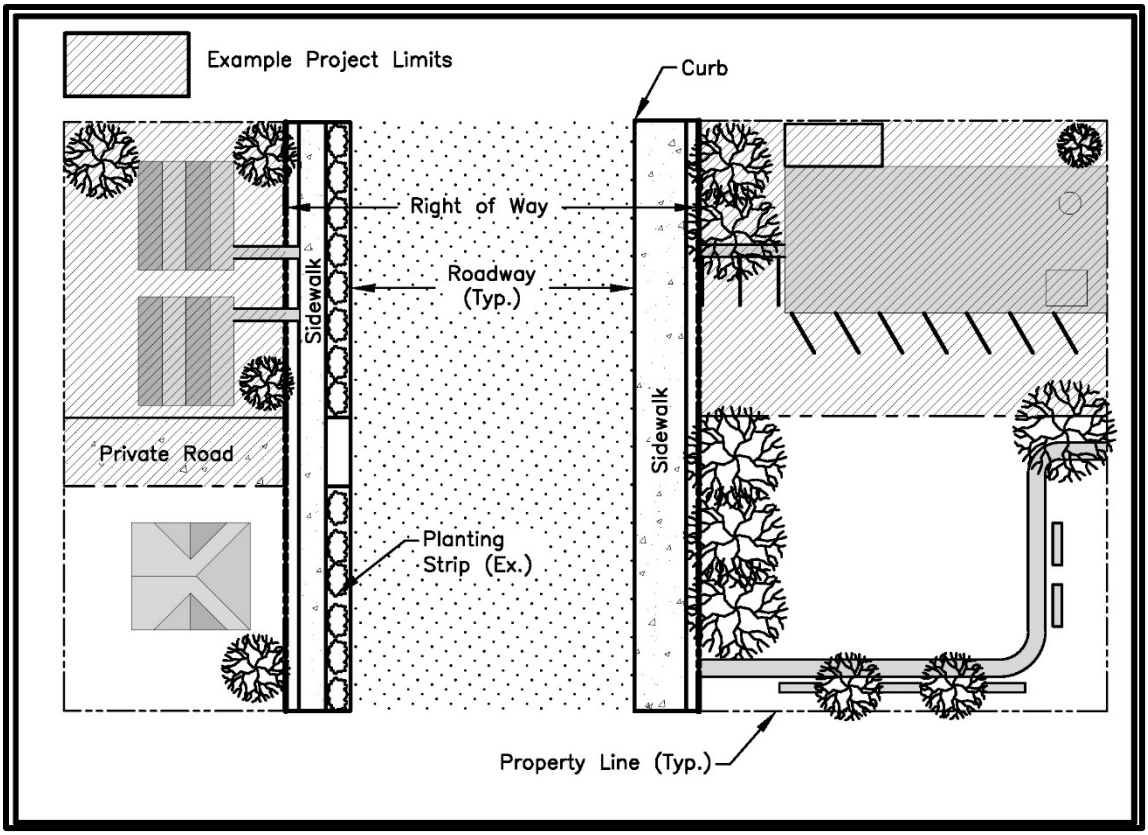

Figure 2.1 Parcel-based Project Site Definition.

2.2.2. Sidewalk Project

A sidewalk project (Figure 2.2) is defined in SMC, Section 22.801.200.

Stormwater Code Language
SMC, Section 22.801.200 - *"Sidewalk project" means a project for the creation of a new sidewalk or replacement of an existing sidewalk, including any associated planting strip, apron, curb ramp, curb, or gutter, and necessary roadway grading and repair. If the total new plus replaced hard surface in the roadway exceeds 10,000 square feet, the entire project is a roadway project.*

Projects that meet the definition of a roadway project (SMC 22.801.190) are not considered sidewalk projects and must meet the requirements of *Section 2.2.4* Roadway Project regardless of the amount of new or replaced hard surface in the roadway or alley.

Projects whose sole purpose is to upgrade existing hard surfaces for ADA compliance are considered a sidewalk project or trail project if not otherwise exempt. Note that this designation does not extend to additional work, such as extending or altering a sidewalk, stairwell, or parking spaces beyond what is necessary to meet ADA compliance of an existing hard surface.

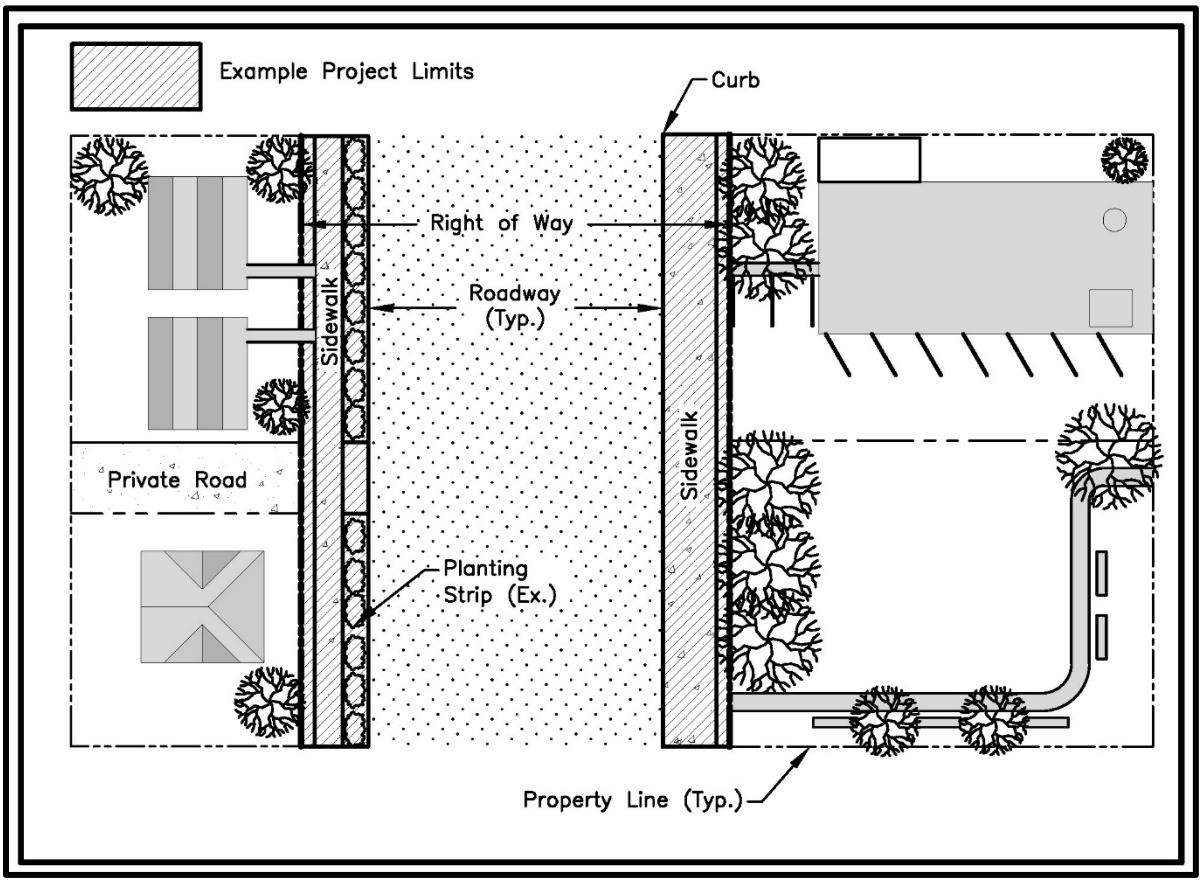

Figure 2.2. Sidewalk-only Project Site Definition.

2.2.3. Trail Project

A **trail project** (Figure 2.3) is defined in SMC, Section 22.801.210.

Stormwater Code Language
SMC, Section 22.801.210 - *"Trail project" means a project for the creation of a new trail or replacement of an existing trail, and which does not contain pollution-generating hard surfaces.*

The following trail portions of a project site may follow the requirements of *Volume 1, Section 4.2* Trail and Sidewalk Projects if the trail portion:

1. Is not integral to the portions of the parcel-based project (i.e., the trail can function without the parcel-based project improvements), and
2. Does not have a surface discharge from a natural or constructed conveyance system from the site.

Those trails, paths, or sidewalks that are integral with and contiguous to a parcel-based project or roadway project must meet the requirements of *Volume 1, Section 4.1* Parcel-based Projects or *Volume 1, Section 4.3*. Roadway Projects, respectively.

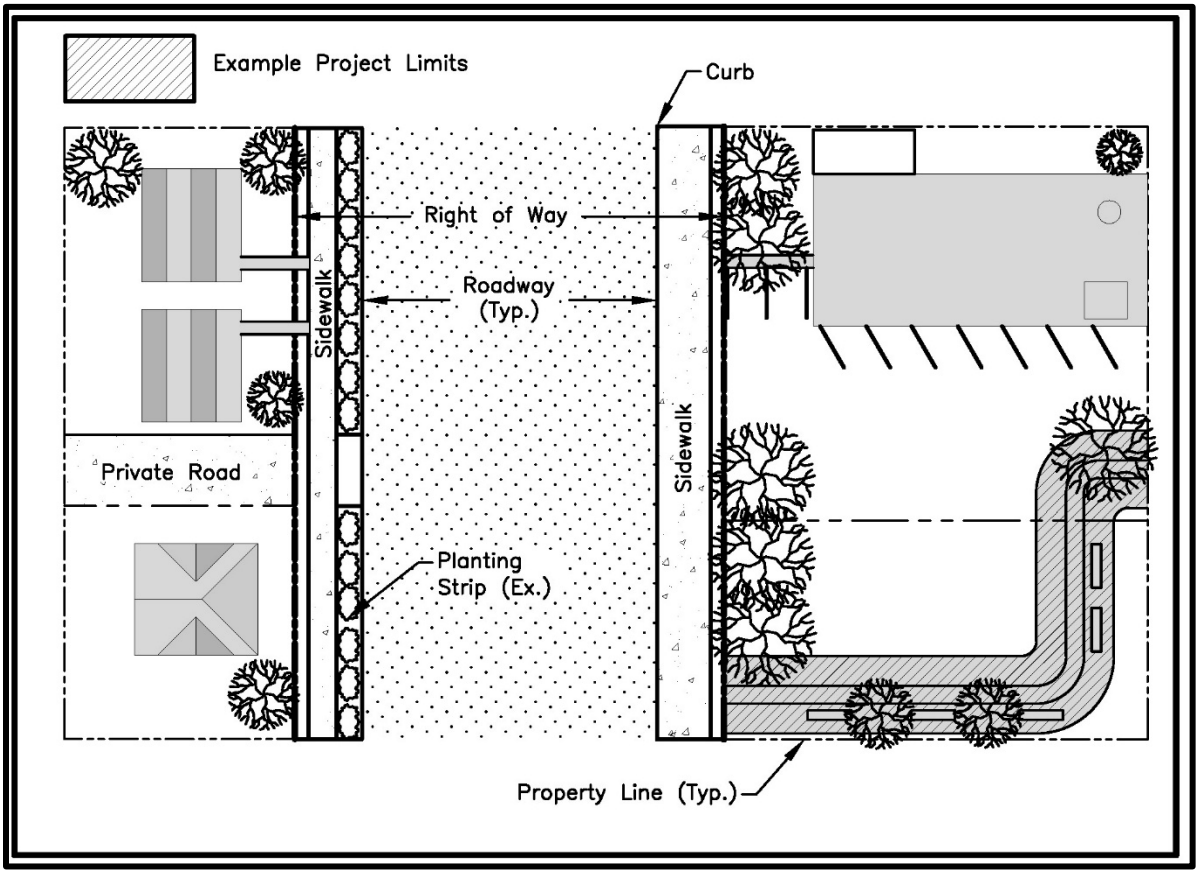

Figure 2.3. Trail Project Definition.

2.2.4. Roadway Project

A **roadway project** (Figure 2.4) is defined in SMC, Section 22.801.190.

Stormwater Code Language
SMC, Section 22.801.190 - *"Roadway project" means a project located in the public right-of-way that involves the creation of a new or replacement of an existing roadway or alley. The boundary of the public right-of-way shall form the boundary between the parcel and roadway portions of a project*

Typically, the boundary of the public right-of-way forms the boundary between the parcel and roadway portions of a project, but special circumstances may exist (refer to *Section 2.7.1*).

Projects that do not meet the definition of a roadway project (i.e., projects that include any development in addition to the creation of a new or replacement of an existing roadway or alley), are parcel-based projects. As an example, portions of projects that include building development and associated hard surfaces (e.g., parking lot) located in the public right-of-way are considered parcel-based projects (refer to *Section 4.1* for requirements).

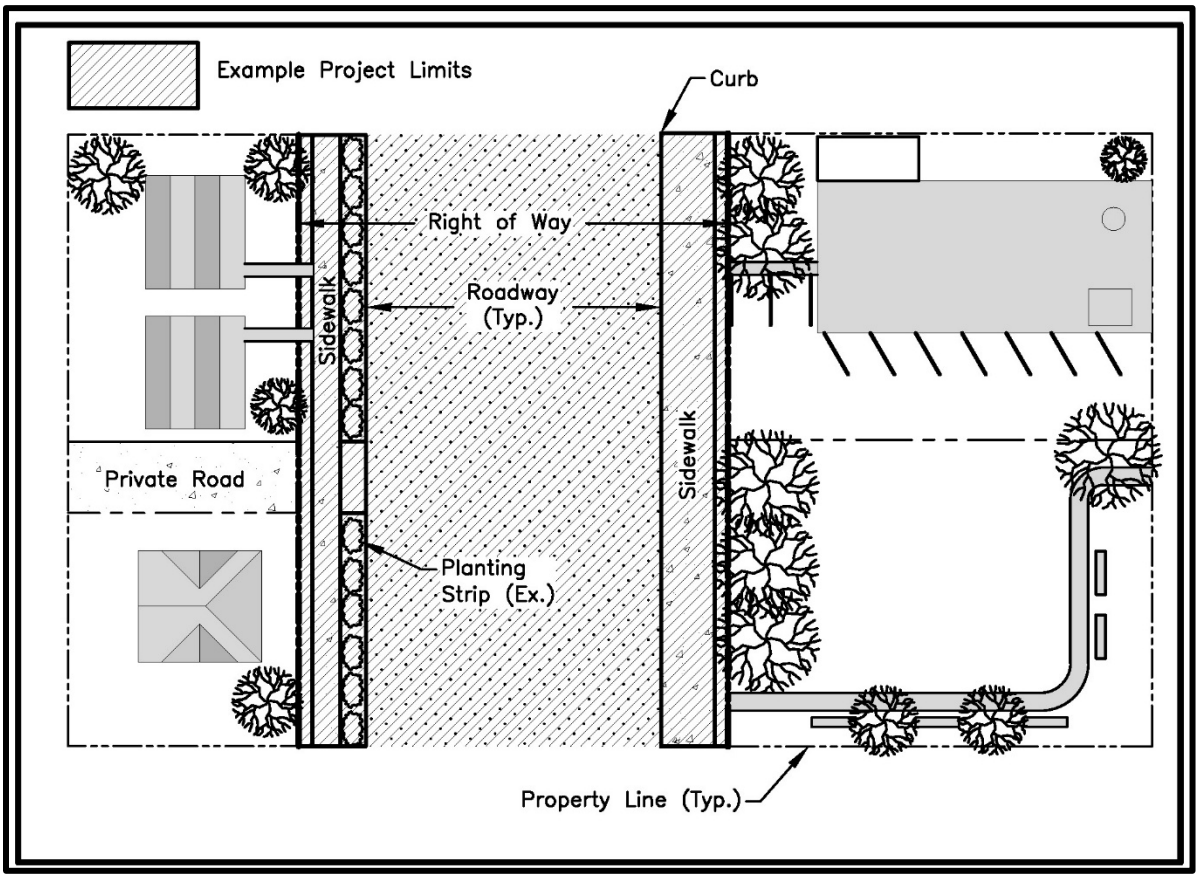

Figure 2.4. Roadway Project Site Definition.

2.2.5. Utility Project

Applicable utility projects are described in SMC, Subsection 22.800.040.A.2.a. Note that the installation of side sewers, service drains, and underdrains require a Side Sewer Permit per SMC, Section 21.16.070 (Permit and Fee Required for Connection and Repairs).

Installation of a new fuel tank is not considered a utility project. Projects that include fuel dispensing equipment, installation of underdrains for groundwater collection, parking or driveway areas for utility maintenance or operation, buildings for utility maintenance or operation, or pavement replacement or repair beyond the extent required for the utility maintenance, repair, or installation are not considered a utility project.

Stormwater Code Language
SMC 22.800.040.A.2.a — *Maintenance, repair, upgrade, or installation of underground or overhead utility facilities, such as, but not limited to, pipes, conduits, and vaults, that replaces the ground surface with in-kind material or materials with similar runoff characteristics is exempt from Section 22.805.070 (Minimum requirements for on-site stormwater management), Section 22.805.080 (Minimum requirements for flow control), and Section 22.805.090 (Minimum requirements for treatment), except installation of underground or overhead utility facilities that are integral with and contiguous to a trail or sidewalk project, parcel-based project, or a road-related project must comply with Section 22.805.040 (Minimum requirements for trail and sidewalk projects), Section 22.805.050 (Minimum requirements for parcel-based projects), or Section 22.805.060 (Minimum requirements for roadway projects), respectively.*

Note that utility projects are not exempt from other Stormwater Code requirements, including SMC, Section 22.805.020 (Minimum Requirements for All Projects).

The limits of a utility project include only the area disturbed that is necessary for the utility work (including any over-excavation necessary) and required ADA updates per the federal Americans with Disabilities Act.

2.2.6. Pavement Maintenance Project

Applicable pavement maintenance projects are described in SMC, Subsection 22.800.040.A.2.b and are limited to the pavement maintenance practices identified in SMC, Section 22.801.040.

Stormwater Code Language
SMC, 22.800.040.A.2.b – *Pavement maintenance practices, as defined in Section 22.801.170, are exempt from Section 22.805.070 (Minimum requirements for on-site stormwater management), Section 22.805.080 (Minimum requirements for flow control), and Section 22.805.090 (Minimum requirements for treatment) except pavement maintenance practices that are integral with and contiguous to a parcel-based project or a road-related project must comply with Section 22.805.050 (Minimum requirements for parcel-based projects) or Section 22.805.060 (Minimum requirements for roadway projects), respectively.*
SMC, 22.801.170 - *"Pavement maintenance practices" means repair and maintenance of an existing surface including sidewalks, limited to:* 1. *Targeted pothole and square cut patching;* 2. *Overlaying existing asphalt, concrete, or brick pavement with asphalt or concrete, so long as the base course is not exposed;* 3. *Shoulder grading;* 4. *Reshaping or regrading drainage systems, including adding curb, gutter, or wedge curbs;* 5. *Crack sealing; and* 6. *Vegetation maintenance.* *"Pavement maintenance practices" does not include work that: increases the vehicle capacity of a roadway or parking area; adds new hard surface or results in replaced hard surface (except for pothole or square cut patching); or materially alters a roadway's characteristics.*

Note that pavement maintenance projects are not exempt from other Stormwater Code requirements, including SMC, Section 22.805.020 (Minimum Requirements for All Projects).

The limits of a pavement maintenance project include only the area disturbed that is necessary for the pavement maintenance work and required ADA updates per the federal Americans with Disabilities Act.

2.2.7. Remediation Project

Applicable remediation projects are described in SMC, Subsection 22.800.040.A.2.c.

Stormwater Code Language
SMC, SMC 22.800.040.A.2.c **–** *Land disturbing activity that includes replacing the ground surface with in-kind material or with materials having equivalent runoff characteristics and is associated solely with soil remediation or tank removal for the purpose of removing contaminants and pollutants and not associated with other development is not required to comply with subsections 22.805.050.A and 22.805.060.A (Soil amendment), Section 22.805.070 (Minimum requirements for on-site stormwater management), or Section 22.805.080 (Minimum requirements for flow control). Projects that include any development in addition to soil remediation or tank removal are not exempt.*

Note that remediation projects are not exempt from other Stormwater Code requirements, including SMC, Section 22.805.020 (Minimum Requirements for All Projects).

2.2.8. Retrofit Project

Applicable retrofit projects are described in SMC, Subsection 22.800.040.A.2.d.

Stormwater Code Language
SMC, 22.800.040.A.2.d **–** *Drainage control facilities that are part of a public retrofit project installed to meet Appendix 12 to the City's municipal stormwater NPDES permit or for combined sewer control, or other voluntary retrofit project, are not required to comply with Section 22.805.070 (Minimum requirements for on-site stormwater management), Section 22.805.080 (Minimum requirements for flow control), or Section 22.805.090 (Minimum requirements for treatment). This exemption does not include land disturbing activities or hard surfaces that are not integral with or are in addition to the drainage control facilities described above, or installation of drainage control facilities that are otherwise required to meet this subtitle.*

Note that retrofit projects are not exempt from other Stormwater Code requirements, including SMC, Section 22.805.020 (Minimum Requirements for All Projects).

Examples of projects that meet the criteria for retrofit projects include projects whose purpose is to reduce runoff, improve water quality, reduce flooding, reduce sanitary sewer overflows (SSOs), or combined sewer overflows (CSOs) and are not otherwise installed to meet the requirements of SMC, Chapter 22.805. Examples of retrofit projects include:

1. Installation of flow control facilities (e.g., detention tanks, pump stations).
2. Installation of water quality treatment facilities (e.g., water quality treatment pond).
3. Installation of green stormwater infrastructure (e.g., natural drainage systems, bioretention cells).
4. Retrofit of existing drainage and wastewater infrastructure.
5. Restoration of riparian buffer.
6. Restoration of forest cover.
7. Floodplain reconnection project.
8. Removal of impervious or hard surfaces not associated with other development.
9. Other actions to address stormwater runoff and water quality treatment.

As specified in SMC, Subsection 22.800.040.A.2.d, this exemption for retrofit projects does not include land disturbing activities or hard surfaces that are not integral to, are in addition to, or are otherwise required to meet the Stormwater Code. For example, community benefit amenities installed in addition to the retrofit drainage control facility (e.g., trails, playground areas) must meet the requirements (e.g., On-site Stormwater Management, Flow Control) of the applicable project type (e.g., Trail and Sidewalk Projects, Parcel-based Projects).

All retrofit projects must use on-site BMPs identified in Subsection 22.805.070.D or other infiltration BMPs per Volume 3 to the maximum extent feasible for those hard surfaces that do not drain to or are not otherwise managed by the retrofit project (e.g., drainage control facility maintenance access roads).

2.2.9. WSDOT Project

For the purposes of this Manual, a WSDOT project (that will manage stormwater as stated in SMC, Subsection 22.800.040.A.6) includes WSDOT roadway projects within state rights-of-way under WSDOT control and within the jurisdiction of the City.

In addition to the other provisions in Subsection 22.800.040.A.6, WSDOT projects must comply with Stormwater Code requirements when discharging to a public drainage system or combined sewer system as prescribed in Subsection 22.800.040.A.6.c.

Applicable WSDOT projects are described in SMC, Subsection 22.800.040.A.6.

Stormwater Code Language
SMC, 22.800.040.A.6 – *With respect to all state highway right-of-way under Washington State Department of Transportation (WSDOT) control within the jurisdiction of The City of Seattle, WSDOT shall use the current, approved Highway Runoff Manual (HRM) for its existing and new facilities and rights-of-way, as addressed in WAC 173-270-030(1) and (2). Exceptions to this exemption, where more stringent stormwater management requirements apply, are addressed in WAC 173-270-030(3)(b) and (c).* a. *When a state highway is located in the jurisdiction of a local government that is required by Ecology to use more stringent standards to protect the quality of receiving waters, WSDOT shall comply with the same standards to promote uniform stormwater management.* *b. WSDOT shall comply with standards identified in watershed action plans for WSDOT rights-of-way, to the extent required by state law.* *c. Other instances where more stringent local stormwater standards apply are projects subject to tribal government standards or to the stormwater management-related permit conditions imposed under Chapter 25.09 to protect environmentally critical areas and their buffers (under the Growth Management Act), an NPDES permit, or shoreline master programs (under the Shoreline Management Act). In addition, WSDOT shall comply with local jurisdiction stormwater standards when WSDOT elects, and is granted permission, to discharge stormwater runoff into a municipality's drainage system or combined sewer system.*
References
• Volume 1, Section 4.3 (SMC, Section 22.805.060) – Minimum Requirements for Roadway Projects • WSDOT Highway Runoff Manual • WAC, Sections 173-270-030(1) and (2) – Best Management Practices – Approved Manual Required and Amendments to Manual • WAC, Sections 173-270-030(3)(b) and (c) – More Stringent Standards • SMC, Chapter 25.09 – Environmentally Critical Areas

2.3. Step 3 – Identify the Receiving Water and Downstream Conveyance

For minimum requirement purposes, runoff leaving the project site is classified based on the type of system and receiving water into which the project site discharges. The project proponent must identify the receiving water or point of discharge for the stormwater runoff

from the project site (e.g., wetland, lake, creek, salt water, or combined sewer) for review and approval or disapproval by the Director. Refer to *Section 3.2* and *Section 3.12*.

The minimum requirements vary considerably by type of receiving water and downstream conveyance; therefore, it is very important to determine and specify the receiving water and type of downstream conveyance. Note: there may be multiple downstream receiving waters (e.g., a creek that flows into a small lake). In this case, the minimum requirements for all downstream receiving waters must apply.

Portions of watersheds near the City limits discharge to adjacent jurisdictions. In these cases, the more stringent requirements between the Seattle Stormwater Code and Manual and the receiving jurisdiction's requirements will be applied for determining stormwater mitigation requirements (e.g., discharges to nutrient-critical receiving waters). Refer to the Phase I and Phase II Municipal Stormwater Permits for enforceable documents that are functionally equivalent to Ecology's requirements.

Seattle has a complicated system due to historical annexations, major sewer and drainage projects, and other complexities. Therefore, prior to proceeding with project design, confirm your project discharge location through the City's Preliminary Application Report (PAR) process to determine your project requirements. For projects that are not required to go through the PAR process, contact the following review team(s) based on the project type, location, and information needed:

1. Projects conducted on private parcels:
    a. Approved point of discharge: SPU Side Sewer Team at SideSewerInfo@seattle.gov
    b. For Stormwater Code and Manual requirements: SDCI Drainage Review Team using the SDCI Contact Us-Send Us a Question website (https://www.seattle.gov/sdci/about-us/contact-us).
2. Developer-related projects conducted in the right-of-way:
    a. SPU_PlanReview@seattle.gov.
3. Capital improvement projects conducted in the right-of-way:
    a. SPU_CIP_Review@seattle.gov for capital improvement projects conducted in the right-of-way.

The receiving waters and systems in Seattle include the following:

- **Wetlands**: Designated under SMC, Section 25.09.020. Discharges are to the wetland or the associated drainage basin.
- **Creek Basins**: Include stream basins throughout Seattle, generally referred to as "creek basins." Discharges are to the creek or the associated drainage basin whether or not a creek is formally typed (see Figures 2.5 and 2.6 for reference). Creeks in piped systems are considered creeks.
- **Public Combined Sewer**: Discharges are to the public combined sewer or its associated basin (see Figure 2.7 for reference).

- **Small Lake Basins**: Discharges are to the small lake or the associated drainage basin (see Figure 2.5 for reference).
- **Designated Receiving Waters**: Discharges are to the designated receiving water or its associated drainage basin (see Figures 2.8 and 2.9 for reference).
- **Capacity-constrained System:** Capacity constraints in any downstream conveyance can modify the flow control requirements for discharges. This includes discharges directly to the capacity-constrained system or its associated upstream basin (see Figure 2.10 for reference). All ditch and culvert systems are capacity constrained. In addition, at the time of publication, the Director has determined the following areas to be capacity-constrained:
  - Densmore Basin
  - Portions of the Pike/Pine Corridor
  - South Park (including both separated storm and combined sewers)
- **Nutrient-critical Receiving Waters:** Discharges are to the nutrient-critical receiving water or its associated drainage basin (see Figure 2.5). At the time of publication, the Director has determined the following areas to be nutrient-critical receiving waters based on Ecology's Water Quality Assessment:
  - Green Lake Basin

Drainage basin and system figures are provided for reference only. Refer to the SMC Chapter 22.801 definitions for determining basin limits and system types.

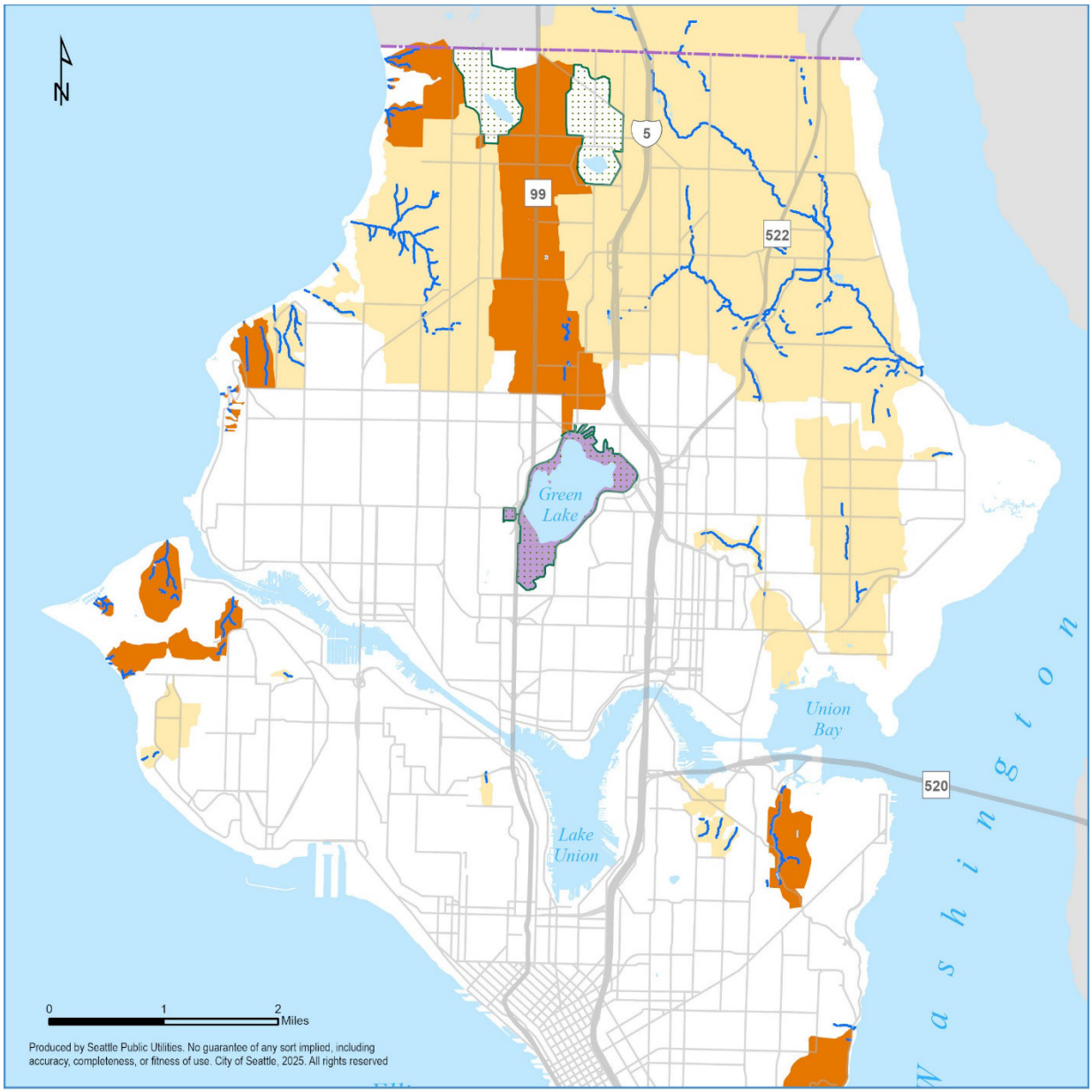

Figure 2.5. North End Creek and Small Lake Basins.

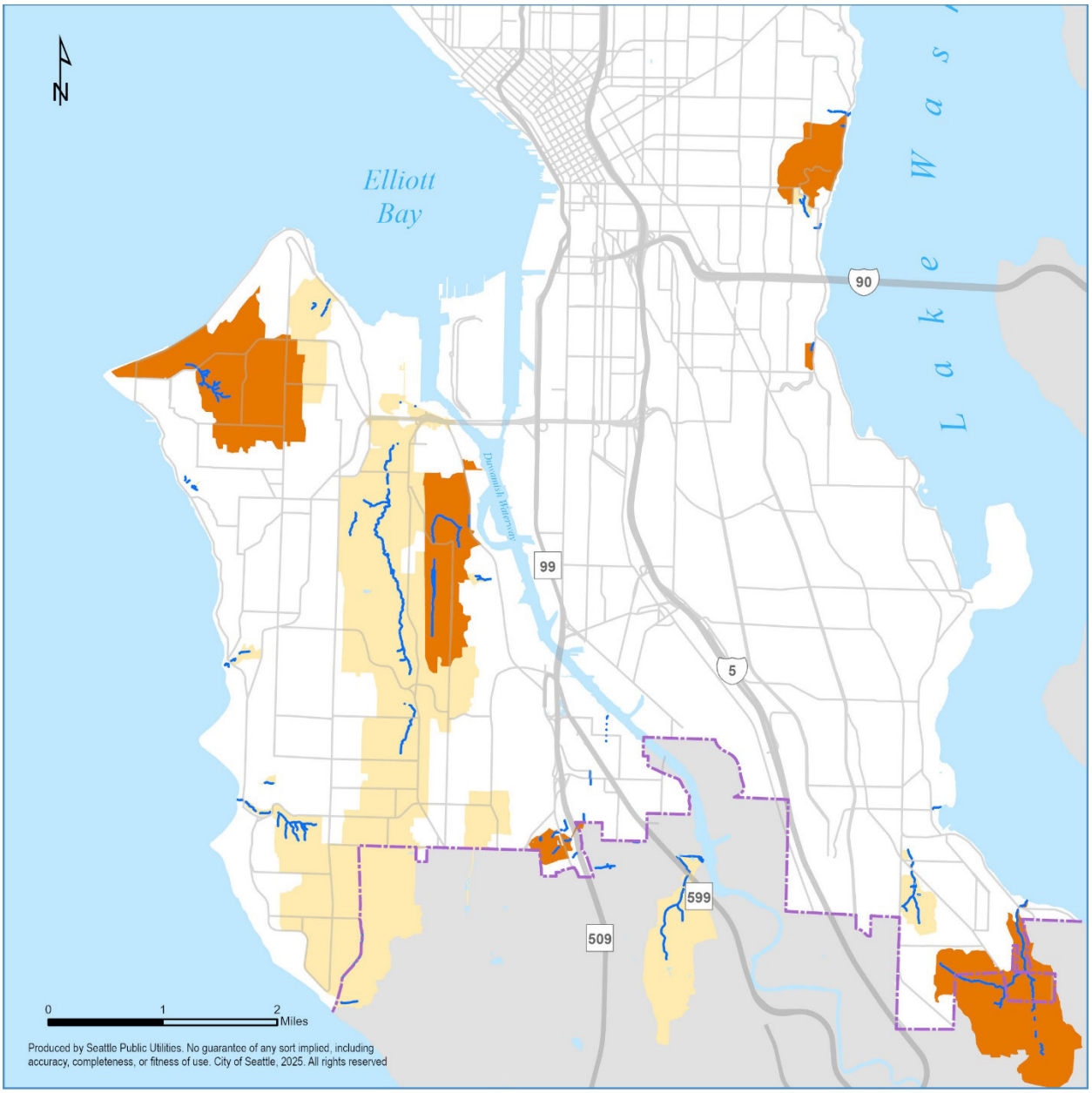

Figure 2.6. South End Creek Basins.

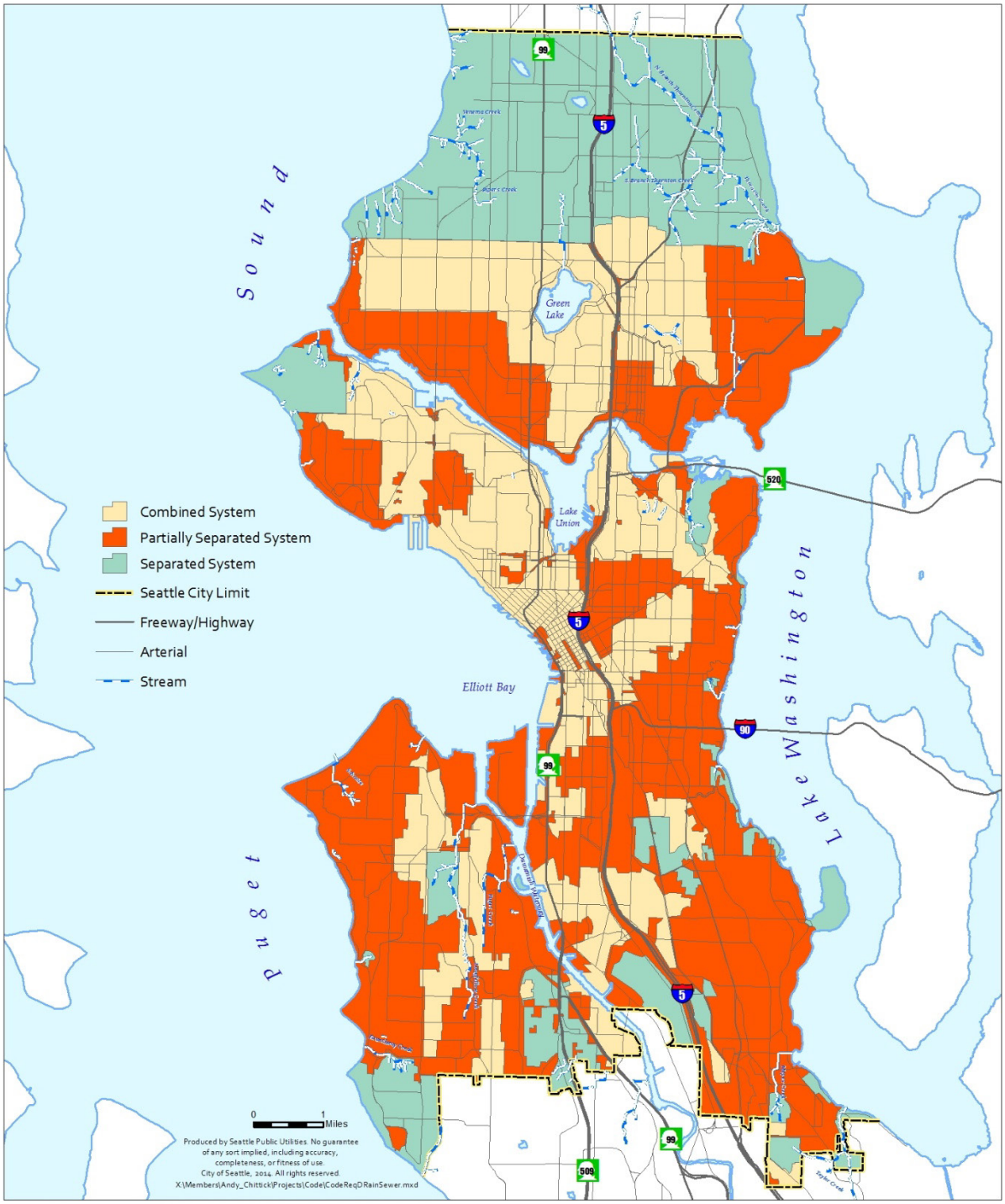

Figure 2.7. Public Combined Sewer Basins.

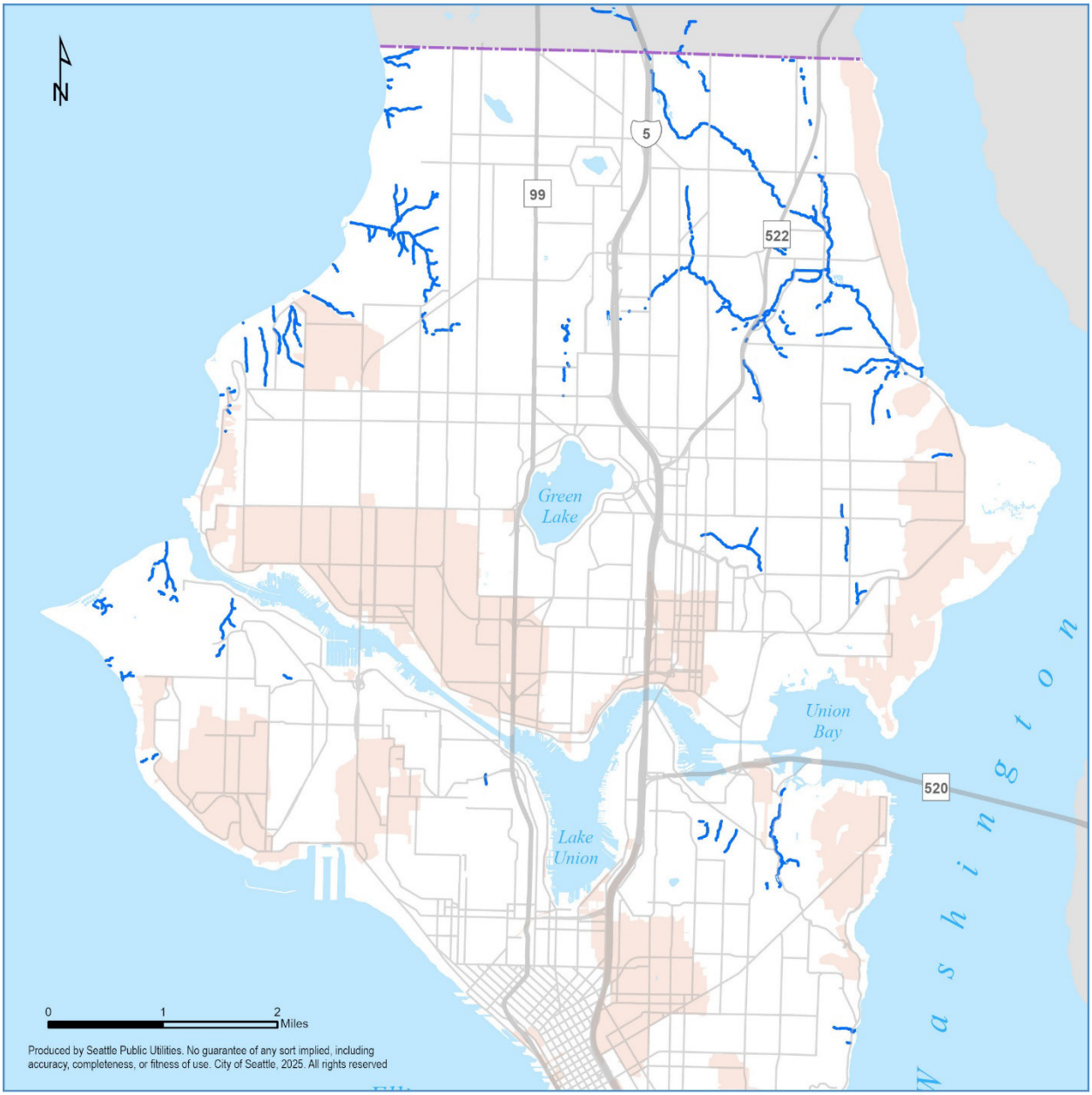

Figure 2.8. North End Designated Receiving Water Drainage Areas.

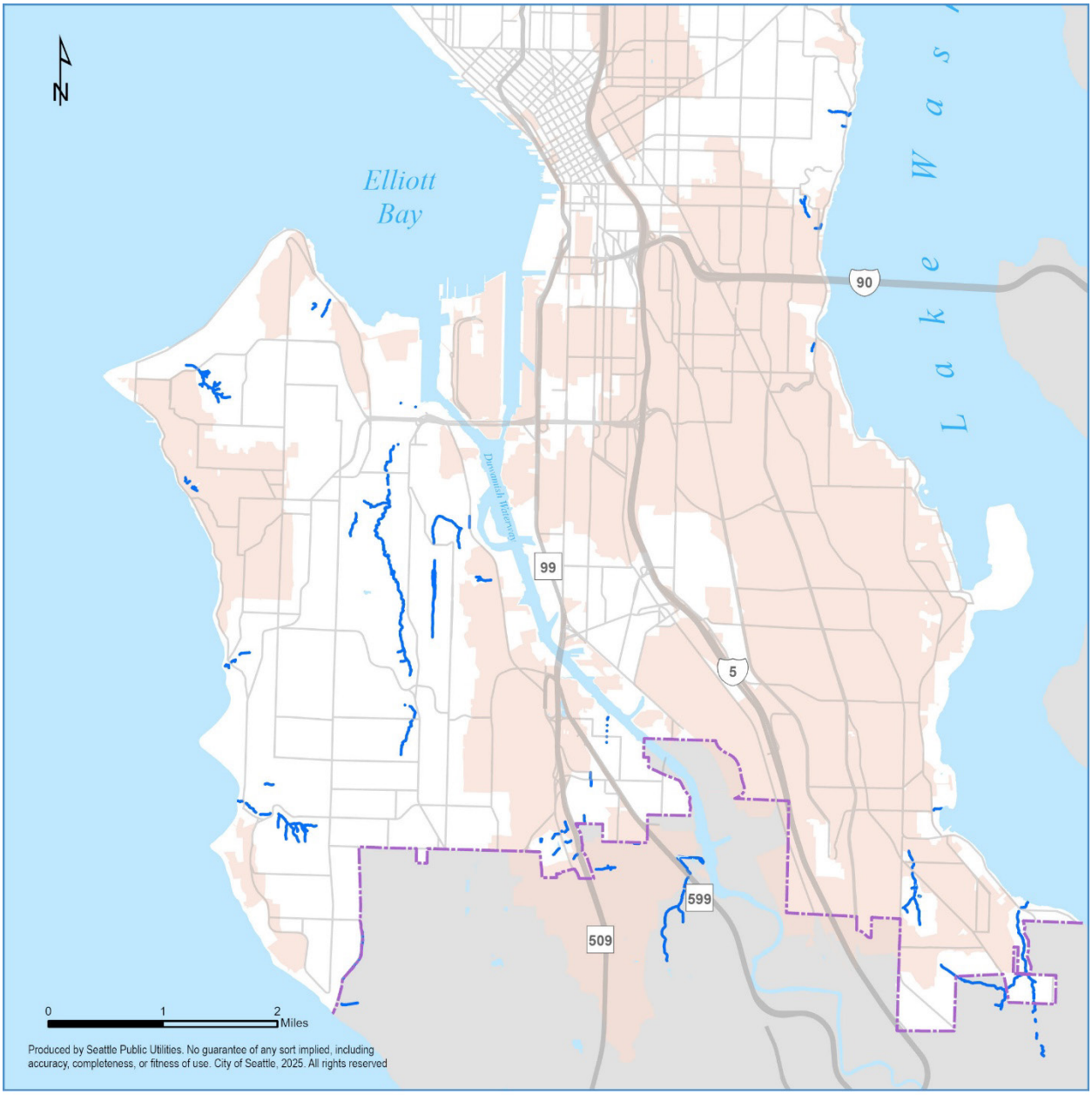

Figure 2.9. South End Designated Receiving Water Drainage Areas.

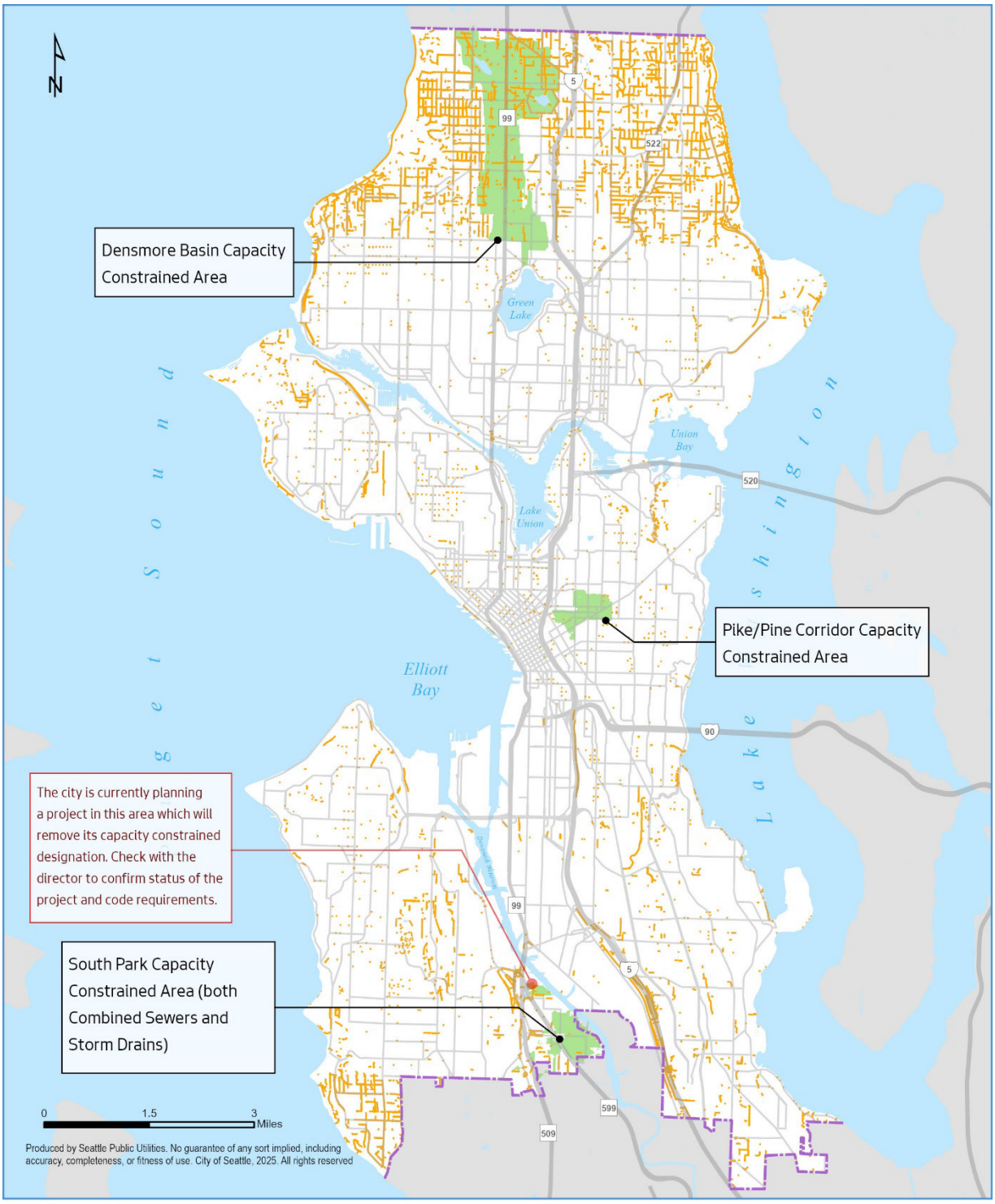

Figure 2.10. Capacity-constrained Systems.

2.4. Step 4 – Perform Site Assessment and Planning

After the applicable minimum requirements are identified, each project must evaluate project design considerations and perform a site assessment as outlined below. The goal of the site assessment and planning step is to identify any additional issues that must be addressed in association with stormwater management requirements. This step must be completed before any on-site stormwater management, flow control, or treatment BMPs are selected.

Site-specific factors to consider may include but are not limited to:

- Site boundaries and structures.
- Location and size of existing trees and their driplines / canopies within the site or offsite if the driplines/canopies of the trees extend onto the site.
- Site topography and dispersion feasibility (refer to *Volume 3, Section 3.1)*.
- Soil conditions and infiltration capacity (refer to *Volume 3, Section 3.2)*.
- Critical area issues (e.g., wetlands, streams / riparian corridors, flood plains, steep slopes, landslide-prone areas, and landfills or contaminated sites).
- Contaminated soils or groundwater on or near the site (refer to *Section 2.4.7*).
- Groundwater elevations for temporary or permanent dewatering (refer to *Section 2.4.5*).
- Special circumstances (e.g., discharge to multiple drainage basins with differing requirements) (refer to *Section 2.7.1*).

Project proponents need to evaluate all applicable code requirements and conduct a full site assessment to characterize site opportunities and constraints before choosing and designing stormwater strategies. Additional information on drainage control reviews and required plan submittals is included in *Section 2.8*.

2.4.1. Identifying Key Project Components

Chapter 3 presents steps for determining the applicable on-site stormwater management, flow control, and water quality treatment requirements. The following sections provide additional guidance on key project components that can significantly influence the project design and approach and should be considered part of the site assessment and planning step.

2.4.2. Project Boundaries and Structures

Project boundaries, nearby structures, and other related issues can directly affect designs for stormwater management. The following must be addressed before selecting a stormwater BMP:

- Project Boundaries: The project boundaries typically define the limits of disturbance and can affect the thresholds and applicable minimum requirements. Project boundaries generally coincide with the right-of-way, property line, or both but may include multiple properties. Refer to *Section 2.1*.

- Setbacks: Property lines, existing and proposed structures, and adjacent right-of-way boundaries must be identified and considered to evaluate project impacts on adjacent properties.
- Location of Buildings: All existing and proposed buildings must be identified, including all existing and proposed temporary and permanent structures (e.g., retaining walls) and hard surfaces (e.g., driveways and patios). Structures on neighboring properties can also affect stormwater BMP selection.
- Foundations and Footing Drains: The type of proposed foundations and footing drains, including location and extent, must be determined and include the following:
    - Conventional spread footings
    - Pile shaft
    - Basement
    - Footing drains and their associated point of discharge, where applicable (refer to *Section 3.2.1*)
    - Water-tight foundation without footing drains
    - Elevation of groundwater table in relation to the footings and basement

2.4.3. Soil Condition Assessment

The soil type and land cover types on the project site must be evaluated to assess the infiltration capacity of the site and the applicability of various stormwater BMPs. General requirements for determining infiltration feasibility, site characterization, and infiltration rate are presented in *Volume 3*, *Sections 3.2 and 4.5.2* and *Appendix D*.

2.4.4. Environmentally Critical Areas (ECAs)

Additional regulatory requirements are placed on projects that are within or near ECAs, pursuant to SMC, Chapter 25.09. Depending on the type of ECA, additional requirements or limitations regarding stormwater management may apply.

The following information is needed to assess the impacts on and risks posed to wetlands and to determine the necessary protection level:

- Size, boundary, and characteristics of the proposed project site, wetland contributing drainage area, and the wetland and its buffer.
- Wetland type, category, and habitat score (based on the Wetland Protection Guidelines in Ecology's SWMMWW Volume I, Appendix I-C.
- Presence of rare, endangered, threatened, or sensitive species.
- Presence of breeding populations of native amphibian species.
- Legal access to the wetland.

2.4.5. Temporary and Permanent Groundwater Dewatering

It is important to have early estimates of the groundwater discharge from the project site during construction and once the project is complete. The site's distance to receiving waters or its location in areas where there may be perched, static, tidally influenced, or

hydraulically connected groundwater can have significant impacts on how the project is designed and which other minimum requirements apply. Refer to the Minimum Requirements for Flow Control (*Section 5.3*) and the Minimum Requirements to Ensure Sufficient Capacity (*Section 3.8*).

If temporary dewatering will occur, a Side Sewer Permit for Temporary Dewatering (SSPTD) may be required prior to starting dewatering at the site. The SSPTD may require compliance with a separate Temporary Dewatering Plan, water quality treatment, flow control requirements, and compliance monitoring. If the discharge is to a combined sewer system, a Discharge Authorization Letter from King County Industrial Waste will also be required and the discharge of any groundwater must be metered and billed through the SPU Sewer Submeter Program. See *Section 2.4.7* for additional requirements if the site has known or suspected soil or groundwater contamination or landfills near or within the site.

2.4.6. Topography

Because topography will influence how and where stormwater BMPs are incorporated onto the site, the existing and proposed topography must be considered. Important features to assess include the following:

- Key terrain features, such as closed depressions and grade breaks.
- Natural drainage courses, such as swales, ditches, rills, and gullies.
- Flow entering and exiting the property.
- Roadway grades and elevations.

2.4.7. Site Assessment

The following information must be evaluated as part of the site assessment:

- **Topography:** Topography within 500 feet of the site (geographic information system [GIS] topographic data may be used).
- **Steep Slope or Landslide-prone Areas:** Location of steep slope areas or landslide-prone areas within 500 feet of the site.
- **Septic Systems and Drain Fields**: Location of septic systems and drain fields in the vicinity of the site.
- **Underground Storage Tanks, Aboveground Storage Tanks, Residential Heating Oil Tanks**: Location of underground storage tanks, aboveground storage tanks, or residential heating oil tanks in the vicinity of the site.
- **Contaminated Sites and Landfills**: Location of contaminated sites and abandoned landfills within 100 feet of the site (refer to *Volume 3, Section 3.2* contaminated site requirements and resources).

For roadway projects or parcel-based projects with runoff from 5,000 square feet or more of impervious area to infiltrate, the following information must also be evaluated:

- **Site Geology**: Local site geology, including soil or rock units likely to be encountered, the groundwater regime, and geologic history of the site.
- **Water Supply Wells**: Location of water supply wells within 500 feet of the site.

- **Contaminated Sites and Landfills**: Location of contaminated sites and abandoned landfills within 500 feet of the site (refer to *Volume 3, Section 3.1 and 3.2* for restrictions for infiltration or dispersion BMPs in or near contaminated sites and landfills).
- **Groundwater Protection Areas**: Location of groundwater protection areas, or 1-, 5-, and 10-year time of travel zones for municipal well protection areas, or both.
- **Anticipated Site Use**: Street or highway, residential, commercial, or high-use site that may affect the water quality of stormwater runoff.

For projects proposing to use deep infiltration BMPs, the following information must also be reviewed and mapped:

- Regional geologic mapping.
- Publicly available geotechnical exploration data.
- Steep slope and landslide-prone areas within a quarter mile of the proposed location of the deep infiltration BMP.

Sources of data to evaluate site suitability include, but are not limited to, City of Seattle Department of Construction and Inspections (SDCI) Critical Area maps, Environmental Protection Agency (EPA), Department of Ecology (Ecology), Washington Department of Natural Resources (DNR) Subsurface GIS, Flood Hazard maps, and other mapping information available from the City of Seattle (including Seattle Public Utilities [SPU] and the Seattle Department of Transportation [SDOT]), King County, and consultant reports for other public agencies.) Any of the above information identified as part of the review must be shown on a map relative to the proposed infiltration location(s).

The following resources, in addition to field investigation, must be used to determine if soil or groundwater contamination may be present at the site or within the distance from the site that is required to be evaluated:

- EPA Superfund Program National Priorities List and Map (https://www.epa.gov/superfund/search-superfund-sites-where-you-live)
- EPA Resource Conservation and Recovery Act (RCRA) Program site list (https://www.epa.gov/hwcorrectiveactioncleanups)
- EPA mapping tool that plots the locations of Superfund and RCRA-regulated sites (www.epa.gov/cleanups/cleanups-my-community)
- Ecology regulated contaminated sites (https://ecology.wa.gov/Regulations-Permits/Guidance-technical-assistance/Site-Register-lists-and-data)
- Ecology Toxics Cleanup Program website (https://ecology.wa.gov/Spills-Cleanup/Contamination-cleanup/Cleanup-sites/Toxic-cleanup-sites)

If contaminated soils or groundwater are expected at or near the site, plan for measures to treat contaminated construction stormwater or temporary and permanent groundwater to remove the contaminants before discharging from the site. In addition to City approvals, approvals from either Ecology, in the form of coverage under the construction stormwater

general permit or an individual permit, or King County, through a construction dewatering authorization, will be required.

If evidence of contamination is present or has been previously identified, the must reference applicable geotechnical and environmental engineering reports and, at a minimum, identify the following in the drainage control plans and, when required per *Section 2.8.3*, in the drainage report:

- Confirm the specific contaminants.
- Delineate the nature and extent of environmental contamination.
- Identify the contaminant sources.
- Demonstrate how contamination will be prevented from discharging from the site in construction stormwater runoff or dewatering discharges or from subsurface drainage such as footing drains. This may require temporary and/or permanent treatment.

Using the site assessment information, evaluate the site for infiltration and dispersion suitability based on the limitations and setbacks provided in *Volume 3*, *Sections 3.1 and 3.2* and *Appendix D*, *Section D-2.2.4*. Based on this evaluation, identify all portions of the site where infiltration may be feasible. Additionally, for underground injection control (UIC) wells, setback and site restrictions must be in accordance with the UIC requirements in Volume I of Ecology's SWMMWW. UIC wells are regulated by Ecology under federal and state laws and must comply with all federal and state requirements.

2.4.8. Landscaping Principles

Before designing the site and stormwater infrastructure, consider the following:

- Maintain and use natural drainage patterns.
- Preserve and use natural features and resources, including trees.
- Preserve native vegetation (refer to BMP T5.40, Preserving Native Vegetation, in Volume V of Ecology's SWMMWW.
- Create a multifunctional landscape using the natural site hydrology as a framework for site design.
- Confine and phase construction activities to minimize disturbed areas and impacts on ECAs and their associated buffers.
- Plant new trees in proximity to ground-level impervious surfaces for on-site stormwater management and/or flow control credit.
- Minimize or prevent compaction and protect soils.

Soil type, slope, exposure, depth to groundwater, and the selection of plants chosen for the site will all influence the proposed landscape management approach. However, five basic principles must be considered for all sites to be successful in controlling the export of soil or organic matter, fertilizers, and pesticides in stormwater runoff:

- Minimize bare soil areas.
- Reduce water demand.

- Reduce extent of turf area and manage remaining turf to reduce pollutant impact.
- Select plants with sustainability in mind.
- Reduce or eliminate fertilizers, pesticides, herbicides, and fungicides and, where required, manage application wisely.

Details of each of the five basic principles are provided in the following subsections. The recommendations discussed for each principle are intended as a framework for a variety of site situations, from individual homes to large parks and golf courses. The specific application of each of these principles will vary from site to site depending on the type of landscaping (e.g., grass lawn, planter bed) that is being managed.

2.4.8.1. Principle 1: Minimize Bare Soil Areas

Bare soil areas are one source of solids that can be mobilized and carried downstream by rainfall. Minimizing bare soil areas makes it less likely that solid particles will be dislodged by rainfall. Landscapes can be managed to minimize bare soil using one or more of the following:

- Establish dense plantings of pest-resistant groundcover to shade out weeds. Some easy-care recommendations are rock rose (*Cistus sp.*), snowberry (*Symphoricarpo albus*), salal (*Gaultheria shallon*), and kinnikinick (*Arctostaphylos uva-ursi*).
- If bare soil areas are required, as in planting beds or ball diamonds, surround the bare area with an area of grass or groundcover to filter out solids that may be picked up by stormwater runoff.
    - The denser the grass or groundcover, the more effective it will be in capturing solids in runoff.
    - The filtering area should be as level as feasible, minimizing low spots, where runoff can concentrate and create channels.
    - In general, filtering areas should be about one-fourth as long (along the flowpath) as the area contributing flow, assuming that the slopes are gentle (less than 10 percent). For flat, level areas without dips, this length can be reduced.
- Promptly repair bare patches in lawns or groundcovers that could contribute solids to stormwater runoff.
- Do not place bark or loose mulch on slopes where it can be carried to storm drains or receiving waters.

2.4.8.2. Principle 2: Reduce Water Demand

Reducing the need for irrigation reduces the potential movement of pollutants, conserves water, and saves money.

- Use drought-tolerant or native vegetation.
- Install underground irrigation systems timed to water at night or drip irrigation systems. Systems with automatic leak detection capability will reduce inadvertent runoff due to a break in the system.
- Increase the organic content of soils to improve its water-retention capability.
- Terrace sloped areas to improve water retention.

2.4.8.3. Principle 3: Reduce Turf Area and Manage Remaining Turf to Reduce Pollutant Impact

Turf requires care to look attractive. In addition to mowing, turf areas typically require water, fertilizer, and weed and disease control. However, some practices can reduce or minimize the chemical controls needed.

- Amend soil with organic matter per *Volume 3, Section 5.1*.
- Decide whether all lawn areas need the same level of upkeep: let some areas have a less formal look, if possible, and reduce or eliminate fertilizer and pesticide use in those areas. Apply fertilizer only if the need is indicated by soil testing and apply it at rates recommended by a soil testing laboratory for current conditions.
- Rely on irrigation and lawn aeration as the primary tools for maintaining healthy turf.
- Remove thatch each year to increase water penetration to grass roots and reduce runoff.
- In shady areas, plant groundcovers rather than grass. Turf grasses usually need at least partial sun to remain vigorous.

2.4.8.4. Principle 4: Select Plants with Sustainability in Mind

Plants differ in their ability to cope with different soils, rainfall conditions, pests, diseases, and microclimates. Techniques for creating landscapes requiring less intervention include the use of resilient plant species, the selection of plants with adaptations for particular environments, and the creation of optimal microenvironments. Less watering and a reduced need for pesticide and fertilizer application means less potential for pollutants to leave the site.

- Select disease-resistant plants.
- Select drought-resistant groundcovers, shrubs, and trees in areas with poor soil or little shading.
- Group plants in clusters with tree, shrub, and groundcover layers to create a better microenvironment and to return organic matter back to the soil.
- Plant large, evergreen trees to help reduce the size of stormwater flows.
- Include plants in the landscape that are important for and sustain beneficial insects that control pests such as parasitic wasps.
- Use dense plantings or close spacing to shade out weeds rather than herbicides.
- On steep slopes or erosion-prone areas, use plants with fibrous roots, including but not limited to the following:
    - Ornamental grasses and lawn grasses
    - Dwarf rose (*Rosa gymnocarpa*) — native
    - Nootka rose (*Rosa nutkana*) — native
    - Rock rose (*Cistus* sp.)
    - Rugosa rose (*Rosa rugosa*)
    - Evergreen huckleberry — native

  - Salal (*Gaultheria shallon*) — native
  - Salmonberry (*Rubus spectabilis*) — native
  - Snowberry (*Symphoricarpos albus* or *Symphoricarpos mollis*) — native
  - Sword fern (*Polystichum munitum*) — native
- Use wetland plants in areas with seeps or a high groundwater table.
- Attend to installation details. Write enforceable planting specifications that include details such as soil preparation, plant spacing, plant condition and size, planting depth, transplant handling, and irrigation. During installation, inspect the planting to prevent the use of shortcuts such as blowing the soil mixture around root balls rather than digging the roots into amended native soils. Where possible, specify and install bare-root plants for improved adaptation to native soils.

2.4.8.5. Principle 5: Reduce or Eliminate Fertilizer, Pesticide, Herbicide, and Fungicide Use and Where, Required, Manage Application Wisely

Use of fertilizers, pesticides, and herbicides should be reduced or eliminated to the maximum extent feasible. However, if the landscape plants and turf simply will not survive without fertilizer and some amount of pest management, an Integrated Pest Management plan or landscape management plan (refer to *Appendix I*) must address when and how these actions will be taken so that the impact on water quality will be reduced.

- Keep plants healthy by building healthy soil using composted organic material. Healthy plants can better resist diseases and insect pests.
- Tailor fertilizer formulation to lawn needs. Apply fertilizer only if the need is indicated by soil testing and apply it at rates recommended by a soil testing laboratory for current conditions. Adjust the fertilizer application rate and timing of applications to avoid carry-off in stormwater runoff.
- Reduce the phosphorus (P) concentration in fertilizers when possible by using a low phosphorus formulation or formulations containing only nitrogen or potassium.
- Use an Integrated Pest Management approach to control pests (see *Appendix I*). Include non-chemical control options as a first defense against pests.
- Encourage a diverse insect community in your landscape: Beneficial insects can help control pests, especially pests of trees and shrubs.
- Target pesticide application to the specific pest of concern. Avoid pesticide “mixes” targeting generic problems (such as weed and feed) unless you need each of the formulations for a current problem.
- Apply pesticides only during the life stage when the pest is vulnerable.
- Use fungicides sparingly; they disrupt the base of aquatic food webs. If you need to use fungicides, spray formulations with faster break-down times.
- Tolerate some weeds.

2.4.9. Site Design Considerations

To manage stormwater effectively and efficiently, site design for both the construction phase and the post-development condition should coincide with the design and layout of the stormwater infrastructure. Efforts should be made, as required and encouraged by development codes, to conserve natural areas, retain native vegetation, including tree canopy, reduce impervious surfaces, and integrate stormwater controls into the existing site layout to the maximum extent feasible. With careful planning, these efforts will not only help achieve the minimum requirements contained in the Stormwater Code but can also reduce impacts from development projects and the costs of water quality treatment and flow control.

Before designing the site and stormwater infrastructure, consider the following:

- Stormwater:
  - Identify the approved point of discharge and conveyance system flowpath, both pipe and topographically.
  - Manage stormwater runoff (quantity and quality) as close to the point of origin as feasible.
  - Minimize the required quantity of stormwater collection and conveyance systems.
  - Use simple, non-structural methods for stormwater management.
  - Use dispersion, infiltration, rainwater harvesting, and alternative surface BMPs where feasible
- Impervious and Pervious Surfaces:
  - Fit development to the terrain to minimize land disturbance.
  - For sites with varied soil types, locate impervious areas over less permeable soil (e.g., till). Minimize development over more porous soils. Use areas of porous soils for bioretention and permeable pavement.
  - Cluster buildings together.
  - Minimize impervious surfaces (e.g., buildings and sidewalks).
  - Minimize pollution-generating hard surfaces (PGHS) (e.g., areas subject to vehicular use such as driveways and parking strips).
  - Minimize pollution-generating pervious surfaces (PGPS).

2.5. Step 5 – Calculate Land-disturbing Activity and New Plus Replaced Hard Surface

The thresholds triggering specific Minimum Requirements for Flow Control are based on the amount of the project's new hard surface, replaced hard surface, converted native and nonnative vegetation, and land-disturbing activity. Hard surface means an impervious surface, a permeable pavement, or a vegetated roof. Refer to SMC, Chapter 22.801 and *Appendix A* for detailed definitions of these key terms.

Note that open, uncovered retention or detention facilities shall not be considered as hard surfaces for the purpose of determining whether the minimum requirement thresholds are

exceeded. However, these facilities shall be considered impervious surfaces for the purposes of stormwater facility sizing.

Areas with underdrains designed to remove stormwater from the subgrade (e.g., playfields, playground areas, sports fields, athletic fields, rail yards) must be considered as hard surfaces for the purposes of determining whether the minimum requirement thresholds are exceeded. Note: refer to *Section 2.5.1* for a clarification of threshold determination for sports fields.

All areas connected to the underdrains and surrounding underdrain aggregate with free-draining subbase material or drainage layer, such as a sand or gravel layer or a manufactured drainage mat, must be counted as hard surface area regardless of the distance between the surface and the underdrain or spacing of underdrains. Natural lawn or natural turf areas that do not have a free-draining sand or gravel layer or other type of drainage layer connected to the underdrain or underdrain aggregate are hard surface areas if there are multiple rows of underdrains that are spaced closer than 25 feet apart. Artificial turf is a hard surface unless there are no underdrains, all layers used are permeable, the soil below the turf is not compacted, and the soil is compost amended per the requirements for *Volume 3, Section 5.1*. In addition, refer *Volume 3, Section 5.6.2.5* – Design of Underdrained Surfaces to be Equivalent to Permeable Pavement Surfaces.

For the purposes of determining minimum requirements, a deck with open grating or spacing between boards that allows rainwater to pass through the deck surface is not considered a hard surface only if the entire area below the deck is a pervious surface with amended soils that meet the requirements of *Volume 3, Section 5.1* Soil Amendment BMP. Note: this interpretation is only applicable to the Stormwater Code and Manual and not necessarily to any other City codes, Director's rules, or policies (e.g., Shoreline Master Program in the Land Use Code).

Overlaying existing asphalt, concrete, or brick pavement with asphalt or concrete without expanding the area of coverage is not a new or replaced hard surface if the existing pavement remains and any grinding does not expose the top of the base course or subgrade.

The amount of native vegetation that is removed and replaced with lawn, landscaping, and pasture groundcover must also be calculated.

New plus replaced hard surface areas and converted native vegetation must be quantified separately for work within and outside the right-of-way.

2.5.1. Underdrained Sports Fields

Underdrained sports fields are considered a hard surface for most thresholds (e.g., On-site Stormwater Management, Flow Control, Drainage Review, etc.) but also a pollution-generating pervious surface for Water Quality Treatment thresholds. Refer to the definitions in *Appendix A*.

When determining if Water Quality Treatment is required, underdrained sports fields (natural or artificial turf) are evaluated as pollution-generating pervious surfaces. Refer to *Section 2.6*.

When evaluating all other stormwater code thresholds, underdrained sports fields are evaluated as hard surfaces.

2.5.2. The Difference Between "New" and "Replaced" Hard Surfaces

While most thresholds for requirements in the Seattle Stormwater Code and associated Director's Rules are based on "new plus replaced hard surfaces," there are a few thresholds based on "new hard surface." One example is the Flow Control thresholds for Roadway or Parcel-based Projects in Creek Basins. Refer to *Sections 4.1 and 4.3*.

The following are examples of, but are not limited to, when a hard surface is "new" or "replaced" based on the Stormwater Code definitions.

Structures

The following are examples of structures that are a "new hard surface":

- An existing structure is removed, including the foundation, and a new structure is built, even if the new structure is in the same footprint as the structure that was removed.
- An existing structure is removed and a structure is built in a new location.
- A structure is expanded beyond the existing footing.
- An existing hard surface is upgraded or changed to a structure.
- An existing gravel surface is upgraded or changed to a structure.
- A structure is built where there was previously a pervious surface.

The following is an example of a structure that is a "replaced hard surface":

- The existing structure is removed down to the top of the foundation, but the foundation is not removed, **and** the "replaced" structure is built on the existing foundation.

The existing foundation must remain to be considered a "replaced" hard surface. Otherwise, it is a "new" hard surface.

Non-structure Hard Surfaces

The following are examples of "other" (non-structure) surfaces that are "new hard surface":

- An existing hard surface is removed down to the subgrade and the subgrade is altered by grading activities, such as excavating the subgrade or filling to change the grade, and a hard surface is installed.
- An existing hard surface is removed and a new hard surface is installed in a different location.
- A surface is changed from a pervious surface to a hard surface, for example:
    - Converting lawn to permeable pavement, or

  - upgrading from dirt to gravel, a bituminous surface treatment ("chip seal"), asphalt, concrete, or a hard surface structure).
- A surface is upgraded from gravel to chip seal, asphalt, concrete, or a hard surface structure.

The following is an example of an "other" (non-structure) hard surface that is a "replaced hard surface":

- The existing hard surface is removed down to the subbase or subgrade (where there is no subbase) and replaced, but the subgrade (i.e., soils below the subbase) is not graded (excavated or backfilled).

If grading activities for the subgrade occur, such as excavating the subgrade or filling to change the grade beyond what is required to repair the existing hard surface or base course, then the hard surface is "new."

2.5.3. Remodels and Reconstruction That Maintain Existing Foundations

The following clarifies when a remodel of an existing building or construction on an existing foundation is defined as a "replaced hard surface." For the purposes of this definition, the "foundation" is the building footing, stem wall, and sill plate.

If the roof, walls, and any floor joists are removed, exposing the top of either the sill plate, stem wall, or footing, and the structure is re-built, then the area where the roof was removed is considered "replaced hard surface." This is the case even if an existing slab on grade or a basement remains.

In some cases, the foundation may be replaced but the structure above remains. In these cases, these areas are not considered new or replaced hard surfaces, such as:

- Basement conversions where the basement is deepened by excavating and adding new foundation, but the structure above the basement level is retained.
- Remodels that crib the existing structure to raise it and add new structure below, and the roof, walls, or floor joists of the existing structure are retained.

Figures 2.11, 2.12, 2.13, 2.14 and 2.15 include examples of remodels and reconstruction with the new and replaced hard surfaces identified.

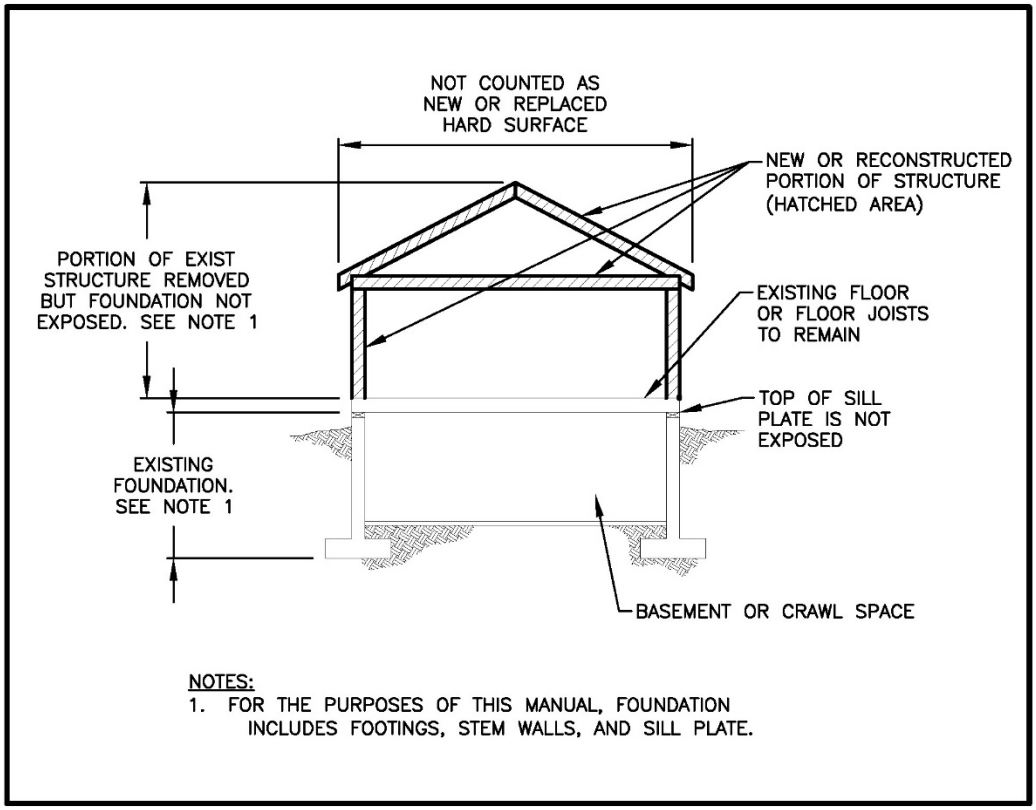

Figure 2.11. Example of Existing Hard Surface to Remain with Existing Floor Joists to Remain.

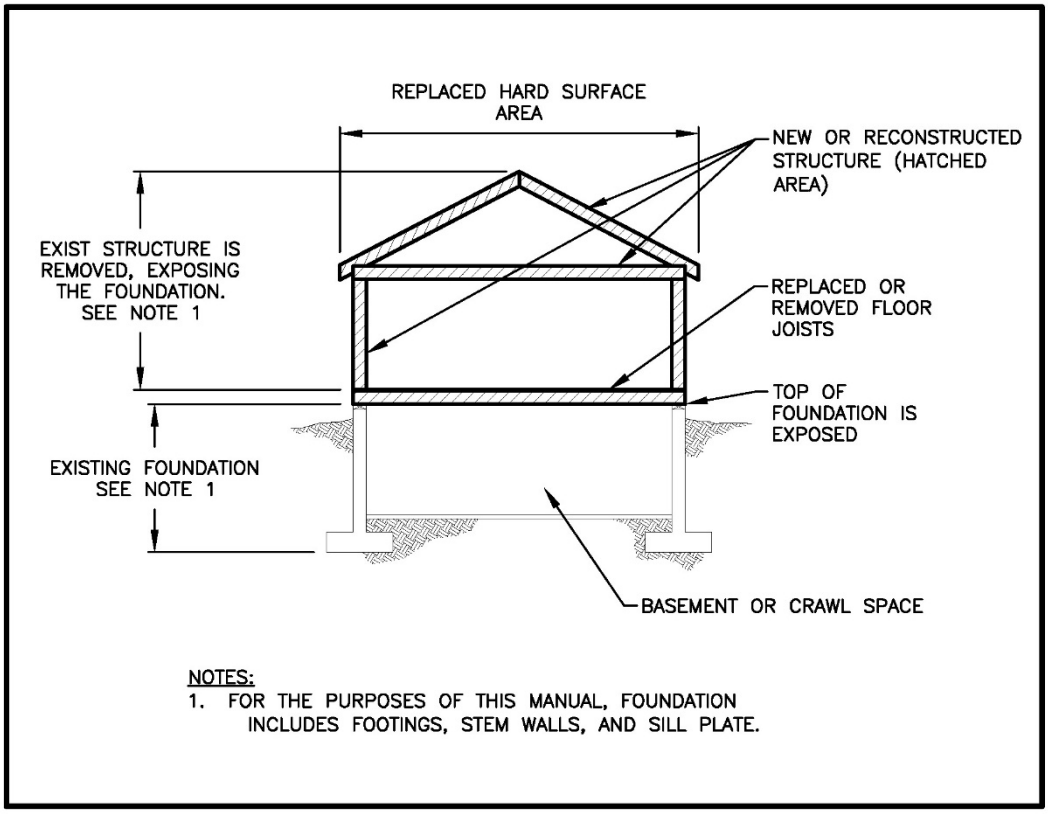

Figure 2.12. Example of Replaced Hard Surface with Floor Joists Removed or Replaced.

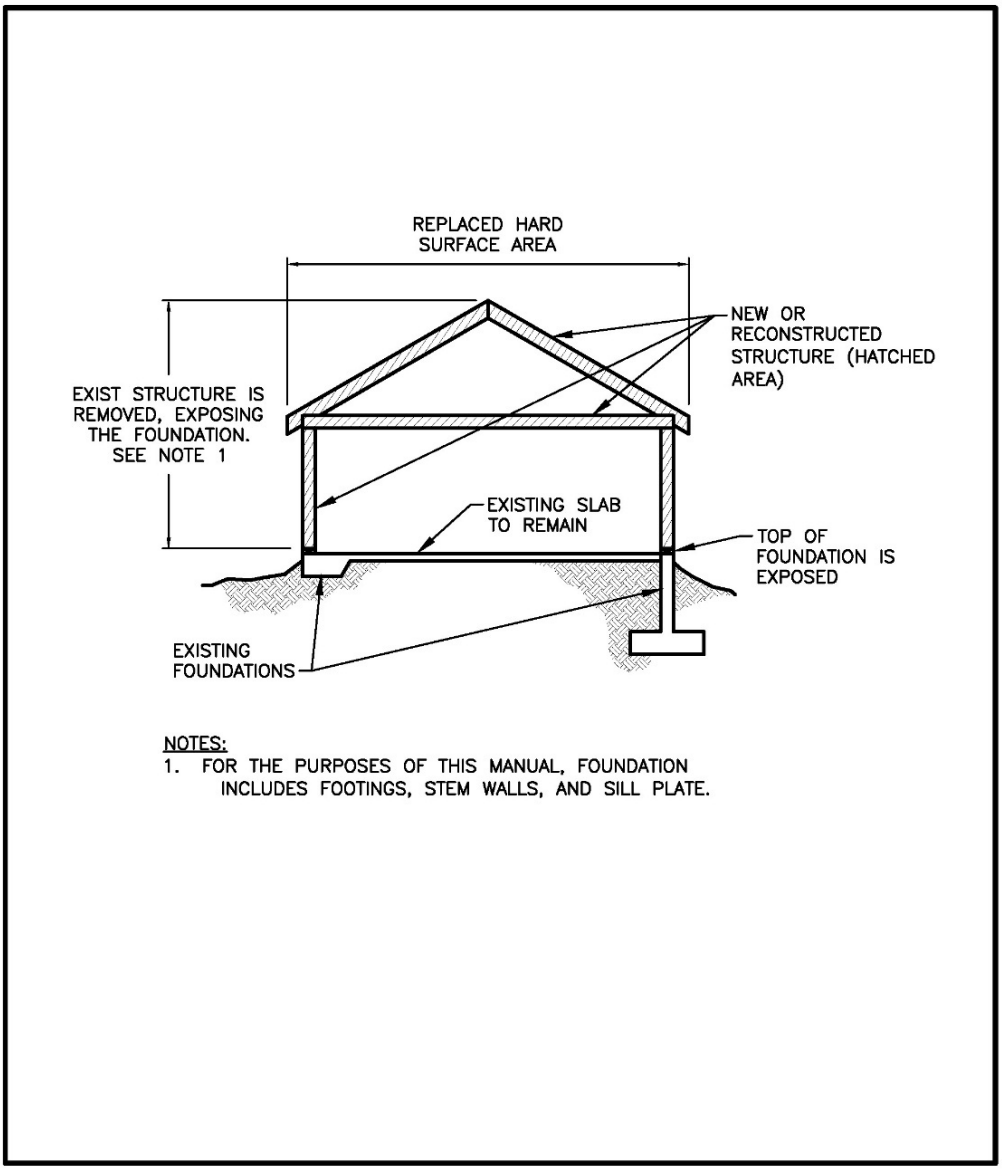

Figure 2.13. Example of Replaced Hard Surface with Structure Removed Down to Slab on Grade/ Footings.

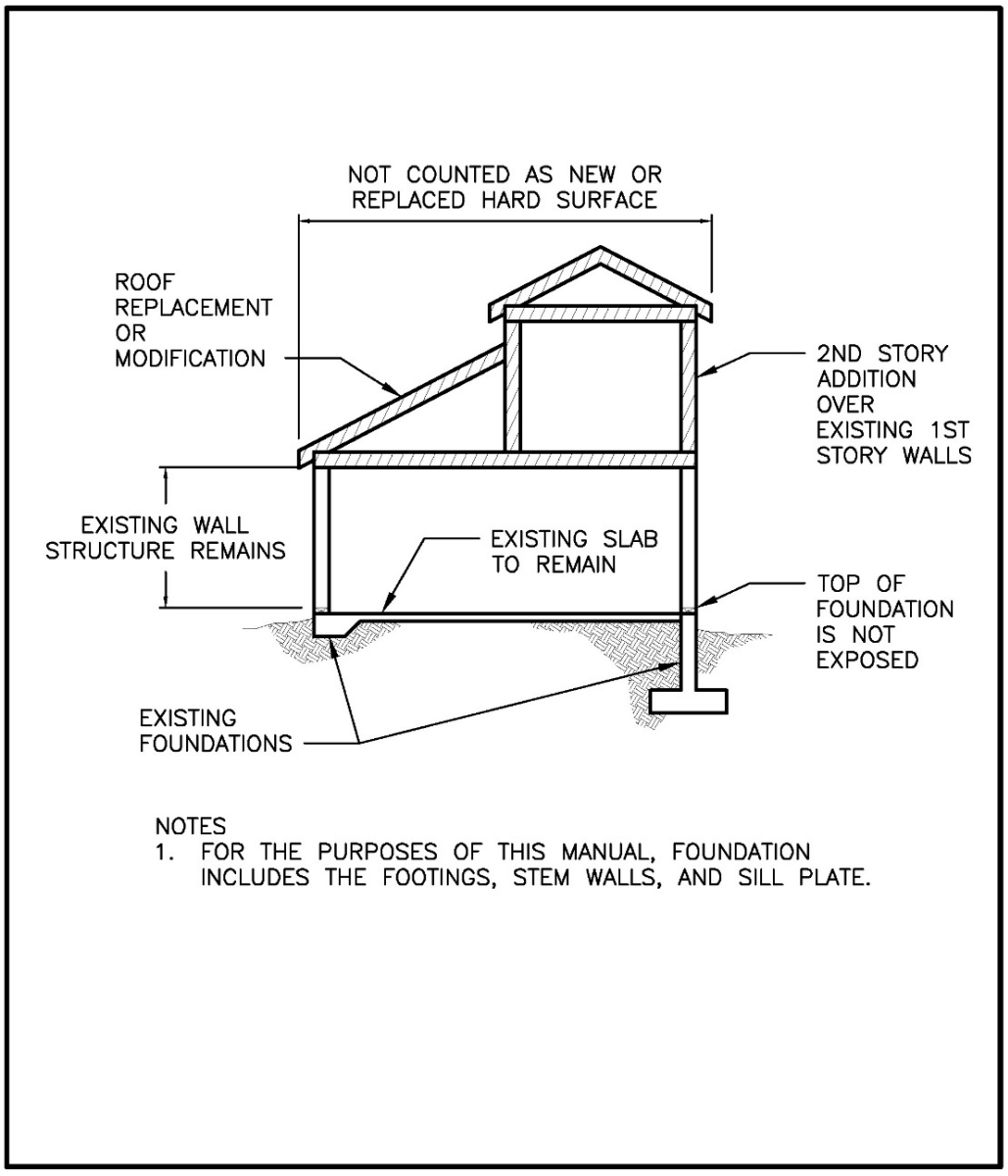

Figure 2.14. Example of Existing Hard Surface to Remain with Existing 1st Floor Walls Remaining.

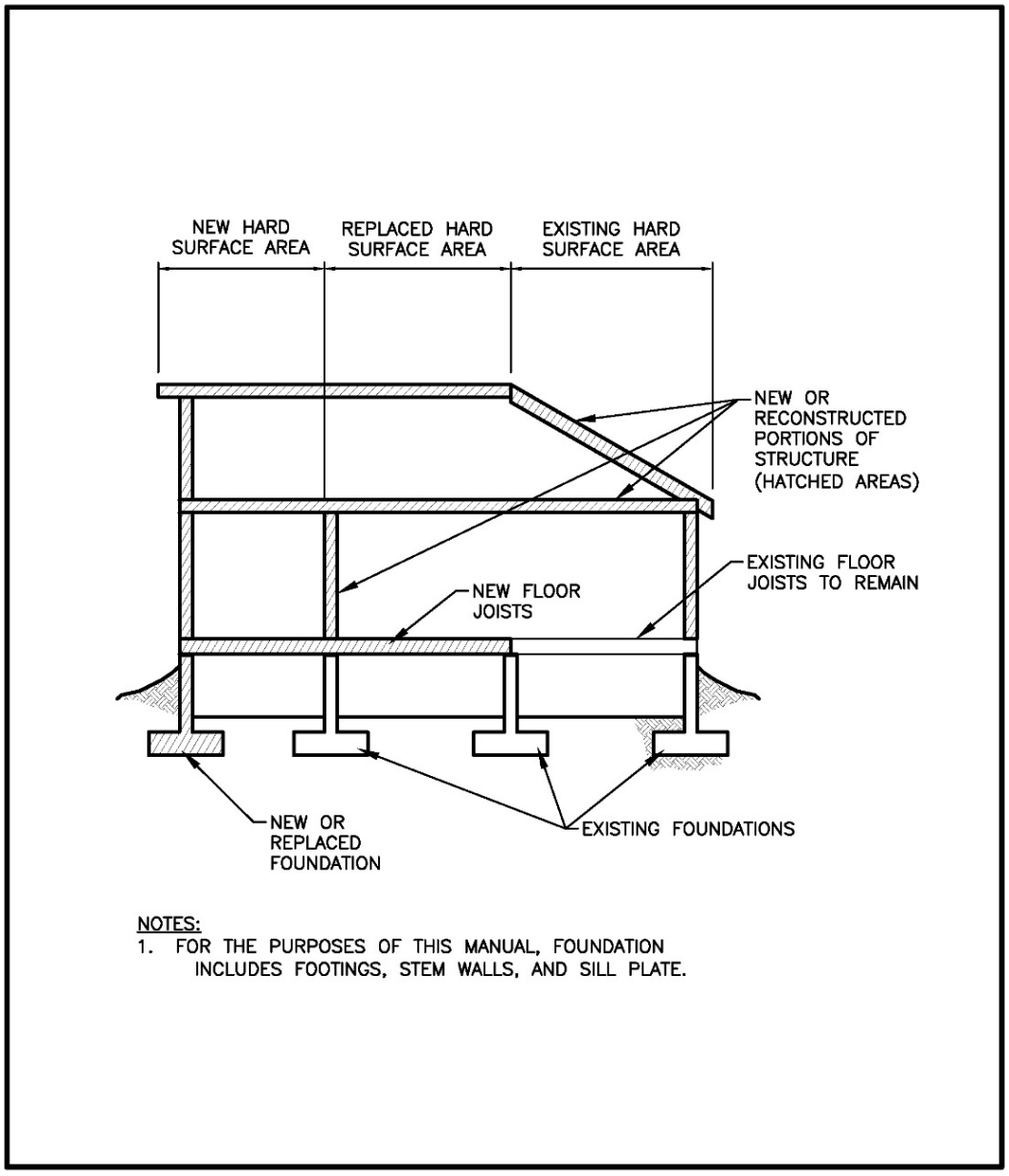

Figure 2.15. Example with New, Replaced, and Existing Hard Surfaces.

2.6. Step 6 – Calculate New Plus Replaced Pollution-generating Surface

The thresholds triggering specific Minimum Requirements for Water Quality Treatment are based on the total amount of the project's new plus replaced pollution-generating hard surface (PGHS) and new plus replaced pollution-generating pervious surface (PGPS). PGHS and PGPS include areas that are considered a significant source of pollutants in stormwater runoff. Refer to SMC, Chapter 22.801 and *Appendix A* for detailed definitions of these key terms.

Examples of PGHS include areas subject to vehicular use (including permeable pavement); industrial activities; and outdoor storage of erodible or leachable materials, wastes, or chemicals. Metal roofs are considered a PGHS unless coated with an inert, non-leachable material (e.g., baked-on enamel coating).

Examples of PGPS include lawns, landscaped areas, golf courses, parks, cemeteries, and sports fields (natural and artificial turf). Note: refer to *Section 2.5.1* for a clarification about underdrained sports fields. Refer to SMC, Chapter 22.801 and *Appendix A* for detailed definitions of these key terms.

Typically, new plus replaced PGHS and PGPS must be quantified separately for work within and outside the right-of-way.

2.7. Step 7 – Determine Which Minimum Requirements Apply

An overview of the minimum requirements applicable to all project types is included in *Chapter 3*. In addition, an overview of the minimum requirements specific to each project type is included in *Chapter 4*.

Based on the information obtained from Step 1 through Step 6, the applicable minimum requirements for specific project types can be determined for:

- Soil amendment (*Section 5.1*)
- On-site stormwater management (*Section 5.2*)
- Flow control (*Section 5.3*)
- Water quality treatment (*Section 5.4*)

In limited cases, there may be potential Exemptions, Adjustments, or Exceptions to the minimum requirements of the Stormwater Code. Refer to Chapter 7 for more information.

In addition, certain locations in the City may be subject to additional or modified requirements based on other Director's Rules, Policies, and Tips, such as:

- SPU Director's Rule DWW-210 — Public Drainage System Requirements
- SPU Director's Rule DWW-430.1 — Flow Control Requirements for Projects in Identified Public Combined Sewer Basins (SODO/Downtown Waterfront)

- SPU Director's Rule DWW-420.1 — Yesler Terrace Community Director's Rule: Allowable Stormwater, Groundwater, and Sewer Release Rates to the Combined Sewer System and Infiltration Zones
- SDCI Tip 505 — High Point Impervious Surface Calculation
- SDCI Director's Rule 14-2008 — Infiltration Facilities in Peat Settlement-prone Areas
- SPU Design Standards and Guidelines – including the GSI Manual
- Streets Illustrated (Seattle Right-of-Way Improvements Manual)
- Seattle Standard Plans and Specifications

Note: Under certain circumstances, the ECA code requires Water Quality Treatment and Flow Control in some locations where it is not required per this Manual (e.g., shoreline areas, riparian corridors).

2.7.1. Special Circumstances

Some projects do not closely fit defined project types or have complicating elements. These projects require a case-by-case review (no review of special circumstances sets a precedent) to determine the applicable minimum requirements. These projects must first go through a pre-permit review process to assist the proponent in identifying the specific minimum requirements to be applied. Project requirements will typically be based on requirements for parcel-based projects (refer to *Section 4.1*), roadway projects (refer to *Section 4.3*), or a combination in addition to minimum requirements for all projects (refer to *Chapter 3*).

The following list is not comprehensive but gives the proponent an indication of the complexity of the special circumstances. Examples of special circumstances projects include:

- Bridges or tunnels
- Construction over water
- Closed-contour low point basins
- Draining into more than one basin with conflicting requirements
- Multiple blocks or a subdivision
- Railroads including light rail
- Rail stations including light rail
- Work performed in more than one jurisdiction
- Land disturbing activity that includes more than one project type (e.g., utility projects and pavement maintenance projects).

Projects that propose to develop multiple blocks or a subdivision have the potential for greater impacts to the existing drainage system or public combined sewer. These projects may require a more comprehensive downstream analysis examining a larger range of flow and discharge conditions to demonstrate that the project meets the requirement to ensure sufficient capacity (SMC, Subsection 22.805.020H) and will not cause a significant adverse impact to receiving waters or up-gradient or down-gradient properties (SMC, Subsection 22.805.020A).

Similarly, projects that discharge to closed-contour low point basins may be required to demonstrate the project will not cause a significant adverse impact to down-gradient properties (SMC, Subsection 22.805.020H) and increase either the frequency or severity of flooding, including for peak flows with a 1 percent annual probability.

Projects that discharge to multiple drainage basins will be analyzed separately by drainage basin. To determine which minimum requirements apply and which part of the drainage system or public combined sewer will be analyzed to ensure sufficient capacity, the proponent must prepare exhibits showing the land-disturbing activity anticipated for each receiving water and drainage basin and downstream drainage system. Refer to *Section 2.3*.

The Director of SPU may determine that subbasins within the public combined sewer system or designated receiving waters are sufficiently distinct and separated to be analyzed independently and as separate areas. Discharges to each of the small lake basins will be analyzed independently and are considered separate areas.

Discharges to each creek basin will be analyzed independently and are considered separate areas. In addition, discharges to distinct branches of a creek or where the two points that discharge to a single creek branch are more than 1/4 mile apart will be analyzed independently and are considered separate areas.

If a project requires compliance with more than one flow control standard (e.g., the Peak Control Standard and the Pre-developed Pasture Standard), the facility must be sized to meet all applicable standards.

Once the applicable minimum requirements have been identified, proceed to *Volume 3*, *Chapters 3*, *4*, and *5* to begin the BMP selection and design process.

2.8. Step 8 – Determine Drainage Control Review and Submittal Requirements

Most construction and land use projects in Seattle require a permit from SDCI, SDOT, or both. Drainage Control Review types include: Preliminary Drainage Review, Standard Drainage Review, and Comprehensive Drainage Review. The type of Drainage Control Review is based on the project type and the proposed total amount of new plus replaced hard surface and the total amount of land-disturbing activity.

Forms and submittal documents for projects not conducted in the right-of-way (typically on private property) can be found on the SDCI website (www.seattle.gov/sdci/codes/codes-we-enforce-(a-z)/stormwater-code).

Forms and submittal documents for projects conducted in the right-of-way can be found on SDOT's website (www.seattle.gov/transportation/permits-and-services/permits/street-improvement-permits).

The City also has resources available on the SDCI website (www.seattle.gov/sdci), including relevant "Tips" with detailed information for construction projects as well as SDCI forms. In addition, SDCI staff may be contacted on the SDCI website (https://www.seattle.gov/sdci/about-us/contact-us).

Refer to *Section 2.7.1* for additional information about complex projects.

2.8.1. Preliminary Drainage Review

Preliminary Drainage Review is required for Master Use Permits (MUPs) and is summarized below.

Stormwater Code Language
SMC, 22.807.020.A – *Thresholds for drainage control review. Drainage control review and approval as described in subsection 22.807.020.B is required for any of the following:* 1. *Preliminary drainage review and approval is required for applications for the following approvals:* a. *Subdivisions (Chapter 23.22);* b. *Short plats (Chapter 23.24);* c. *Unit lot subdivisions (Sections 23.22.062 and 23.24.045);* d. *Lot boundary adjustments (Chapter 23.28); or* e. *Master use permits that would allow development that includes 750 square feet or more of new plus replaced hard surface or 5,000 square feet of land disturbing activity where the Director has determined that a preliminary drainage review is required considering, but not limited, to the following attributes of the site:* 1) *Location within an environmentally critical area or buffer;* 2) *Proximity and tributary to an environmentally critical area or buffer; and* 3) *Proximity and tributary to an area with adequacy, erosion, water quality, or flooding problems.*

The submittals required for Preliminary Drainage Review must include the following at a minimum. Refer to *Appendix B* for additional requirements for specific types of MUPs:

- Preliminary Drainage Control Plan*. The required elements for a Preliminary Drainage Control Plan are the same as for a Drainage Control Plan for Standard or Comprehensive Review with the following differences:
  - On-site Stormwater Management BMPs for proposed lots or parcels where the future development is unknown must show conceptual BMPs.
  - Tables for estimated new and replaced hard surface area for each proposed lot, parcel, tract, etc.
- Preliminary Site Plan (elements can be incorporated within Drainage Control Plan).* The required elements for a Preliminary Site Plan are the same as for a Site Plan.
- Preliminary On-site Stormwater Management Documentation.*
- Preliminary Drainage Report or Flow Control and Water Quality Documentation.*

*All submittals for Preliminary Drainage Review must be identified as "Preliminary." Preliminary Drainage Review approval does not permit construction. Standard or Comprehensive Drainage Review approval will be required for all associated construction permits.

Note: Refer to *Appendix B* for instances when some of the listed items may be deferred to the construction permits rather than being submitted with the MUP application.

2.8.2. Standard Drainage Review

Standard Drainage Review typically applies to projects that include:

- 750 square feet or more but less than 10,000 square feet of land disturbing activity;
- Less than 5,000 square feet of new plus replaced hard surface .
- An approved off-site point of discharge,
- No new outfalls to receiving waters.

For a project with no off-site discharge point as determined by the Director (refer to *Volume 3*, *Section 4.3.2*) or that includes installation of a new receiving water outfall, the drainage control plan must be prepared by a licensed engineer (SMC 22.807.020.B.2.b).

Refer to SMC, Subsection 22.807.020.A for other scenarios when Standard Drainage Review applies.

Stormwater Code Language

SMC, 22.807.020.A — *Thresholds for drainage control review. Drainage control review and approval as described in subsection 22.807.020.B is required for any of the following:*

2. *Standard drainage review and approval is required for the following:*
   a. *Applications other than those listed in subsection 22.807.020.A.1 that include any land disturbing activity encompassing an area of 5,000 square feet or more, including demolition permits;*
   b. *Applications for a building permit or other construction permit that authorizes the construction or installation of 750 square feet or more of new plus replaced hard surface;*
   c. *Applications for which a grading permit or approval is required pursuant to Chapter 22.170 [Grading Code];*
   d. *Applications for street use permits for the cumulative addition of 750 square feet or more of new plus replaced hard surface and land disturbing activity;*
   e. *City public works projects or construction contracts, including contracts for day labor and other public works purchasing agreements, for the cumulative addition of 750 square feet or more of new plus replaced hard surface and/or land disturbing activity to the site, except for work performed for the operation and maintenance of park lands under the control or jurisdiction of the Department of Parks and Recreation;*
   f. *Applications for approvals and contracts that include any new or replaced hard surface or any land disturbing activity on a site deemed a potentially hazardous location, as specified in Section 22.800.050 (Potentially Hazardous Locations);*
   g. *Applications for approvals that include any new hard surface in a Category I peat settlement-prone area delineated pursuant to Section 25.09.012 [Designations and Definitions of Environmentally Critical Areas];*
   h. *Whenever an exception to a requirement set forth in this Subtitle VIII or in a rule promulgated under this Subtitle VIII is desired, whether or not review and approval would otherwise be required, including, but not limited to, alteration of natural drainage patterns or the obstruction of watercourses;*
   i. *Whenever roadway project infeasibility pursuant to subsection 22.805.060.E is applied, whether or not review and approval would otherwise be required; or*
   j. *Applications for approvals for activities or projects for:*
      1) *Fueling at dedicated stations, for new or substantially altered fueling stations.*
      2) *In-water and over-water fueling.*
      3) *Maintenance and repair of vehicles and equipment.*
      4) *Concrete and asphalt mixing and production.*
      5) *Recycling, wrecking yard, and scrap yard operations.*
      6) *Storage of liquids in aboveground tanks.*
      7) *Other projects that the Director determines pose a hazard to public health, safety, or welfare; endanger any property; adversely affect the safety and operation of City right-of-way, utilities, or other property owned or maintained by the City; or adversely affect the functions and values of an environmentally critical area or buffer.*

The submittals required for Standard Drainage Review must include the following at a minimum:

- Construction Stormwater Control and Soil Management Plan (refer to *Volume 2 and Volume 3, Section 5.1*) including a dewatering plan if groundwater dewatering (e.g. trench dewatering, wellpoint dewatering, mass excavation dewatering) will occur.
- Standard Drainage Control Plan:
  - Site and drainage control summary.
  - Existing drainage infrastructure.
  - Location of drainage discharge from the site.
  - Drainage collection and conveyance measures (e.g., inlets, catch basins, maintenance holes, downspouts, drain lines, subgrade drainage, pumps, etc.).
  - Identification of uphill run-on areas (i.e., areas that may contribute stormwater runoff onto the project site).
  - On-site Stormwater Management BMPs and hard surface identification (refer to On-site Stormwater Management documentation below).
  - Flow Control BMPs.
  - Water Quality Treatment BMPs.
  - Source Control BMPs.
  - Identification of which of the following standards are met with each BMP using the following abbreviations:
    - On-site Stormwater Management (OSM)
    - Flow Control (FC)
    - Water Quality (WQ)
    - Source Control (SC)
  - Maintenance instructions.
- Site Plan (elements can be incorporated within Drainage Control Plan)
  - Address of project and permit number.
  - Limits of disturbance, including all clearing, grading, and other land-disturbing activity.
  - Creeks, streams, shorelines, and any other Environmentally Critical Areas (ECAs) or their buffers.
  - Areas to be protected.
  - Names, widths, and improvement types of adjacent streets and alleys.
  - Type, location, and dimension of curbs, sidewalks, and street trees.
  - All other trees at least 6 inches in diameter or larger measured 4.5 feet above the ground.
  - Location of all existing and proposed driveways, parking areas, and other paved areas and hard surfaces.

  - Size and shape of current and proposed buildings (including overhangs) and all other structures (retaining walls, etc.).
  - Entrances.
  - Building identifiers (for sites with more than one building).
  - Existing grades, ground elevations, or both including contours; flow lines, slope arrows, or both; tops and bottoms of slopes; and retaining walls, etc.
  - Proposed grades, ground elevations, or both including contours; spot elevations; flow lines, slope arrows, or both; tops and bottoms of slopes; and retaining walls, etc. with enough information to identify drainage patterns.
  - Existing and proposed retaining walls.
  - Existing and proposed below grade and above grade utilities and infrastructure.
  - Property line dimensions.
  - Existing and proposed easements.
  - Setbacks.
- On-site Stormwater Management Documentation:
  - Hard surface identification (e.g., roofs, driveways, sidewalks, patios).
  - On-site Stormwater Management BMP selection and sizing (refer to *Volume 3*, *Section 3.3*, and *Chapter 5*).
  - Documentation of On-site Stormwater Management BMPs determined to be infeasible (refer to *Appendix C*).
  - Where dispersion is not feasible, documentation demonstrating infeasibility (refer to *Volume 3*, *Section 3.1*).
  - Where infiltration is not feasible, documentation demonstrating infeasibility (refer to *Volume 3*, *Section 3.2*).
  - Subsurface investigation, infiltration test results, or groundwater analysis, as required per *Volume 3*, *Sections 3.2* and *5.4.1*, and *Appendix D*.
- Flow control documentation, if triggered. Required documentation may include:
  - Flow control BMP selection and sizing (refer to *Volume 3*, *Section 3.4*, and *Chapter 5*).
  - Details of any flow control device assembly, including orifice and weir sizing and elevations, if used.
  - Modeling documentation (refer to *Appendix F*).
  - Subsurface investigation, infiltration test results, or groundwater analysis as required per *Volume 3*, *Sections 3.2* and *5.4.1*, and *Appendix D*.
- Memorandum of Drainage Control for projects not located in the right-of-way, including at a minimum (SMC, Subsection 22.807.020.B.1.d):
  - The legal description of the site.
  - A summary of the terms and limitations of the drainage control plan.

- Identify all stormwater BMPs specific to the project (e.g., catch basins, permeable pavement surfaces, detention pipes, biofiltration swales, wash pads).
- An agreement to inform future purchasers, successors, or assignees of the existence, limitations, and inspection and maintenance requirements of the stormwater BMPs.
- Landscape management plan (if applicable).
- The side sewer permit number, date, and name.
- Permission for the City to enter the property for inspection, monitoring, correction, and abatement purposes.
- Acknowledgment by the owner(s) that the City is not responsible for the adequacy or performance of the drainage control plan, and a waiver of any and all claims against the City for any harm, loss, or damage related to the plan or to drainage or erosion on the property, except for claims arising from the City's sole negligence.
- The owner(s)' signatures acknowledged by a notary public.

- Operations and maintenance (O&M) plan for stormwater BMPs or include reference to the O&M requirements in *Appendix G* on the Drainage Control Plan.

2.8.3. Comprehensive Drainage Review

Stormwater Code Language

SMC, 22.807.020.A — *Thresholds for drainage control review. Drainage control review and approval as described in subsection 22.807.020.B is required for any of the following:*

3. *Comprehensive drainage review and approval is required for applications other than those listed in subsection 22.807.020.A.1 that include:*
   a. *5,000 square feet or more of new plus replaced hard surface;*
   b. *10,000 square feet or more of land disturbing activity;*
   c. *A project that has no available off-site point of discharge for stormwater as determined by the Director;*
   d. *An infiltration facility that is designed to fully infiltrate all stormwater runoff directed to it;*
   e. *An installation of a new outfall to a receiving water; or*
   f. *Demolition of a building with a roof area of 5,000 square feet or greater, even if the existing building slab remains.*

A Comprehensive Drainage Plan must be prepared by an engineer licensed in the State of Washington.

In addition to the requirements of the Standard Drainage Review, the following information is required for the Comprehensive Drainage Review:

- Comprehensive Drainage Control Plan consisting of:
  - A Comprehensive Drainage Control Construction Drawing including all elements of a Standard Drainage Control Plan.
  - A Comprehensive Construction Stormwater Control and Soil Management Plan narrative, supporting calculations, and supporting documents, including the Checklist to Select Large Project Construction BMPs (refer to Table 1b in *Volume 2, Chapter 3*. This may be prepared by a qualified professional other than an engineer (e.g., landscape architect), but when the plan includes engineering calculations, it must be stamped and signed by an engineer licensed in the State of Washington.
  - A Comprehensive Drainage Control Report, including but not limited to (refer to *Appendix B* for other required elements and recommended format):
    - A narrative detailing the proposed project, summary of minimum requirements, and proposed stormwater management.
    - Narrative of existing conditions, including drainage basins, existing surface types, soil conditions, groundwater conditions, Environmentally Critical Areas (ECAs), and known contamination.
    - Dispersion feasibility analysis and documentation (refer to *Volume 3, Section 3.1*).
    - Infiltration feasibility analysis and documentation (refer to *Volume 3, Section 3.2*).

- On-site Stormwater Management Documentation and supporting calculations (if triggered). Refer to *Section 2.8.2*.
- Flow control documentation and supporting calculations (if triggered). Refer to *Section 2.8.2*.
- Water quality documentation and supporting calculations (if triggered).
- Landscape management plan (if applicable). Refer to *Appendix I*.
- Source control documentation and calculations (if required).
- Drainage basin maps.
- Inspection and O&M requirements and schedule for stormwater BMPs and for any applicable landscape management plans.

- Refer to *Volume 3, Section 4.3.2* for specific requirements for projects with no off-site point of discharge. In some cases, projects with less than 1,500 square feet of new plus replaced hard surface will not require preparation by a licensed engineer.

2.8.4. Additional Documentation

Additional information may be required by the Director based on project specifics (e.g., infeasibility evaluation, existing conditions) to allow adequate evaluation of a project for compliance with the requirements and purpose of the Stormwater Code and other laws and regulations.

Such information includes, but is not limited to:

- Soils analysis
- Geotechnical report
- Survey of existing native vegetation cover (SMC, Section 25.11.050)
- Topographic or boundary survey (SMC, Section 25.09.330)
- Environmental assessment for potentially contaminated sites.
- Special Inspections for contaminated sites. Sites with contaminated soils or groundwater may require special inspections by a third-party during construction at the developer's/owner's expense to ensure that contaminated stormwater or groundwater does not leave the site without treatment or is disposed at a facility that is permitted and authorized to accept the type of discharges present, as determined by the Director.
- Downstream analysis
- Upstream analysis
- Basin analysis
- Landscape management plan (See *Appendix I* for submittal requirements)
- Closed contour analysis
- Adjustment requests substantiating the requirements of SMC, Subsection 22.800.040.B.
- Exception requests meeting the requirements of SMC, Subsection 22.800.040.C.

CHAPTER 3 – Minimum Requirements for All Projects

All projects are required to comply with the minimum requirements listed in SMC, Chapter 22.805, even when drainage control review is not required. The specifics of the minimum requirements applicable to all projects per SMC, Section 22.805.020 are summarized in the following subsections.

Note that this section summarizes but does not replace or alter Stormwater Code requirements.

3.1. Maintaining Natural Drainage Patterns

Stormwater Code Language
SMC, 22.805.020.A – *Minimum requirements for maintaining natural drainage patterns. For all projects, natural drainage patterns shall be maintained and discharges shall occur at the natural location to the maximum extent feasible and consistent with subsection 22.805.020.B. Drainage water discharged from the site shall not cause a significant adverse impact to receiving waters or down-gradient properties. Drainage water retained or infiltrated on the site shall not cause significant adverse impact to up-gradient or down-gradient properties.*
References
• Volume 1, Section 3.2 (SMC, Section 22.805.020.B) – Minimum Requirements for Discharge Point • Public Drainage System Requirements Director's Rule DWW-210

Discharges from the project site must not cause a significant adverse impact to downstream receiving waters and down-gradient properties or systems. All concentrated discharge locations (i.e., discharges from pipe systems, culverts, and ditches) must address energy dissipation.

3.2. Discharge Point

3.2.1. Approved Point of Discharge

All projects must convey stormwater flow to an approved point of discharge and include overflows for all stormwater BMPs.

Stormwater Code Language
SMC, 22.805.020.B – *Minimum requirements for discharge point. The discharge point for drainage water from each site shall be selected using criteria that shall include, but not be limited to, preservation of natural drainage patterns and whether the capacity of the drainage system is adequate for the flow rate and volume. For those projects meeting the drainage review threshold, the proposed discharge point shall be identified in the drainage control plan required by this subtitle, for review and approval or disapproval by the Director.*
References
• Public Drainage System Requirements Director's Rule DWW-210

A project's approved point of discharge as determined by the Director, in order of priority, includes:

1. Receiving waters
2. Piped public drainage system (also known as Pipe Storm Drain [PSD])
3. Ditch and culvert system
4. Public combined sewer system
5. Infiltration on site

Extension of the **piped** public drainage system may be required even if a ditch and culvert system or a public combined sewer abuts a project (refer to *Section 3.12* and the Public Drainage System Requirements Director's Rule (SPU Director's Rule DWW210)).

Note: Stormwater and groundwater must not be conveyed to or enter a sanitary sewer (SMC, Section 21.16.220), including those systems that were permitted as a formerly combined system.

Refer to SPU's Water & Sewer Map for "Permitted Use" in determining if a system is classified as a public sanitary sewer: https://www.seattle.gov/utilities/construction-resources/water-and-sewer-map.

3.2.2. Conveyance Systems to Point of Discharge

The types of conveyance systems to the approved point of discharge, in order of priority, include:

1. Direct pipe connections
2. Ditch (also known as conveyance swale) and culvert system
3. Gutter or street flow line
4. Surface dispersal

3.3. Flood-prone Areas

Stormwater Code Language
SMC, 22.805.020.C – *Minimum requirements for flood-prone areas. On sites within flood-prone areas, responsible parties are required to employ procedures to minimize the potential for flooding on the site and to minimize the potential for the project to increase the risk of floods on adjacent or nearby properties. Flood control measures shall include those set forth in other titles of the Seattle Municipal Code and rules promulgated thereunder, including, but not limited to, Chapter 23.60A (Seattle Shoreline Master Program Regulations), Chapter 25.06 (Floodplain Development), and Chapter 25.09 (Regulations for Environmentally Critical Areas).*

3.4. Construction Site Stormwater Pollution Prevention Control

The Construction Stormwater Control and Soil Management Plan applies best management practices (BMPs) that fall within the following 19 elements of water quality, air quality, and downstream resource protection and are required by the Stormwater Code (SMC, Subsection 22.805.020.D).

Stormwater Code Language
Excerpt from SMC, 22.805.020.D – Minimum Requirements for Construction Stormwater Pollution Prevention Plan. Temporary and permanent construction controls shall be used to accomplish [the 19 construction site stormwater pollution prevention control requirements outlined in SMC 22.805.020.D and Volume 2, Construction Stormwater Control]. All projects are required to meet each of the elements below or document why an element is not applicable. Additional controls may be required by the Director when minimum controls are not sufficient to prevent erosion or transport of sediment or other pollutants from the site. 1. Mark Clearing Limits and Environmentally Critical Areas 2. Retain Top Layer 3. Establish Construction Access 4. Protect Downstream Properties and Receiving Waters 5. Prevent Erosion and Sediment Transport from the Site 6. Prevent Erosion and Sediment Transport from the Site by Vehicles 7. Stabilize Soils 8. Protect Slopes 9. Protect Storm Drains 10. Stabilize Channels and Outlets 11. Control Pollutants 12. Control Dewatering 13. Maintain BMPs 14. Inspect BMPs 15. Execute Construction Stormwater Control and Soil Management Plan 16. Minimize Open Trenches 17. Phase the Project 18. Install Flow Control and Water Quality Facilities 19. Protect Stormwater BMPs

Refer to the Stormwater Code or *Volume 2, Chapter 3* for full code text.

These 19 elements cover protection strategies, including:

- Limiting project site impacts.
- Protecting the public drainage system, combined and sanitary sewers, and downstream receiving waters.
- Preventing erosion and sedimentation.
- Managing activities and sources.

Project designers must review the applicable elements in Volume 2, Chapter 2 and ensure the specific requirements under each of the 19 elements are fully addressed by the project site stormwater pollution prevention controls.

Refer to *Volume 1, Section 2.8.3* (Comprehensive Drainage Plan) to determine when a Construction Stormwater Control Plan must be prepared by an engineer licensed in the State of Washington.

3.5. Protect Wetlands

Stormwater Code Language
SMC, 22.805.020.E – *Protect wetlands. All projects discharging into a wetland or its buffer, either directly or indirectly through a drainage system, shall prevent impacts to wetlands that would result in a net loss of functions or values.*
SMC, 22.801.240 – *"Wetland function" means the physical, biological, chemical, and geologic interactions among different components of the environment that occur within a wetland. Wetland functions can be grouped into three categories: functions that improve water quality; functions that change the water regime in a watershed, such as flood storage; and functions that provide habitat for plants and animals.*
SMC, 22.801.240 – *"Wetland values" means wetland processes, characteristics, or attributes that are considered to benefit society.*

All wetlands (Categories I, II, III, and IV) must receive the following general protections:

1. Comply with regulations issued under federal and state laws that regulate the discharge of pollutants to surface waters, including the Construction Stormwater General NPDES Permit.
2. Comply with Seattle ECA Code SMC 25.09 – Regulations for Environmentally Critical Areas. Refer to SMC 25.09.160.C for allowed and prohibited activities in wetland and wetland buffers. Development is prohibited and includes but is not limited to grading, filling, draining, or any alteration to the functions and values of the wetland (including but not limited to negative impacts on trees and vegetation, habitat, flood control, and water quality unless an ECA exception is granted or as provided in the ECA Code. Note: installation of drainage systems or other utilities is considered “development,” which is prohibited in wetlands and wetland buffers.
3. Protect the wetland buffer as required by all local and state regulations.

4. Retain areas of native vegetation connecting the wetland and its buffer with nearby wetlands and other abutting areas of native vegetation, if possible.
5. Consider installing wetland protection-related signage.
6. Any stormwater management practices, such as On-site Stormwater Management, Water Quality Treatment, and Flow Control BMP implementation or construction of stormwater conveyance facilities (e.g., piped, ditches, culverts, etc.), must be done outside of the wetland buffer boundary unless an ECA exception is granted or as provided in the ECA Code.
7. Discharge from a BMP or project site must be dispersed using a method to spread out the flow before entering the wetland buffer. Preferably use Dispersion BMP from *Volume 3, Section 5.3*. If that is not feasible, then use a level spreader sized for permanent discharges.
8. Consider fences to restrict human access without interfering with wildlife movement.

In addition, Flow Control, per *Section 5.3.1* - Wetland Protection Standards, is required for certain Parcel-based and Roadway Projects as identified *in Section 4.1.3.1 and 4.3.3.1*.

3.6. Protect Streams and Creeks

Stormwater Code Language
SMC, 22.805.020.F – *Protect Streams and creeks. All projects, including projects discharging directly to a stream or creek, or to a drainage system that discharges to a stream or creek, shall maintain the water quality in any affected stream or creek by selecting, designing, installing, and maintaining temporary and permanent controls.*

3.7. Protect Shorelines

Stormwater Code Language
SMC, 22.805.020.G – *Protect shorelines. All projects discharging directly or indirectly through a drainage system into the shoreline district as defined in Chapter 23.60A (Seattle Shoreline Master Program Regulations) shall prevent impacts to water quality and stormwater quantity that would result in a net loss of shoreline ecological functions as defined in WAC 173-26-020(13).*

3.8. Ensure Sufficient Capacity

Stormwater Code Language
SMC, 22.805.020.H –*Ensure sufficient capacity. All projects with 5,000 square feet or more of new plus replaced hard surface or one acre of land disturbing activity, all projects with an excavation depth of 12 feet or more below the existing grade, all projects with an excavation depth of less than 12 feet located in an area expected to have shallow groundwater depths, and all projects that alter the drainage pattern from 5,000 square feet or more of an existing, new, or replaced hard surface or 3/4 of an acre or more of a pervious surface from a site to a downstream system not previously connected via discrete conveyance shall ensure that sufficient capacity exists in the drainage system and public combined sewer to carry existing and anticipated loads, including any flows from dewatering activities. Capacity analysis shall extend to at least 1/4-mile from the discharge point of the site. Sites at which there is insufficient capacity may be required to install a flow control facility or improve the drainage system or public combined sewer to accommodate flow from the site. Unless approved otherwise by the Director as necessary to meet the purposes of this subtitle:* 1. *Capacity analysis for discharges to the drainage system shall be based on peak flows with a 4 percent annual probability (25-year recurrence interval); and* 2. *Capacity analysis for discharges to the public combined sewer shall be based on peak flows with a 20 percent annual probability (5-year recurrence interval).*
References
• Volume 3, Section 4.3 – Conveyance and Overflow General Design Requirements • Appendix F – Hydrologic Analysis and Design • SMC, Section 22.805.020.N – Public Drainage System Requirements • Public Drainage System Requirements Director's Rule DWW-210

3.9. Install Source Control BMPs

Stormwater Code Language
SMC, 22.805.020.I – *Install source control BMPs. Source control BMPs shall be installed for discharges, properties, and by businesses and public entities for specific pollution-generating activities as specified in Chapter 22.803 and in the joint SPU/SDCI Directors' Rule titled "Seattle Stormwater Manual" at "Volume 4—Source Control," to the extent necessary to prevent prohibited discharges as described in Section 22.802.020 [Prohibited Discharges] and to prevent contaminants from coming in contact with drainage water. This requirement applies to the pollution-generating activities that are stationary or occur in one primary location and to the portion of the site being developed. Examples of installed source controls include, but are not limited to, the following:* 1. *A roof, awning, or cover erected over the pollution-generating activity area;* 2. *Ground surface treatment in the pollution-generating activity area to prevent interaction with, or breakdown of, materials used in conjunction with the pollution-generating activity;* 3. *Containment of drainage from the pollution-generating activity to a closed sump or tank. Contents of such a sump or tank must be pumped or hauled by a waste handler, or treated prior to discharge to a public drainage system;* 4. *Construct a berm or dike to enclose or contain the pollution-generating activities;* 5. *Direct drainage from containment area of pollution-generating activity to a closed sump or tank for settling and appropriate disposal, or treat prior to discharging to a public drainage system;* 6. *Pave, treat, or cover the containment area of pollution-generating activities with materials that will not interact with or break down in the presence of other materials used in conjunction with the pollution-generating activity; and* 7. *Prevent precipitation from flowing or being blown onto containment areas of pollution-generating activities.*

3.10. Do Not Obstruct Watercourses

Stormwater Code Language
SMC, 22.805.020.J – *Do not obstruct watercourses. Watercourses shall not be obstructed.*
SMC, 22.808.010.A.1.d – *Obstruction of watercourse or public drainage system. It is a violation to obstruct a watercourse or public drainage system without authorization or approval by the Director.*

3.11. Comply with Side Sewer Code

A side sewer permit is required for any repair, replacement, or alteration of the sewer or drainage system. Any change to the point of discharge must be approved. A change of use that introduces contaminants or process water to the drainage system, public combined sewer, or public sanitary sewer must also be approved and may require pretreatment. For information on side sewer permits, contact the SPU Side Sewer Program at (206) 684-5362 or sidesewerinfo@seattle.gov. For information on King County discharge requirements, contact the Industrial Waste Program at (206) 477-5300 or Info.KCIW@kingcounty.gov.

Stormwater Code Language
SMC, 22.805.020.K – *Comply with Side Sewer Code* 1. *All privately owned and operated drainage control facilities or systems, whether or not they discharge to a public drainage system or public combined sewer, shall be considered side sewers and subject to Chapter 21.16 (Side Sewer Code), SPU Director's Rules promulgated under Title 21, and the design and installation specifications and permit requirements of SPU for side sewer and drainage systems.* 2. *Side sewer permits and inspections shall be required for constructing, capping, altering, or repairing privately owned and operated drainage systems as provided for in Chapter 21.16. When the work is ready for inspection, the permittee shall notify the Director of SPU. If the work is not constructed according to the plans approved under this Subtitle VIII, Chapter 21.16, the SPU Director's Rules promulgated under Title 21, and SPU design and installation specifications, then the Director may issue a stop work order under Chapter 22.808 [Stormwater Code Enforcement] and require modifications as provided for in this Subtitle VIII and Chapter 21.16.*

3.12. Extension of Public Drainage System

3.12.1. Projects Not Constructed in the Right-of-Way

Stormwater Code Language
SMC, 22.805.020.L – *Extension of the public drainage system for projects not constructed in the public right-of-way. For projects not constructed in the public right-of-way, extension of the piped public drainage system across the full extent of the parcel boundary in the abutting public place shall be required for any of the following:* 1. *All projects where the Director has determined an extension is required considering, but not limited to, the following attributes of the project:* a. *Poses a hazard to public health, safety, or welfare;* b. *Endangers any property;* c. *Adversely affects the safety and operation of public right-of-way, utilities, or other property owned or maintained by the City;* d. *Adversely affects the functions and values of an environmentally critical area or buffer;* e. *Adversely affects an area with known erosion or flooding problems; or* f. *Adversely affects receiving waters, any properties, or right-of-way.* 2. *All projects with 5,000 square feet or more of new plus replaced hard surface, unless:* a. *The piped public drainage system is already accessible within an abutting public place to each existing, proposed, or adjusted parcel; or* b. *The project is otherwise not required to extend by rules promulgated by the Director.*
References
• Public Drainage System Requirements Director's Rule DWW-210

3.12.2. Projects Constructed in the Right-of-Way

Stormwater Code Language
SMC, 22.805.020.M – *Extension of the public drainage system for projects constructed in the public right-of-way. For projects constructed in the public right-of-way, extension of the piped public drainage system across the full extent of the site shall be required for any of the following:* 1. *All projects where the Director has determined an extension is required considering, but not limited to, the following attributes of the project:* a. *Poses a hazard to public health, safety, or welfare;* b. *Endangers any property;* c. *Adversely affects the safety and operation of City right-of-way, utilities, or other property owned or maintained by the City;* d. *Adversely affects the functions and values of an environmentally critical area or buffer;* e. *Adversely affects an area with known erosion or flooding problems; or* f. *Adversely affects receiving waters, any properties, or right-of-way.* 2. *The project's total new plus replaced hard surface is 50 percent or more of the existing hard surfaces within the project limits. The project limits are defined by the length of the project and the width of the right-of-way. If a project encompasses more than one intersection, the project limits are further defined by one intersection to the other and blocks may vary in length, unless:* g. *The piped public drainage system is already accessible within the site across the full extent of the site; or* h. *The project is otherwise not required to extend by rules promulgated by the Director.*
References
• Public Drainage System Requirements Director's Rule DWW-210

3.13. Public Drainage System Requirements

Stormwater Code Language
SMC, 22.805.020.N – *Public drainage system requirements. Public drainage systems shall be constructed in accordance with the City's Standard Plans and Specifications, SPU's Design Standards and Guidelines, and as specified in rules promulgated by the Director of SPU.*
References
• City of Standard Specifications for Road, Bridge, and Municipal Construction • City of Seattle Standard Plans for Municipal Construction • SPU Design Standards and Guidelines • Public Drainage System Requirements Director's Rule DWW-210

3.14. Maintenance and Inspection

Projects that construct on-site stormwater management, flow control, and water quality treatment BMPs must comply with the maintenance and inspection requirements specified in SMC, Section 22.807.090. Refer to *Appendix G* – Stormwater Control Operations and Maintenance Requirements and *Appendix I* – Landscape Management Plans and Integrated Pest Management Plans for additional maintenance and inspection requirement information.

Stormwater Code Language

SMC, 22.807.090 – *Maintenance and inspection*

A. Responsibility for Maintenance and Inspection. The owner and other responsible parties shall maintain drainage control facilities, source controls, and other facilities and implement landscape management plans required by this subtitle and by rules adopted hereunder to keep these facilities in continuous working order. The owner and other responsible parties shall inspect permanent drainage control facilities, temporary drainage control facilities, and other temporary best management practices or facilities on a schedule consistent with this subtitle and sufficient for the facilities to function at design capacity. The Director may require the responsible party to conduct more frequent inspections and/or maintenance when necessary to ensure functioning at design capacity. The owner(s) shall inform future purchasers and other successors and assignees to the property of the existence of the drainage control facilities and the elements of the drainage control plan, the limitations of the drainage control facilities, and the requirements for continued inspection and maintenance of the drainage control facilities and for implementation of a landscape management plan, if applicable.

B. Inspection by City. The Director of SPU may establish inspection programs to evaluate and, when required, enforce compliance with the requirements of this subtitle and accomplishment of its purposes. Inspection programs may be established on any reasonable basis, including, but not limited to: routine inspections; random inspections; inspections based upon complaints or other notice of possible violations; inspection of drainage basins or areas identified as higher than typical sources of sediment or other contaminants or pollutants; inspections of businesses or industries of a type associated with higher than usual discharges of contaminants or pollutants or with discharges of a type more likely than the typical discharge to cause violations of state or federal water or sediment quality standards or the City's NPDES stormwater permit; and joint inspections with other agencies inspecting under environmental or safety laws. Inspections may include, but are not limited to: reviewing maintenance and repair records; sampling discharges, surface water, groundwater, and material or water in drainage control facilities; and evaluating the condition of drainage control facilities and other best management practices.

C. Entry for inspection and abatement purposes

1. New installations and connections. When any new drainage control facility is installed on private property, and when any new connection is made between private property and a public drainage system, sanitary sewer or combined sewer, the property owner shall grant, pursuant to subsection 22.807.020.B.1.c (Memorandum of drainage control), the City the right to enter the property at reasonable times and in a reasonable manner pursuant to an inspection program established pursuant to subsection 22.807.090.B, and to enter the property when the City has a reasonable basis to believe that a violation of this subtitle is occurring or has occurred, and to enter when necessary for abatement of a public nuisance or correction of a violation of this subtitle.

2. Existing real property and discharges. Owners of property with existing discharges or land uses subject to this subtitle who are not installing a new drainage control facility or making a new connection between private property and a public drainage system, sanitary sewer, or combined sewer shall have the option to execute a permission form for the purposes described above when provided with the form by the Director of SPU.

CHAPTER 4 – Minimum Requirements Based on Project Type

In addition to the minimum requirements for all projects presented in *Chapter 3*, additional requirements apply based on project type and are summarized in this chapter. Project types are defined in *Chapter 2*, *Step 2*.

Flow charts are included in the parcel-based and roadway project sections (*Sections 4.1* and *4.3*) to summarize the key minimum requirements.

The key project type minimum requirements include:

- Soil Amendment
- On-site Stormwater Management
- Flow Control
  - Wetland Protection Standard
  - Pre-developed Forested Standard
  - Pre-developed Pasture Standard
  - Peak Control Standard
- Water Quality Treatment
  - Basic Treatment
  - Oil Treatment
  - Phosphorus Treatment
  - Metals Treatment (previously known as Enhanced Treatment)

The standards are described in more detail in *Chapter 5*. For each project type, the minimum requirements are a function of the following factors (refer to *Chapter 2*):

- The receiving water, type of downstream conveyance, or both.
- The amount of new plus replaced hard surface (Note: permeable pavement, vegetated roof systems, and areas with underdrains count toward determining this threshold.).
- The amount of converted native vegetation.
- The amount of new plus replaced pollution-generating hard surface (PGHS).
- The amount of new plus replaced pollution-generating pervious surface (PGPS).

In addition, certain locations in the City may be subject to additional or modified requirements based on additional Director's Rules, Policies, other Codes (e.g., ECA Code), or past agreements. For example, such areas include parts of the SODO and Downtown waterfront areas, the Yesler Terrace Development, the High Point Re-development, Peat Settlement-prone ECAs. Refer to Step 7 (*Section 2.7*) for more information.

4.1. Parcel-based Projects

Parcel-based projects must meet the minimum requirements for soil amendment (SMC, Subsection 22.805.050.A), on-site stormwater management (SMC, Section 22.805.070), flow control (SMC, Section 22.805.080), and water quality treatment (SMC, Section 22.805.090) when applicable. Key minimum requirements for parcel-based projects are summarized in Figures 4.1a through 4.1c. Refer to *Volume 1, Section 5.1.* Soil Amendment for more information.

4.1.1. Soil Amendment

Stormwater Code Language
SMC, 22.805.050 - Minimum requirements for parcel-based projects A — *Soil amendment. Retain and protect undisturbed soil in areas not being developed, and prior to completion of the project, amend all new, replaced, and disturbed topsoil (including construction lay-down areas) with organic matter to the extent required by and in compliance with the rules promulgated by the Director.*
References
• Volume 1, Section 2.2.1 – Parcel-based Project • Volume 1, Section 5.1 – Soil Amendment • Volume 3, Section 5.1 – Soil Amendment BMP

4.1.2. On-site Stormwater Management

Stormwater Code Language
SMC, 22.805.050 - Minimum requirements for parcel-based projects *B — On-site stormwater management. Parcel-based projects shall meet the minimum requirements for on-site stormwater management contained in Section 22.805.070, to the extent allowed by law, if:* 1. *For a project on a lot most recently created, adjusted, altered, or otherwise amended by a plat or other lawful document recorded with the King County Recorder on or after January 1, 2016, and where that document either created the lot or altered the size of the lot, either the total new plus replaced hard surface is 750 square feet or more or land disturbing activity is 7,000 square feet or more; or* 2. *For any other project, either the total new plus replaced hard surface is 1,500 square feet or more or the land disturbing activity is 7,000 square feet or more.*
References
• Volume 1, Section 2.2.1 – Parcel-based Project • Volume 1, Section 5.2 (SMC, Section 22.805.070) – On-site Stormwater Management • Volume 3, Section 3.3 – BMP Selection for On-site Stormwater Management

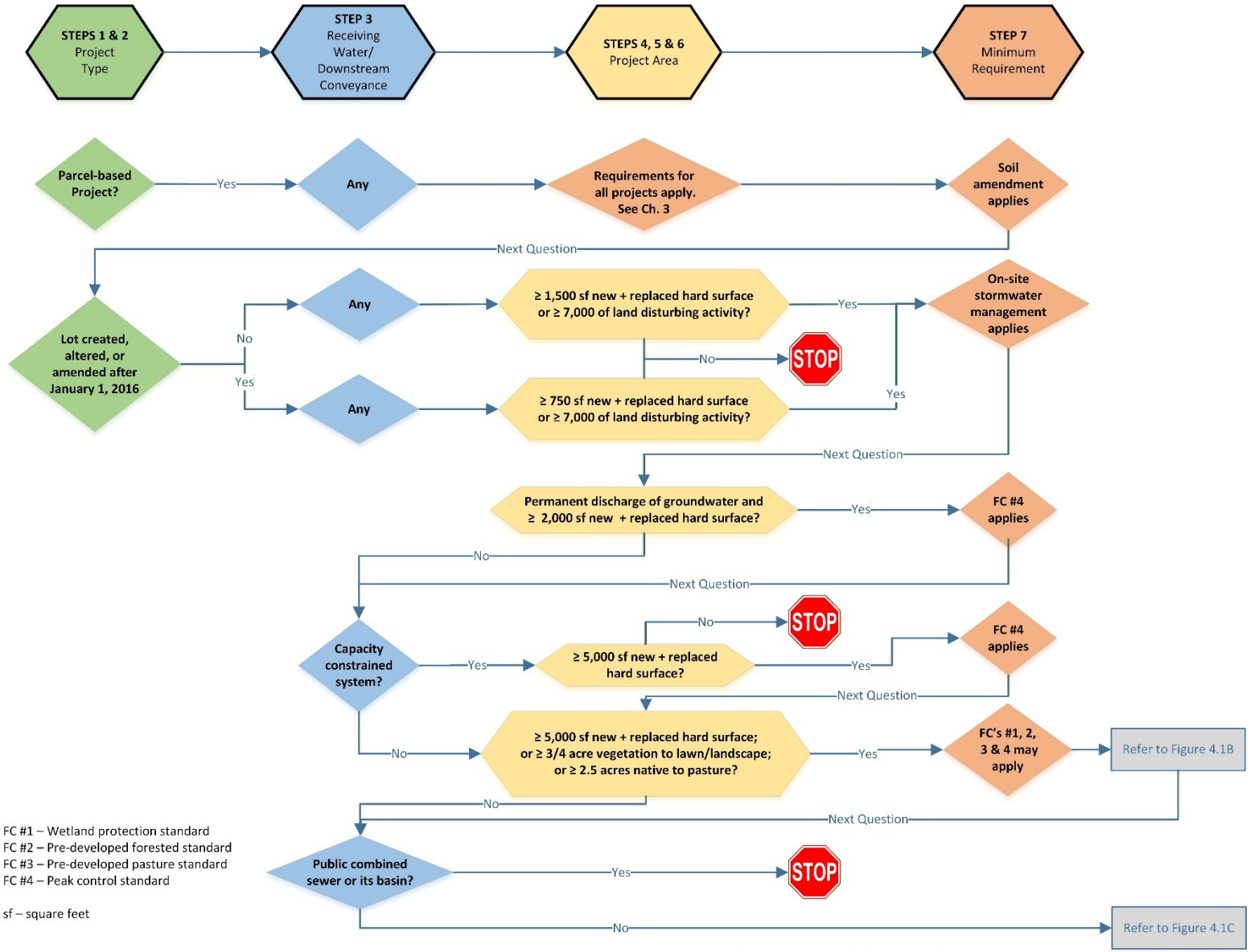

Figure 4.1A. Project Minimum Requirements for Parcel-based Projects.

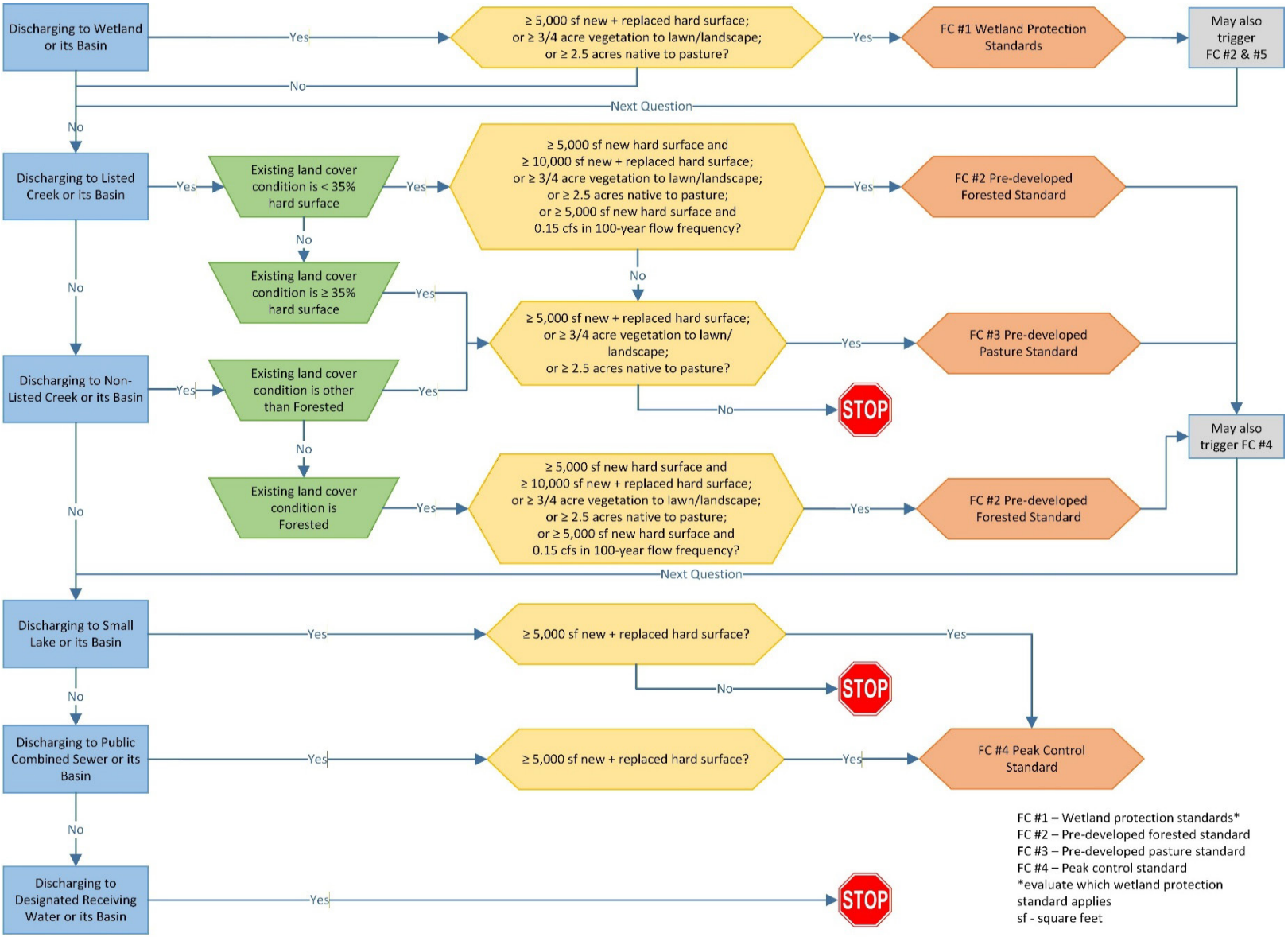

Figure 4.1B. Project Minimum Requirements for Parcel-based Projects (continued).

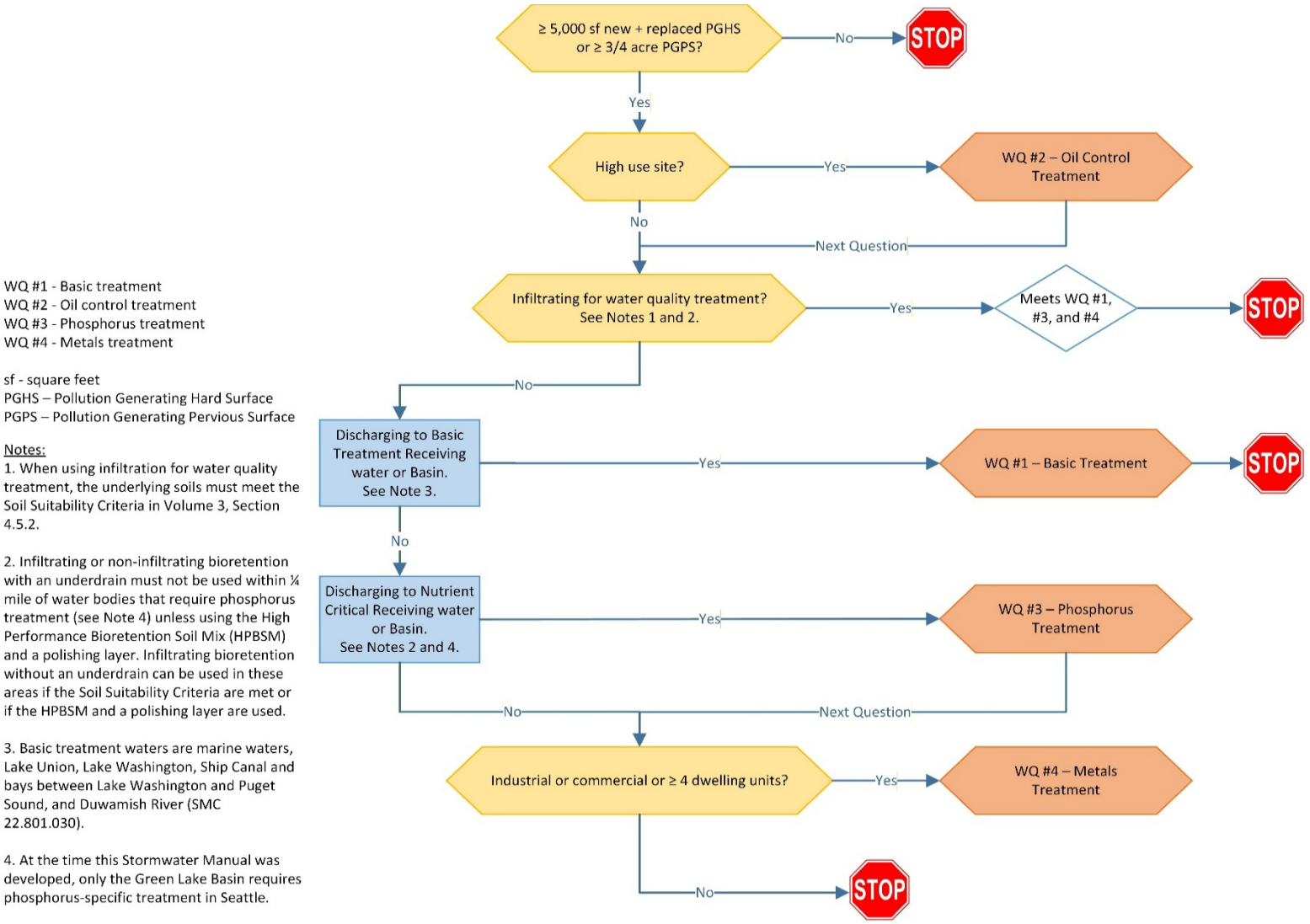

Figure 4.1C. Project Minimum Requirements for Parcel-based Projects (continued).

4.1.3. Flow Control

In addition to meeting a forested, pasture, or wetland protection standard, parcel-based projects discharging to a capacity-constrained system (SMC, Section 22.801.040) will also be required to meet the peak control standard (SMC, Subsection 22.805.080.B.5) if required per *Section 4.1.3.6* Parcel-based Projects Discharging to a Capacity-constrained System – Flow Control.

4.1.3.1. Parcel-based Projects Discharging to Wetlands – Flow Control

Stormwater Code Language
SMC, 22.805.050 - Minimum requirements for parcel-based projects C.1 — *Discharges to wetlands. Parcel-based projects discharging into a wetland, or to the drainage basin of a wetland, shall:* *a. Comply with Section 22.805.020 (Minimum requirements for all projects), including, but not limited to subsection 22.805.020.E (Protect wetlands).* *b. Comply with the minimum requirements for wetland protection contained in subsection 22.805.080.C (Wetland protection standards) if:* *1) The total new plus replaced hard surface is 5,000 square feet or more; or* *2) The project converts 3/4 acres or more of vegetation to lawn or landscaped areas, and from the project there is a surface discharge into a natural or constructed conveyance system from the site; or* 3) *The project converts 2.5 acres or more of native vegetation to pasture and from the project there is a surface discharge into a natural or constructed conveyance system from the site.*
References
• Volume 1, Section 2.2.1 – Parcel-based Project • Volume 1, Section 3.5 – Protect Wetlands • Volume 1, Section 5.3.1 (SMC, Section 22.805.080.C.1) – Wetland Protection Standards • SWMMWW Volume I, Appendix I-C (Ecology 2024)

4.1.3.2. Parcel-based Projects Discharging to Listed Creek Basins – Flow Control

Stormwater Code Language

SMC, 22.805.050 - Minimum requirements for parcel-based projects

C. Flow control. Parcel-based projects shall meet the minimum requirements for flow control contained in Section 22.805.080, to the extent allowed by law, as prescribed below.

2 — Discharges to listed creek basins. Parcel-based projects discharging into Blue Ridge Creek, Broadview Creek, Discovery Park Creek, Durham Creek, Frink Creek, Golden Gardens Creek, Kiwanis Ravine/Wolfe Creek, Licton Springs Creek, Madrona Park Creek, Mee-Kwa-Mooks Creek, Mount Baker Park Creek, Puget Creek, Riverview Creek, Schmitz Creek, Taylor Creek, or Washington Park Creek, or to the drainage basin of such creek, shall:

a. Comply with subsection 22.805.080.D (Pre-developed forested standard) if the existing hard surface coverage is less than 35 percent and one or more of the following apply:

1) The project adds 5,000 square feet or more of new hard surface and the total new plus replaced hard surface is 10,000 square feet or more; or

2) The project converts 3/4 acres or more of vegetation to lawn or landscaped areas, and from the project there is a surface discharge into a natural or constructed conveyance system from the site; or

3) The project converts 2.5 acres or more of native vegetation to pasture, and from the project there is a surface discharge into a natural or constructed conveyance system from the site; or

4) The project adds 5,000 square feet or more of new hard surface and, through a combination of effective hard surfaces and converted pervious surfaces, causes a 0.15 cubic feet per second increase in the 100-year recurrence interval flow frequency as estimated using a continuous model approved by the Director.

b. Comply with subsection 22.805.080.E (Pre-developed pasture standard) if the criteria in subsection 22.805.050.C.2.a do not apply and one or more apply:

1) The total new plus replaced hard surface is 5,000 square feet or more; or

2) The project converts 3/4 acres or more of vegetation to lawn or landscaped areas, and from the project there is a surface discharge into a natural or constructed conveyance system from the site; or

3) The project converts 2.5 acres or more of native vegetation to pasture, and from the project there is a surface discharge into a natural or constructed conveyance system from the site.

References

- Volume 1, Section 2.2.1 – Parcel-based Project
- Volume 1, Section 2.3 – Figures 2.5 and 2.6
- Volume 1, Section 5.3.2 (SMC, Section 22.805.080.D) – Pre-developed Forested Standard
- Volume 1, Section 5.3.3 (SMC, Section 22.805.080.E) – Pre-developed Pasture Standard
- Volume 3, Section 3.4 – BMP Selection for Flow Control
- Volume 3, Section 4.1 – Sizing Approach

Note: The 0.15 cfs increase is a comparison of the post-project runoff to the existing condition runoff. The post-project runoff calculations may account for proposed BMPs.

4.1.3.3. Parcel-based Projects Discharging to Non-listed Creek Basins – Flow Control

Stormwater Code Language

SMC, 22.805.050 - Minimum requirements for parcel-based projects

C. Flow control. Parcel-based projects shall meet the minimum requirements for flow control contained in Section 22.805.080, to the extent allowed by law, as prescribed below.

3 — *Discharges to non-listed creek basins. Parcel-based projects discharging into a creek not listed in subsection 22.805.050.C.2, or to the drainage basin of such creek, shall:*

a. *Comply with subsection 22.805.080.D (Pre-developed forested standard) if the existing land cover is forested and one or more of the following apply:*

   1) *The project adds 5,000 square feet or more of new hard surface and the total new plus replaced hard surface is 10,000 square feet or more; or*

   2) *The project converts 3/4 acres or more of vegetation to lawn or landscaped areas, and from the project there is a surface discharge into a natural or constructed conveyance system from the site; or*

   3) *The project converts 2.5 acres or more of native vegetation to pasture, and from the project there is a surface discharge into a natural or constructed conveyance system from the site; or*

   4) *The project adds 5,000 square feet or more of new hard surface and, through a combination of effective hard surfaces and converted pervious surfaces, causes a 0.15 cubic feet per second increase in the 100-year recurrence interval flow frequency as estimated using a continuous model approved by the Director.*

b. *Comply with subsection 22.805.080.E (Pre-developed pasture standard) if the criteria in subsection 22.805.050.C.3.a do not apply and one or more of the following apply:*

   1) *The total new plus replaced hard surface is 5,000 square feet or more; or*

   2) *The project converts 3/4 acres or more of vegetation to lawn or landscaped areas, and from the project there is a surface discharge into a natural or constructed conveyance system from the site; or*

   3) *The project converts 2.5 acres or more of native vegetation to pasture, and from the project there is a surface discharge into a natural or constructed conveyance system from the site.*

References

- Volume 1, Section 2.2.1 – Parcel-based Project
- Volume 1, Section 2.3 – Figures 2.5 and 2.6
- Volume 1, Section 5.3.2 (SMC, Section 22.805.080.D) – Pre-developed Forested Standard
- Volume 1, Section 5.3.3 (SMC, Section 22.805.080.E) – Pre-developed Pasture Standard
- Volume 3, Section 3.4 – BMP Selection for Flow Control
- Volume 3, Section 4.1 – Sizing Approach

Note: The 0.15 cfs increase is a comparison of the post-project runoff to the existing condition runoff. The post-project runoff calculations may account for proposed BMPs.

4.1.3.4. Parcel-based Projects Discharging to Small Lake Basins – Flow Control

Stormwater Code Language
SMC, 22.805.050 - Minimum requirements for parcel-based projects *C. Flow control. Parcel-based projects shall meet the minimum requirements for flow control contained in Section 22.805.080, to the extent allowed by law, as prescribed below.* 4 — *Discharges to small lake basins. Parcel-based projects discharging into Bitter Lake, Green Lake, or Haller Lake, or to the drainage basin of such lake, shall comply with subsection 22.805.080.G (Peak control standard) if the total new plus replaced hard surface is 5,000 square feet or more.*
References
• Volume 1, Section 2.2.1 – Parcel-based Project • Volume 1, Section 2.3 – Figures 2.5 and 2.6 • Volume 1, Section 5.3.5 (SMC, Section 22.805.080.G) – Peak Control Standard • Volume 3, Section 3.4 – BMP Selection for Flow Control • Volume 3, Section 4.1 – Sizing Approach

4.1.3.5. Parcel-based Projects Discharging to Public Combined Sewer – Flow Control

At the time this Manual was developed, one public combined sewer basin was determined to have sufficient capacity to carry existing and anticipated loads. Parcel-based projects are not required to provide peak flow control in this basin. Refer to the SDCI website to determine which basins are included in this category (www.seattle.gov/sdci/codes/codes-we-enforce-(a-z)/stormwater-code).

Stormwater Code Language
SMC, 22.805.050 - Minimum requirements for parcel-based projects *C. Flow control. Parcel-based projects shall meet the minimum requirements for flow control contained in Section 22.805.080, to the extent allowed by law, as prescribed below.* 5 — *Discharges to public combined sewer. Unless the Director of SPU has determined that the public combined sewer has sufficient capacity to carry existing and anticipated loads, parcel-based projects discharging into the public combined sewer or its basin shall comply with subsection 22.805.080.G (Peak control standard) if the total new plus replaced hard surface is 5,000 square feet or more.*
References
• Volume 1, Section 2.2.1 – Parcel-based Project • Volume 1, Section 2.3 - Figure 2.7 – Public Combined Sewer Basins • Volume 1, Section 5.3.5 (SMC, Section 22.805.080.G) – Peak Control Standard • Volume 3, Section 3.4 – BMP Selection for Flow Control • Volume 3, Section 4.1 – Sizing Approach

4.1.3.6. Parcel-based Projects Discharging to a Capacity-constrained System – Flow Control

Stormwater Code Language

SMC, 22.805.050 - Minimum requirements for parcel-based projects

C. Flow control. Parcel-based projects shall meet the minimum requirements for flow control contained in Section 22.805.080, to the extent allowed by law, as prescribed below.

6 — *Discharges to a capacity-constrained system. In addition to applicable minimum requirements for flow control in subsection 22.805.050.C.1 through subsection 22.805.050.C.5, parcel-based projects discharging into a capacity-constrained system or its basin shall also comply with subsection 22.805.080.G (Peak control standard) if the total new plus replaced hard surface is 5,000 square feet or more unless the downstream system only includes ditches or culverts and the system has been determined to have sufficient capacity as specified in subsection 22.805.020.H (Ensure sufficient capacity).*

References

- Volume 1, Section 2.2.1 – Parcel-based Project
- Volume 1, Section 2.3 – Figures 2.10
- Volume 1, Section 3.8 – (SMC, Section 22.805.020.H) - Ensure Sufficient Capacity
- Volume 1, Section 4.1.3.1 (SMC, Section 22.805.050.C.1) – Discharges to Wetlands
- Volume 1, Section 4.1.3.2 (SMC, Section 22.805.050.C.2) – Discharges to Listed Creek Basins
- Volume 1, Section 4.1.3.3 (SMC, Section 22.805.050.C.3) – Discharges to Non-listed Creek Basins
- Volume 1, Section 4.1.3.4 (SMC, Section 22.805.050.C.4) – Discharges to Small Lake Basins
- Volume 1, Section 4.1.3.5 (SMC, Section 22.805.050.C.5) – Discharges to Public Combined Sewer
- Volume 1, Section 4.1.3.6 (SMC, Section 22.805.050.C.6) – Discharges to Capacity-constrained System
- Volume 1, Section 4.1.3.7 (SMC, Section 22.805.050.C.7) – Discharges from Groundwater
- Volume 1, Section 5.3.5 (SMC, Section 22.805.080.G) – Peak Control Standard
- Volume 3, Section 3.4 – BMP Selection for Flow Control
- Volume 3, Section 4.1 – Sizing Approach

4.1.3.7. Parcel-based Projects Discharging Groundwater – Flow Control

Stormwater Code Language

SMC, 22.805.050 - Minimum requirements for parcel-based projects

C. Flow control. Parcel-based projects shall meet the minimum requirements for flow control contained in Section 22.805.080, to the extent allowed by law, as prescribed below.

7 — Discharges from groundwater. In addition to applicable minimum requirements for flow control in subsection 22.805.050.C.1 through subsection 22.805.050.C.6, parcel-based projects that will permanently discharge groundwater to a public drainage system or to a public combined sewer shall also comply with subsection 22.805.080.G (Peak control standard) if the total new plus replaced hard surface is 2,000 square feet or more.

SMC, 22.801.080 "G" — *"Groundwater" means "groundwater" as defined in chapter 173-200 WAC (Water Quality Standards for Groundwaters of the State of Washington) and includes water, perched or otherwise, in a saturated zone or stratum beneath the surface of land or below a surface water body.*

References
• Volume 1, Section 2.2.1 – Parcel-based Project • Volume 1, Section 4.1.3.1 (SMC, Section 22.805.050.C.1) – Discharges to Wetlands • Volume 1, Section 4.1.3.2 (SMC, Section 22.805.050.C.2) – Discharges to Listed Creek Basins • Volume 1, Section 4.1.3.3 (SMC, Section 22.805.050.C.3) – Discharges to Non-listed Creek Basins • Volume 1, Section 4.1.3.4 (SMC, Section 22.805.050.C.4) – Discharges to Small Lake Basins • Volume 1, Section 4.1.3.5 (SMC, Section 22.805.050.C.5) – Discharges to Public Combined Sewer • Volume 1, Section 4.1.3.6 (SMC, Section 22.805.050.C.6) – Discharges to Capacity-constrained System • Volume 1, Section 4.1.3.7 (SMC, Section 22.805.050.C.7) – Discharges from Groundwater • Volume 1, Section 5.3.5 (SMC, Section 22.805.080.B.5) – Peak Control Standard

Note: If the subsurface drainage for a project (e.g., footing drains, wall drains) extends into a zone containing groundwater, perched or otherwise, evaluation of groundwater discharge is required.

If the total estimated groundwater discharge rate from the project site during the wet season is less than 5 gallons per minute for sites less than 1 acre or less than 5 gallons per minute per acre for sites 1 acre or greater, then the groundwater discharge is de minimis and will not trigger Peak Control Standard. However, if the flow control is triggered by another condition, the estimated groundwater discharge rate must be considered in the sizing of the flow control BMPs. Estimates of groundwater discharge must be made by a licensed geotechnical engineer or hydrogeologist.

4.1.4. Water Quality Treatment

Stormwater Code Language
SMC, 22.805.050 - Minimum requirements for parcel-based projects D — *Treatment. Parcel-based projects not discharging to the public combined sewer shall comply with the minimum requirements for treatment contained in Section 22.805.090 for flows from the total new plus replaced pollution-generating hard surface and the new plus replaced pollution-generating pervious surface, to the extent allowed by law, if:* 1. *The total new plus replaced pollution-generating hard surface is 5,000 square feet or more; or* 2. *The total new plus replaced pollution-generating pervious surfaces is 3/4 acres or more, and from which there is a surface discharge in a natural or constructed conveyance system from the site.*
References
• Volume 1, Section 2.2.1 – Parcel-based Project • Volume 1, Section 5.4 (SMC, Section 22.805.090) – Water Quality Treatment • Volume 3, Section 3.5 – BMP Selection for Water Quality Treatment • Volume 3, Section 4.1 – Sizing Approach

4.2. Trail and Sidewalk Projects

The applicable code language and references for trail and sidewalk projects are summarized below. Note that trail and sidewalk projects are not required to install flow control or water quality treatment BMPs if the project meets the definition of a trail or sidewalk project.

4.2.1. Soil Amendment

Stormwater Code Language
SMC, 22.805.040 — *Minimum requirements for trail and sidewalk projects* *A. Soil amendment. Retain and protect undisturbed soil in areas not being developed, and prior to completion of the project, amend all new, replaced, and disturbed topsoil (including construction lay-down areas) with organic matter to the extent required by and in compliance with the rules promulgated by the Director.*
References
• Volume 1, Section 2.2.2 – Sidewalk Project • Volume 1, Section 2.2.3 – Trail Project • Volume 1, Section 5.1 – Soil Amendment • Volume 3, Section 5.1 – Soil Amendment BMP

4.2.2. On-site Stormwater Management

Stormwater Code Language
SMC, 22.805.040 — *Minimum requirements for trail and sidewalk projects* *B. On-site stormwater management. All trail and sidewalk projects with 2,000 square feet or more of new plus replaced hard surface or 7,000 square feet or more of land disturbing activity shall meet the minimum requirements for on-site stormwater management contained in Section 22.805.070, to the extent allowed by law.*
References
• Volume 1, Section 2.2.2 – Sidewalk Project • Volume 1, Section 2.2.3 – Trail Project • Volume 1, Section 5.2 (SMC, Section 22.805.070)– On-site Stormwater Management • Volume 3, Section 3.3 – BMP Selection for On-site Stormwater Management

4.3. Roadway Projects

Roadway projects must meet the minimum requirements for soil amendment (SMC, Subsection 22.805.060.A), on-site stormwater management (SMC, Subsection 22.805.020.F), flow control (SMC, Section 22.805.080), and water quality treatment (SMC, Section 22.805.090) when applicable. Key minimum requirements for roadway projects are summarized in Figures 4.2a through 4.2c.

4.3.1. Soil Amendment

Stormwater Code Language
SMC, 22.805.060- *Minimum requirements for roadway projects* A — *Soil amendment. Retain and protect undisturbed soil in areas not being developed, and prior to completion of the project, amend all new, replaced, and disturbed topsoil (including construction lay-down areas) with organic matter to the extent required by and in compliance with the rules promulgated by the Director.*
References
• Volume 1, Section 2.2.4 – Roadway Project • Volume 1, Section 5.1 – Soil Amendment • Volume 3, Section 5.1 – Soil Amendment BMP

4.3.2. On-site Stormwater Management

Stormwater Code Language
SMC, 22.805.060- *Minimum requirements for roadway projects* *B — On-site stormwater management. All roadway projects with 2,000 square feet or more of new plus replaced hard surface or 7,000 square feet or more of land disturbing activity shall meet the requirements for on-site stormwater management contained in Section 22.805.070, to the extent allowed by law, except as provided in subsection 22.805.060.E.*
References
• Volume 1, Section 2.2.4 – Roadway Project • Volume 1, Section 5.2 (SMC, Section 22.805.070) – On-site Stormwater Management • Volume 3, Section 3.3 – BMP Selection for On-site Stormwater Management

4.3.3. Flow Control

In addition to meeting a forested, pasture, or wetland protection standard, roadway projects discharging to a capacity-constrained system (SMC, Section 22.801.040) will also be required to meet the existing condition standard (SMC, Subsection 22.805.080.B.4) if required per *Section 4.3.3.5* Roadway Projects Discharging to a Capacity-Constrained System – Flow Control.

4.3.3.1. Roadway Projects Discharging to Wetlands – Flow Control

Stormwater Code Language

SMC, 22.805.060 - *Minimum requirements for roadway projects*

C. Flow control. Roadway projects shall meet the minimum requirements for flow control contained in Section 22.805.080, to the extent allowed by law, as prescribed below, except as provided in subsection 22.805.060.E.

1 — *Discharges to wetlands. Roadway projects discharging into a wetland or to the drainage basin of a wetland, shall:*

a. *Comply with Section 22.805.020 (Minimum requirements for all projects), including, but not limited to subsection 22.805.020.E (Protect wetlands).*

b. *Comply with the minimum requirements for wetland protection contained in subsection 22.805.080.C (Wetland protection standards) if the existing hard surface coverage is less than 35 percent and one or more of the following apply:*

   1) *The total new plus replaced hard surface is 5,000 square feet or more; or*

   2) *The project converts 3/4 acres or more of vegetation to lawn or landscaped areas, and from the project there is a surface discharge into a natural or constructed conveyance system from the site; or*

   3) *The project converts 2.5 acres or more of native vegetation to pasture and from the project there is a surface discharge into a natural or constructed conveyance system from the site.*

c. *Comply with the minimum requirements for wetland protection contained in subsection 22.805.080.C (Wetland protection standards) if the existing hard surface coverage is greater than or equal to 35 percent and one or more of the following apply:*

   1) *The total new plus replaced hard surface is 10,000 square feet or more. If the new plus replaced hard surfaces total 50 percent or more of the existing hard surfaces within the project limits, comply with subsection 22.805.080.C for the flows from the total new plus replaced hard surfaces; if the new plus replaced hard surfaces total less than 50 percent, comply with subsection 22.805.080.C for the flows from the total new hard surfaces. The project limits are defined by the length of the project and the width of the right-of-way; or*

   2) *The project converts 3/4 acres or more of vegetation to lawn or landscaped areas, and from the project there is a surface discharge into a natural or constructed conveyance system from the site; or*

   3) *The project converts 2.5 acres or more of native vegetation to pasture and from the project there is a surface discharge into a natural or constructed conveyance system from the site.*

References

- Volume 1, Section 2.2.4 – Roadway Project
- Volume 1, Section 3.5 (SMC, Section 22.805.020.E) – Protect Wetlands
- Volume 1, Section 5.3.1 (SMC, Section 22.805.080.B.1) – Wetland Protection Standards
- SWMMWW Volume I, Appendix I-C (Ecology 2024)

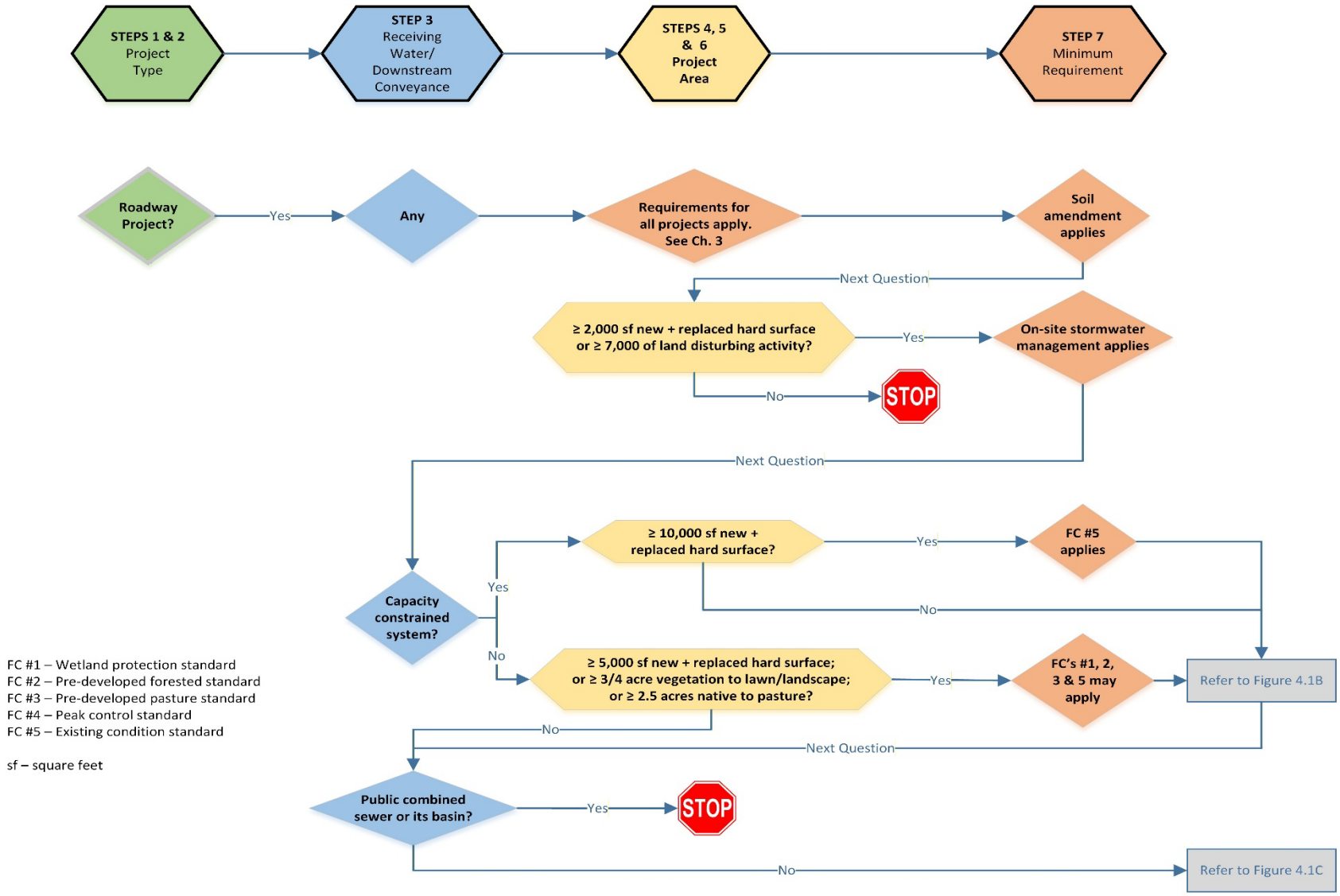

Figure 4.2A. Project Minimum Requirements for Roadway Projects.

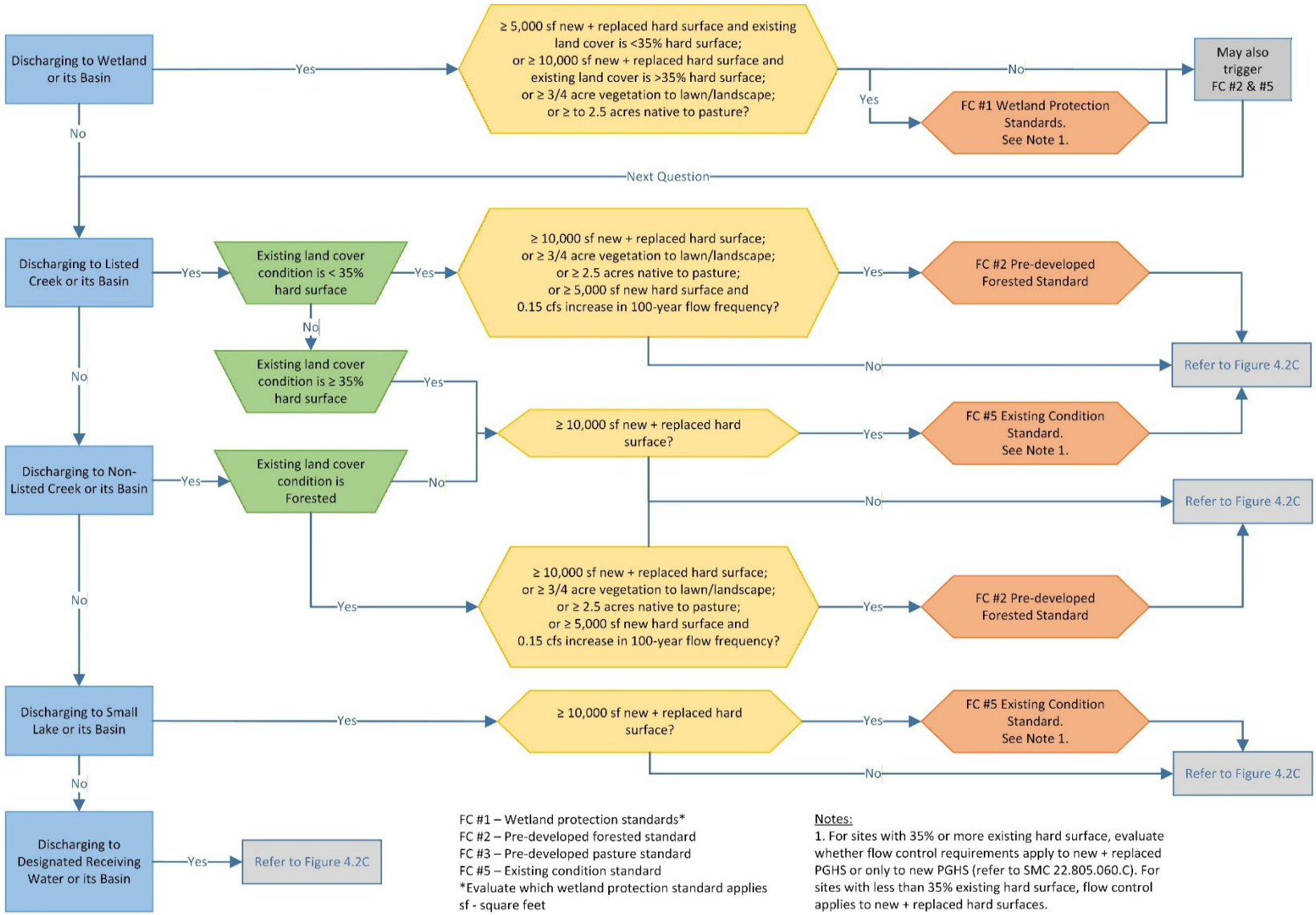

Figure 4.2B. Project Minimum Requirements for Roadway Projects (continued).

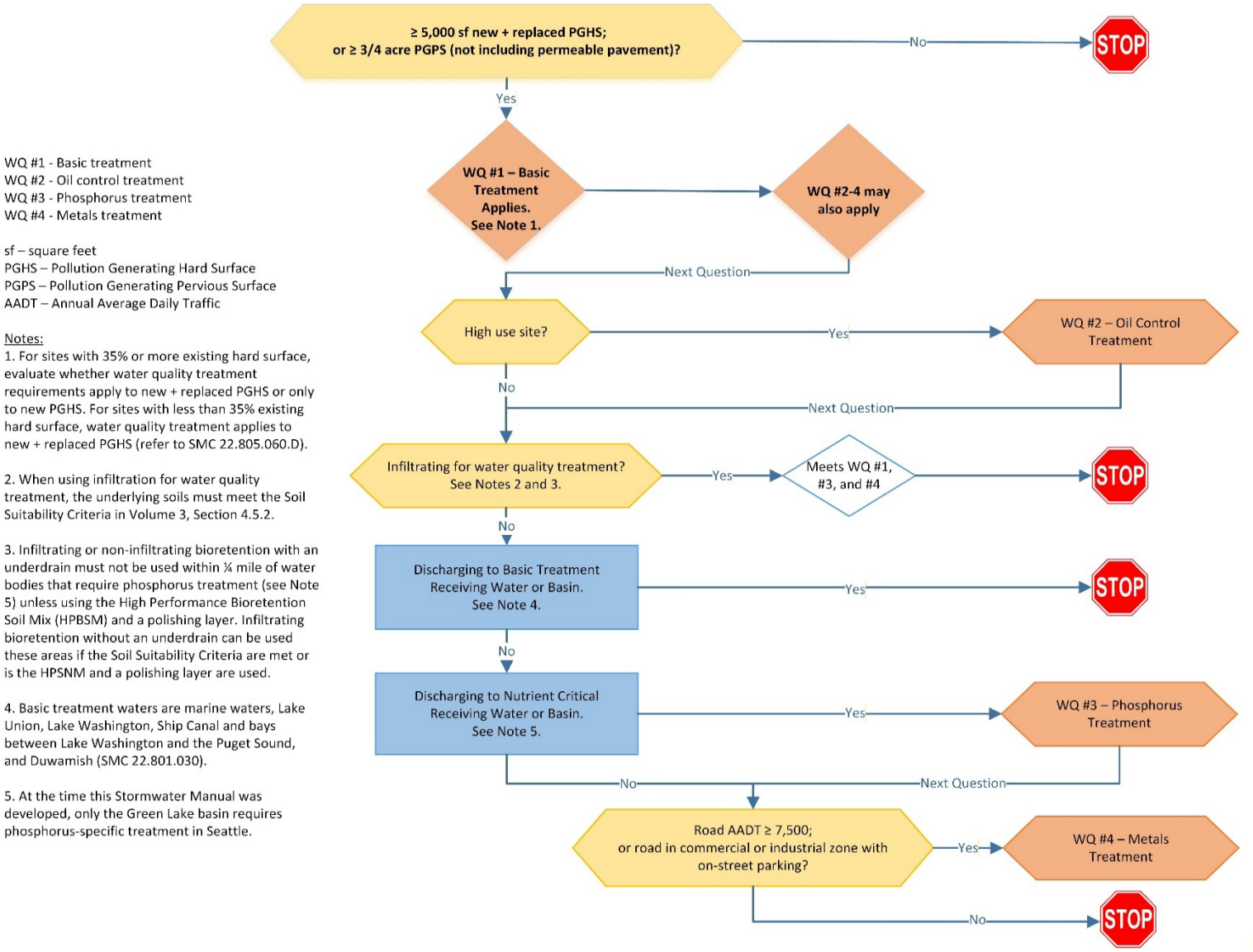

Figure 4.2C. Project Minimum Requirements for Roadway Projects (continued).

4.3.3.2. Roadway Projects Discharging to Listed Creek Basins – Flow Control

Stormwater Code Language

SMC, 22.805.060- *Minimum requirements for roadway projects*

C. Flow control. Roadway projects shall meet the minimum requirements for flow control contained in Section 22.805.080, to the extent allowed by law, as prescribed below, except as provided in subsection 22.805.060.E.

2 — Discharges to listed creek basins. Roadway projects discharging into Blue Ridge Creek, Broadview Creek, Discovery Park Creek, Durham Creek, Frink Creek, Golden Gardens Creek, Kiwanis Ravine/Wolfe Creek, Licton Springs Creek, Madrona Park Creek, Mee-Kwa-Mooks Creek, Mount Baker Park Creek, Puget Creek, Riverview Creek, Schmitz Creek, Taylor Creek, or Washington Park Creek, or to the drainage basin of such creek, shall:

a. Comply with subsection 22.805.080.D (Pre-developed forested standard) if the existing hard surface coverage is less than 35 percent and one or more of the following apply:

1) The project adds 10,000 square feet or more of new plus replaced hard surface; or

2) The project converts 3/4 acres or more of vegetation to lawn or landscaped areas, and from the project there is a surface discharge into a natural or constructed conveyance system from the site; or

3) The project converts 2.5 acres or more of native vegetation to pasture, and from the project there is a surface discharge into a natural or constructed conveyance system from the site; or

4) The project adds 5,000 square feet or more of new hard surface and, through a combination of effective hard surfaces and converted pervious surfaces, causes a 0.15 cubic feet per second increase in the 100-year recurrence interval flow frequency as estimated using a continuous model approved by the Director.

b. Comply with subsection 22.805.080.F (Existing condition standard) if the criteria in subsection 22.805.060.C.2.a do not apply and the total new plus replaced hard surface is 10,000 square feet or more, and:

1) If the new plus replaced hard surfaces total 50 percent or more of the existing hard surfaces within the project limits, comply with subsection 22.805.080.F (Existing condition standard) for the flows from the total new plus replaced hard surfaces. The project limits are defined by the length of the project and the width of the right-of-way; or

2) If the new plus replaced hard surfaces total less than 50 percent of the existing hard surfaces within the project limits, comply with subsection 22.805.080.F (Existing condition standard) for the flows from the total new hard surfaces. The project limits are defined by the length of the project and the width of the right-of-way.

References

- Volume 1, Section 2.2.4 – Roadway Project
- Volume 1, Section 2.3 – Figures 2.5 and 2.6
- Volume 1, Section 5.3.2 (SMC, Section 22.805.080.D) – Pre-developed Forested Standard
- Volume 1, Section 5.3.4 (SMC, Section 22.805.080.F) – Existing Condition Standard
- Volume 3, Section 3.4 – BMP Selection for Flow Control
- Volume 3, Section 4.1 – Sizing Approach

4.3.3.3. Roadway Projects Discharging to Non-listed Creek Basins – Flow Control

Stormwater Code Language

SMC, 22.805.060 - *Minimum requirements for roadway projects*

C. Flow control. Roadway projects shall meet the minimum requirements for flow control contained in Section 22.805.080, to the extent allowed by law, as prescribed below, except as provided in subsection 22.805.060.E.

3 – *Discharges to non-listed creek basins. Roadway projects discharging into a creek not listed in subsection 22.805.060.C.2, or to the drainage basin of such creek, shall:*

a. *Comply with subsection 22.805.080.D (Pre-developed forested standard) if the existing land cover is forested and one or more of the following apply:*

   1) *The project adds 10,000 square feet or more of new plus replaced hard surface; or*

   2) *The project converts 3/4 acres or more of vegetation to lawn or landscaped areas, and from the project there is a surface discharge into a natural or constructed conveyance system from the site; or*

   3) *The project converts 2.5 acres or more of native vegetation to pasture, and from the project there is a surface discharge into a natural or constructed conveyance system from the site; or*

   4) *The project adds 5,000 square feet or more of new hard surface and, through a combination of effective hard surfaces and converted pervious surfaces, causes a 0.15 cubic feet per second increase in the 100-year recurrence interval flow frequency as estimated using a continuous model approved by the Director.*

b. *Comply with subsection 22.805.080.F (Existing condition standard) if the criteria in subsection 22.805.060.C.3.a do not apply and the total new plus replaced hard surface is 10,000 square feet or more, and:*

   1) *If the new plus replaced hard surfaces total 50 percent or more of the existing hard surfaces within the project limits, comply with subsection 22.805.080.F (Existing condition standard) for the flows from the total new plus replaced hard surfaces. The project limits are defined by the length of the project and the width of the right-of-way; or*

   2) *If the new plus replaced hard surfaces total less than 50 percent of the existing hard surfaces within the project limits, comply with subsection 22.805.080.F (Existing condition standard) for the flows from the total new hard surfaces. The project limits are defined by the length of the project and the width of the right-of-way.*

References

- Volume 1, Section 2.2.4 – Roadway Project
- Volume 1, Section 2.3 – Figures 2.5 and 2.6
- Volume 1, Section 5.3.2 (SMC, Section 22.805.080.D) – Pre-developed Forested Standard
- Volume 1, Section 5.3.4 (SMC, Section 22.805.080.F) – Existing Condition Standard
- Volume 3, Section 3.4 – BMP Selection for Flow Control
- Volume 3, Section 4.1 – Sizing Approach

4.3.3.4. Roadway Projects Discharging to Small Lake Basins – Flow Control

Stormwater Code Language

SMC, 22.805.060 - *Minimum requirements for roadway projects*

C. Flow control. Roadway projects shall meet the minimum requirements for flow control contained in Section 22.805.080, to the extent allowed by law, as prescribed below, except as provided in subsection 22.805.060.E.

4 – *Discharges to small lake basins. Roadway projects discharging into Bitter Lake, Green Lake, or Haller Lake, or to the drainage basin of such lake, shall comply with subsection 22.805.080.F (Existing condition standard) if the total new plus replaced hard surface is 10,000 square feet or more, and:*

a. *If the new plus replaced hard surfaces total 50 percent or more of the existing hard surfaces within the project limits, comply with subsection 22.805.080.F (Existing condition standard) for the flows from the total new plus replaced hard surfaces. The project limits are defined by the length of the project and the width of the right-of-way; or*

b. *If the new plus replaced hard surfaces total less than 50 percent of the existing hard surfaces within the project limits, comply with subsection 22.805.080.F (Existing condition standard) for the flows from the total new hard surfaces. The project limits are defined by the length of the project and the width of the right-of-way.*

References

- Volume 1, Section 2.2.4 – Roadway Project
- Volume 1, Section 2.3 – Figures 2.5 and 2.6
- Volume 1, Section 5.3.4 (SMC, Section 22.805.080.F) – Existing Condition Standard
- Volume 3, Section 3.4 – BMP Selection for Flow Control
- Volume 3, Section 4.1 – Sizing Approach

4.3.3.5. Roadway Projects Discharging to a Capacity-constrained System – Flow Control

Stormwater Code Language
SMC, 22.805.060- *Minimum requirements for roadway projects* *C. Flow control. Roadway projects shall meet the minimum requirements for flow control contained in Section 22.805.080, to the extent allowed by law, as prescribed below, except as provided in subsection 22.805.060.E.* 5 – *Discharges to a capacity-constrained system. In addition to applicable minimum requirements for flow control in subsection 22.805.060.C.1 through subsection 22.805.060.C.4, roadway projects discharging into a capacity-constrained system or its basin shall also comply with subsection 22.805.080.F (Existing condition standard) if the total new hard surface is 10,000 square feet or more unless the downstream system only includes ditches or culverts and has been determined to have sufficient capacity as specified in 22.805.020.H (Ensure sufficient capacity).*
SMC, 22.801.040 – *"Capacity-constrained system" means a drainage system or public combined sewer that the Director of SPU has determined to have inadequate capacity to carry existing and anticipated loads, or a drainage system that includes ditches or culverts.*
References
• Volume 1, Section 2.2.4 – Roadway Project • Volume 1, Section 2.3 – Figures 2.10 • Volume 1, Section 3.8 – (SMC, Section 22.805.020.H) - Ensure Sufficient Capacity • Volume 1, Section 5.3.4 (SMC, Section 22.805.080.F) – Existing Condition Standard • Volume 3, Section 3.4 – BMP Selection for Flow Control • Volume 3, Section 4.1 – Sizing Approach

4.3.4. Water Quality Treatment

Stormwater Code Language

See SMC, 22.805.060. – *Minimum requirements for roadway projects*

D. Treatment. Roadway projects not discharging to the public combined sewer shall, to the extent allowed by law, except as provided in subsection 22.805.060.E:

1. If the site has less than 35 percent existing hard surface coverage, and the project's total new plus replaced pollution-generating hard surface is 5,000 square feet or more, comply with the minimum requirements for treatment contained in Section 22.805.090 for flows from the total new plus replaced pollution-generating hard surface and new plus replaced pollution-generating pervious surface; and

2. If the site has greater than or equal to 35 percent existing hard surface coverage and the project's total new plus replaced pollution-generating hard surface is 5,000 square feet or more, and

a. If the new plus replaced pollution-generating hard surfaces total 50 percent or more of the existing hard surfaces within the project limits, comply with the minimum requirements for treatment contained in Section 22.805.090 for flows from the total new plus replaced pollution-generating hard surface and new plus replaced pollution-generating pervious surface. The project limits are defined by the length of the project and the width of the right-of-way; or

b. If the new plus replaced pollution-generating hard surfaces total less than 50 percent of the existing hard surfaces within the project limits, comply with the minimum requirements for treatment contained in Section 22.805.090 for flows from the total new pollution-generating hard surface and new pollution-generating pervious surface. The project limits are defined by the length of the project and the width of the right-of-way; and

3. If the total new plus replaced pollution-generating pervious surfaces is 3/4 acres or more, and from which there is a surface discharge in a natural or constructed conveyance system from the site, comply with the minimum requirements for treatment contained in Section 22.805.090 for flows from the total new plus replaced pollution-generating pervious surface and the new plus replaced pollution-generating hard surface.

References

- Volume 1, Section 2.2.4 – Roadway Project
- Volume 1, Section 5.4 (SMC, Section 22.805.090) – Water Quality Treatment
- Volume 3, Section 3.5 – BMP Selection for Water Quality Treatment
- Volume 3, Section 4.1 – Sizing Approach

CHAPTER 5 – Minimum Requirement Standards

This chapter summarizes the standards related to the following minimum requirements:

- Soil amendment (*Section 5.1*)
- On-site stormwater management (*Section 5.2*)
- Flow control (*Section 5.3*)
- Water quality treatment (*Section 5.4*)

5.1. Soil Amendment

Projects triggering this minimum requirement must retain and protect undisturbed soil in areas not being developed and, prior to completion of the project, amend all new, replaced, and disturbed topsoil with organic matter. General soil amendment requirements included in the Stormwater Code are summarized below. Refer to *Volume 3, Section 5.1* – Soil Amendment BMP for soil amendment requirements.

Stormwater Code Language
See SMC, Subsection 22.805.040.A; SMC, Subsection 22.805.050.A; SMC, Subsection 22.805.060.A – *Soil amendment. Retain and protect undisturbed soil in areas not being developed, and prior to completion of the project, amend all new, replaced, and disturbed topsoil (including construction lay-down areas) with organic matter to the extent required by and in compliance with the rules promulgated by the Director.*

5.2. On-site Stormwater Management

Projects triggering this minimum requirement must evaluate on-site stormwater management to meet the applicable design requirements for the specific project type and discharge location. On-site stormwater management includes BMPs that can be used to meet flow control and water quality treatment requirements. General on-site stormwater management requirements included in SMC, Section 22.805.070 are summarized below. Refer to *Section 5.2.1* and *5.2.2* for the On-site Performance Standard and the On-site List Approach.

Stormwater Code Language
SMC, 22.805.070 - *Minimum requirements for on-site stormwater management* *A. Applicability. The requirements of this Section 22.805.070 apply as required in Section 22.805.040to Section 22.805.060.* *B. Requirements. On-site stormwater management shall be installed to the extent allowed by law and maintained in compliance with the rules promulgated by the Director to receive flows from that portion of the site being developed and shall:* *1. Comply with either:* *a. Subsection 22.805.070.C (On-site performance standard); or* *b. Subsection 22.805.070.D (On-site lists).*
References
• Volume 1, Section 4.1 – On-site Stormwater Management for Parcel-based Projects • Volume 1, Section 4.2.2 – On-site Stormwater Management for Trail and Sidewalk Projects • Volume 1, Section 4.3.2 – On-site Stormwater Management for Roadway Projects • Volume 1, Section 5.2.1 (SMC, Section 22.805.070.C) – On-site Performance Standard • Volume 1, Section 5.2.2 (SMC, Section 22.805.070.D) – On-site Lists • Volume 3, Section 3.3 – BMP Selection for On-site Stormwater Management • Volume 3, Section 4.1.1 – Sizing Approach - On-site List • Appendix C – On-site List Infeasibility Criteria

Projects triggering this minimum requirement must evaluate on-site stormwater management to meet the applicable design requirements for the given project type, size, and discharge location as summarized in *Chapter 2*. Two approaches that can be used for evaluating Minimum Requirements for On-site Stormwater Management include:

- On-site Performance Standard per *Section 5.2.1*
- On-site Lists per *Section 5.2.2*

5.2.1. On-site Performance Standard

Stormwater Code Language
SMC, 22.805.070.C – *On-site performance standard:* *1. If the existing hard surface coverage is less than 35 percent and the project discharges to a listed creek, or to the drainage basin of such creek:* *a. The post-development discharge durations shall match the discharge durations of a pre-developed forested condition for the range of pre-developed discharge rates from 8 percent of the 2-year peak flow to 50 percent of the 2-year peak flow.* *2. For all other projects:* a. *The post-development discharge durations shall match the discharge durations of a pre-developed pasture condition for the range of pre-developed discharge rates between the 1 percent and 10 percent exceedance values.*

References
• Volume 3, Section 3.3.2 – On-site Performance Standard Approach • Volume 3, Section 4.1.3 – Modeling Approach • Appendix F – Hydrologic Analysis and Design

Refer to *Volume 3, Section 3.3.2* and *Appendix F, Section F-4*, subsection "On-site Performance Standard BMP Design" for guidance about applying the performance standard.

5.2.2. On-site Lists

Stormwater Code Language

SMC, 22.805.070.D – *On-site lists*

1. *For each project surface, follow the appropriate project table in this subsection 22.805.070.D to evaluate on-site BMPs shown for that type of surface, by category. The project tables apply to roofs and other hard (non-roof) surfaces. All on-site BMPs used must comply with the rules promulgated by the Director. For each surface, consider all the applicable on-site BMPs in the first category. Use any that is considered feasible. If none is feasible for that surface, move on to each successive category and repeat the selection process as necessary. Once one on-site BMP is used for a surface, no other on-site BMP is necessary for that surface. If no BMP in the appropriate categories is feasible, then no further evaluation is required for that surface under this subsection 22.805.070.D.1. Feasibility shall be determined by evaluation against:*
   a. *Design criteria, minimum size, limitations, and infeasibility criteria identified for each BMP in this subsection 22.805.070.D and the rules promulgated by the Director; and*
   b. *Competing needs. This subsection 22.805.070.D may be superseded or reduced by the Director if the installation of the BMPs is in conflict with:*
      1) *Any of the following federal or state laws, rules, and standards, as may be amended or superseded: Historic Preservation and Archaeology Laws identified in subsection 22.805.070.E (Historic preservation and archaeology laws), Federal Superfund or Washington State Model Toxics Control Act, Federal Aviation Administration requirements for airports, the Americans with Disabilities Act, and related rules and standards; or*
      2) *Special zoning district design criteria adopted and being implemented pursuant to a community planning process. Special zoning districts include, for example, historic and preservation districts, pedestrian zone overlays, station area overlays, special review districts, multifamily residential zones, urban centers and urban villages, and master planned communities. Specific criteria in these areas include, but are not limited to, minimum Floor Area Ratio standards; zero lot line development; usable open space requirements; minimum sidewalk width and required bicycle facilities; alley, loading, and access requirements; pitched roof standards; and street-level development standards for modulation and projections; or*
      3) *Public health and safety standards; or*
      4) *Transportation regulations to maintain the option for future expansion or multi-modal use of public rights-of-way; or*
      5) *Chapter 15.43 (Tree and Vegetation Management in Public Places); Chapter 25.09 (Regulations for Environmentally Critical Areas); Chapter 25.11 (Tree Protection); and Chapter 23.60A (Standards for Vegetation in the Shoreline Master Plan).*
2. *For parcel-based projects, Table A for 22.805.070 applies.*
3. *For trail and sidewalk projects, Table B for 22.805.070 applies.*
4. *For roadway projects, Table C for 22.805.070 applies.*

References
• Volume 1, Section 5.2.2.1 – Parcel-based Projects On-site List • Volume 1, Section 5.2.2.2 – Trail and Sidewalk Projects On-site List • Volume 1, Section 5.2.2.3 – Roadway Projects On-site List • Volume 3, Section 3.3.1 – On-site List Approach • Volume 3, Section 4.1.1 – On-site List Approach • Appendix C – On-site List Infeasibility Criteria

5.2.2.1. Parcel-based Projects

Table A for 22.805.070 On-site List for Parcel-based Projects

Category	BMPs	Projects Discharging to a Receiving Water Not Designated by Section 22.801.050, Public Combined Sewer, or Capacity-constrained System, or its Basin	Projects Discharging to a Designated Receiving Water or its Basin
1	Full Dispersion	R, S	R, S
	Infiltration Trenches	R, S[g]	R, S[g]
	Drywells	R, S[g]	R, S[g]
	Rainwater Harvesting—Category 1 Sizing	X[e]	X[e]
2	Rain Gardens With or Without Tree	R[a] , S[a]	R[a] , S[a]
	Infiltrating Bioretention With or Without Tree	R, S	R, S
	Infiltrating Soil Cell Bioretention With Tree	X	X
	Permeable Pavement Facilities or approved equivalent	R, S	R, S
	Permeable Pavement Surfaces or approved equivalent[h]	S	S
	Sidewalk/Trail Compost-Amended Strip[h]	S	S
3	Infiltrating Soil Cell Bioretention Without Tree	X	X
	Sheet Flow Dispersion	R, S	R, S
	Concentrated Flow Dispersion	S	S
	Splashblock Downspout Dispersion	R	R
	Trench Downspout Dispersion	R	R
4	Non-infiltrating Bioretention	R[d] , S[d]	R[d] , S[d]
	Non-Infiltrating Soil Cell Bioretention With Tree	X	X
	Rainwater Harvesting—Category 4 Sizing	R[b, f]	X[f]
	Vegetated Roofs	R[c]	R[c]
	Residential Cistern	X	X
5	Perforated Stub-out Connections	R	R
	Trees	S	S

Note that subsection 22.805.070.D.1 requires consideration of all on-site BMPs in a category for feasibility before moving on to each successive category as necessary. Within a category, BMPs may be considered in any order.

Key to Table C for 22.805.070

R = Evaluation is required for all roof runoff from parcel-based projects.

S = Evaluation is required for all other hard (non-roof) surfaces of parcel-based projects, unless otherwise noted below.

X = Evaluation is not required but is allowed.

[a] Rain gardens cannot be used to meet Section 22.805.080 (Minimum Requirements for Flow Control) or Section 22.805.090 (Minimum Requirements for Treatment) or for areas of 5,000 square feet or more hard surface infiltrating on the project site.

[b] Evaluation is not required for projects with less than 20,000 square feet of new plus replaced rooftop surface.

[c] Evaluation is not required for projects with less than 5,000 square feet of new plus replaced rooftop surface.

[d] Water quality treatment BMPs sized to meet Section 22.805.090 (Minimum Requirements for Treatment) may be installed in lieu of non-infiltrating bioretention unless the project discharges to a public combined sewer basin.

[e] Category 1 rainwater harvesting shall be sized to meet the on-site performance standard, subsection 22.805.070.C.

[f] Category 4 rainwater harvesting shall be sized to reduce the runoff volume by 25 percent or more on an annual average basis.

[g] Evaluation of other hard (non-roof) surfaces is not required but is allowed.

[h] Infiltration testing is not required to use for the on-site list approach; it is only necessary to prove infeasibility.

5.2.2.2. Trail and Sidewalk Projects

Table B for 22.805.070 On-site List for Trail and Sidewalk Projects

Category	BMPs	Projects Discharging to a Receiving Water Not Designated by Section 22.801.050, or its Basin	Projects Discharging to a Public Combined Sewer or Capacity-constrained System,[c] or its Basin	Projects Discharging to a Designated Receiving Water, or its Basin
1	Full Dispersion	S	S	S
2	Rain Gardens With or Without Tree	S	S	X
	Infiltrating Soil Cell Bioretention With Tree[d]	X	X	X
	Permeable Pavement Facilities	X	X[a]	X[a, b]
	Permeable Pavement Surfaces[e]	S	S[a]	X[a, b]
	Sidewalk/Trail Compost-Amended Strip[e]	S	S	X
3	Sheet Flow Dispersion	S	S	S
	Concentrated Flow Dispersion	S	S	S
4	Trees	S	S	S

Note that subsection 22.805.070.D.1 requires consideration of all on-site BMPs in a category for feasibility before moving on to each successive category as necessary. Within a category, BMPs may be considered in any order.

Key to Table B for 22.805.070

S = Evaluation is required for all surfaces of trail or sidewalk projects.

X = Evaluation is not required for trail or sidewalk projects.

[a] Minimum permeable pavement area allowed in right-of-way is 2,000 square feet of pavement within the project site.

[b] Installation is not allowed in the right-of-way if new plus replaced pollution-generating hard surface area is less than 2,000 square feet of pavement within the project site

[c] Does not include any project discharging to a receiving water not designated by Section 22.801.050, or its basin, even if the project discharges to a capacity-constrained system or its basin.

[d] Tree is required unless considered infeasible per rules promulgated by the Director.

[e] Infiltration testing is not required to use for the on-site list approach, it is only necessary to prove infeasibility.

5.2.2.3. Roadway Projects

Category	BMPs	Projects Discharging to a Receiving Water Not Designated by Section 22.801.050, or its Basin	Projects Discharging to a Public Combined Sewer or Capacity-constrained System,[g] or its Basin	Projects Discharging to a Designated Receiving Water or its Basin
1	Full Dispersion	S	S	S
2	Rain Gardens With Tree[h]	S[a]	S[a]	S[a]
	Infiltrating Bioretention With Tree[h]	S	S[b]	S[b, c]
	Infiltrating Soil Cell Bioretention With Tree[h]	X	X	X
	Permeable Pavement Facilities	X[d]	X[e, f]	X[c, e, f]
	Permeable Pavement Surfaces[i]	S[d]	S[e, f]	X[c, e, f]
	Sidewalk/Trail Compost-Amended Strip[i]	S[e]	S[e]	S[e]
3	Sheet Flow Dispersion	S	S	S
	Concentrated Flow Dispersion	S	S	S
4	Trees	S	S	S
	Non-Infiltrating Soil Cell Bioretention With Tree[h]	X	X	X

Note that subsection 22.805.070.D.1 requires consideration of all on-site BMPs in a category for feasibility before moving on to each successive category as necessary. Within a category, BMPs may be considered in any order.

Key to Table C for 22.805.070

S = Evaluation is required for all surfaces of Roadway Projects.

X = Evaluation is not required for Roadway Projects, but is allowed.

[a] Rain gardens cannot be used to meet Section 22.805.080 (Minimum Requirements for Flow Control) or Section 22.805.090 (Minimum Requirements for Treatment) or for projects with areas of 5,000 square feet or more hard surface infiltrating on the project site.

[b] Minimum bioretention cell size top area in right-of-way is 500 square feet (including pre-settling area). Evaluation is only required and installation only allowed when contributing area is sufficient to warrant minimum bioretention cell size in right-of-way.

[c] Evaluation is not required, and installation is not allowed, if new plus replaced pollution-generating hard surface is less than 2,000 square feet.

[d] Evaluation of roadway surfaces is not required, and installation is not allowed, if roadway is an arterial street/collector.

[e] Evaluation of roadway surfaces, including alleys, is not required and installation is not allowed.

[f] Minimum permeable pavement area allowed in right-of-way is 2,000 square feet of pavement within the project site.

[g] Does not include any project discharging to a receiving water not designated by Section 22.801.050, or its basin, even if the project discharges to a capacity-constrained system or its basin.

[h] Tree is required unless considered infeasible per rules promulgated by the Director.

[i] Infiltration testing is not required to use for the on-site list approach; it is only necessary to prove infeasibility.

5.3. Flow Control

Projects triggering this minimum requirement must install flow control BMPs meeting the applicable design requirements for the given project type, size, and discharge location as summarized in *Chapter 2*. General flow control requirements included in SMC, Section 22.805.080 are summarized below. Refer to *Sections 5.3.1* through *5.3.5* for specific flow control standards for wetland protection, pre-developed forested, pre-developed pasture, existing condition, and peak control.

Stormwater Code Language
SMC, 22.805.080 – *Minimum requirements for flow control* *A. Applicability. The requirements of this Section 22.805.080 apply to the extent required in Section 22.805.050 to Section 22.805.060.* *B. Requirements. Flow control facilities shall be installed to the extent allowed by law and maintained pursuant to rules promulgated by the Director to receive flows from that portion of the site being developed. Post-development discharge determination must include flows from dewatering activities. All projects shall use on-site BMPs identified in subsection 22.805.070.D or other infiltration BMPs authorized by rule to the maximum extent feasible to meet the minimum requirements. Flow control facilities that receive flows from less than that portion of the site being developed may be installed if the total new plus replaced impervious surface is less than 10,000 square feet, the project site uses only on-site BMPs to meet the requirement, and the on-site BMPs provide substantially equivalent environmental protection as facilities not using on-site BMPs that receive flows from all of the portion of the site being developed.*
References
• Volume 1, Section 4.1.3 – Minimum Requirements for Flow Control for Parcel-based Projects • Volume 1, Section 4.3.3 – Minimum Requirements for Flow Control for Roadway Projects • Volume 1, Section 5.2.2 (SMC 22.805.070.D) – On-site Lists • Volume 1, Section 5.3.1 – Wetland Protection Standards • Volume 1, Section 5.3.2 – Pre-developed Forested Standard • Volume 1, Section 5.3.3 – Pre-developed Pasture Standard • Volume 1, Section 5.3.4 – Existing Condition Standard • Volume 1, Section 5.3.5 – Peak Control Standard • Volume 3, Section 4.1.3 – Modeling Approach • Volume 3, Section 4.4 – Presettling and Pretreatment Requirements • Volume 3, Section 5.4 – Infiltration BMPs

Note:

- If a project requires compliance with the Peak Control Standard and either the Pre-developed Forested or Pre-developed Pasture Standard apply, the BMP must be sized to meet both standards unless otherwise allowed using the Pre-sized Approach (refer to *Volume 3, Section 4.1.2*).
- Projects with 35 percent or greater existing hard surface may manage a smaller portion of the project's new and replaced hard surface area to meet flow control requirements if only On-site BMPs are employed.

  - Specifically, if flow control is required and only On-site BMPs are used, the hard surface area requiring management may be reduced by up to 2,000 square feet if On-site BMPs are used to the maximum extent feasible per 22.805.080.B.

- When off-site flows cannot feasibly bypass proposed flow control BMPs, the flow control BMPs must be modeled and sized to handle the combined total flow (refer to *Volume 3, Section 4.2.2*).
- Flow control BMPs are not required if the site fully infiltrates all flows as determined by a licensed civil engineer using an approved continuous runoff model for the 158-year simulation period (refer to *Appendix F*).
- The Flow Control Standards are applied to the full project site. Stormwater modeling must account for runoff from all hard surfaces and pervious surfaces within the project site. Refer to *Volume 3, Section 4.2.3* for guidance about runoff from the site that bypasses the flow control BMP.
- For detention BMPs, the minimum bottom orifice diameter (i.e., 0.5 inches for underground detention BMPs) will be too large to meet standard release rates in some scenarios, even with minimal head. Refer to *Volume 3, Section 4.1.3.2* for sizing guidance when this occurs.

5.3.1. Wetland Protection Standards

Stormwater Code Language

SMC, 22.805.080.C – *Wetland protection standards*

1. *Protect the functions and values of wetlands and their buffers from all projects discharging stormwater directly or indirectly to them. The hydrologic conditions, vegetative community, and substrate characteristics of the wetlands shall be protected, and impacts caused by changes in water flows and pollutants shall be prevented. The introduction of sediment, heat, and other pollutants and contaminants into wetlands shall be minimized through the selection, design, installation, and maintenance of temporary and permanent controls.*
2. *Before authorizing new discharges to a wetland, alternative discharge locations shall be evaluated and infiltration options outside the wetland shall be maximized unless doing so will adversely impact the functions and values of the affected wetlands.*
3. *If the wetland protection standard cannot be met due to Sections 22.805.070 or 22.805.090, the wetland protection standard shall be met to the maximum extent feasible while fully meeting the on-site stormwater management and water quality treatment requirements, unless an analysis by a wetland professional per rules promulgated under subsection 25.09.330.C (Technical Reports) is conducted that demonstrates that the functions and values of the affected wetland are not protected.*
4. *If one or more of the flow control requirements contained in subsections 22.805.080.D through 22.805.080.F also applies to the project, the wetland standard must be met to ensure that the functions and values of the affected wetland are protected before implementing these flow control requirements to the full extent.*
5. *Notwithstanding any provision in this subtitle, no net loss of wetland functions or values shall result from actions regulated by this subtitle.*
6. *Refer to the Washington State Wetland Rating System for Western Washington: 2014 Update, Version 2.0 (Hruby, 2023) to determine the category, characteristics, and habitat score of the wetland. Wetland classification shall be determined by a wetland professional per rules promulgated under subsection 25.09.330.C (Technical reports).*

Stormwater Code Language

7. *Projects triggering Method 1 or Method 2 in this subsection 22.805.080.C shall refer to I-C.4, Wetland Hydroperiod Protection and I-C-5, Wetland Hydroperiod Data Collection, Evaluation Procedures, and Strategies presented in Appendix I-C of Ecology's Stormwater Management Manual for Western Washington (Ecology 2024) for additional guidance.*
8. *Comply with subsection 22.805.080.C.10 (Wetland Protection Standard—Method 1: Monitoring and Wetland Stage Modeling) if the following applies:*
    a. *The project discharges to a Category I or II depressional or riverine impounding wetland; and*
    b. *The project owner has legal access to the entire wetland for purposes of conducting monitoring in the wetland.*
9. *Comply with subsection 22.805.080.C.11 (Wetland Protection Standard—Method 2: Site Discharge Modeling) if the criteria in subsection 22.805.080.C.8do not apply and one or more of the following applies (or applicability is unknown):*
    a. *The wetland is Class I or II and does not meet the requirements of subsection 22.805.080.C.8.*
    b. *The wetland is Class III or IV and:*
        1) *Has a habitat score greater than 5;*
        2) *Is interdunal and has special characteristics;*
        3) *Provides habitat for rare, threatened, endangered, or sensitive species; or*
        4) *Contains breeding population of any native amphibian. Per Ecology's guidance, wetlands with permanent or seasonal ponding or inundation are assumed to have breeding population of native amphibian.*
10. *Wetland Protection Standard—Method 1: Monitoring and Wetland Stage Modeling. Comply with I-C.4, Wetland Hydroperiod Protection, presented in Appendix I-C of Ecology's Stormwater Management Manual for Western Washington (Ecology 2024).*
11. *Wetland Protection Standard—Method 2: Site Discharge Modeling. The total volume of stormwater discharging from the project site into a wetland shall not be more than:*
    a. *On a daily basis, 20 percent higher or lower than the pre-project volume, and*
    b. *On a monthly basis,*
        1) *20 percent higher or lower than the pre-project volumes for the months of October, November, and December, and*
        2) *15 percent higher or lower than the pre-project volumes for all other months (January through September).*

References

- Volume 1, Section 3.5 – Protect Wetlands
- Volume 1, Section 5.3 - Flow Control
- Volume 1, Section 5.3.2 (SMC, Section 22.805.080.D) – Pre-developed Forested Standard
- Volume 1, Section 5.3.3 (SMC, Section 22.805.080.E) – Pre-developed Pasture Standard
- Volume 1, Section 5.3.4 (SMC, Section 22.805.080.F) – Existing Condition Standard
- Volume 1, Section 5.3.5 (SMC, Section 22.805.080.G) – Peak Control Standard
- Volume 3, Section 3.4 – BMP Selection for Flow Control
- SWMMWW Volume I, Appendix I-C (Ecology 2024)

Note:

- In some cases, other requirements (e.g., on-site stormwater management, flow control, water quality) may also apply when the Wetland Protection Standard applies. To ensure that the functions and values of the wetland are protected in these cases, the designer must attempt to meet all applicable requirements. If the designer is unable to meet all flow control standards, then the requirement to maintain the hydroperiod of the wetland becomes the overriding concern and the designer must show compliance with this Wetland Protection Standard unless a wetland professional demonstrates that values and functions the wetland are maintained. If this is the case, the designer must also provide documentation detailing why they are unable to meet the requirements of the other flow control standards. If the Wetland Protection Standard cannot be fully met due to the implementation of required on-site stormwater management or water quality BMPs, then the designer must attempt to meet the Wetland Protection Standard to the maximum extent feasible, while still meeting the on-site stormwater management and water quality standards, then consult with a wetland professional to demonstrate that the values and functions of the wetland are maintained.
- Refer to the Summer Months Allowable Exception for Method 2 Wetland Hydroperiod Protection in Ecology's SWMMWW Volume 1, Appendix 1-C for an alternative option if the project cannot meet the monthly basis criteria during July, August, and September.

5.3.2. Pre-developed Forested Standard

Stormwater Code Language
SMC, 22.805.080.D – *Pre-developed forested standard. The post-development discharge durations from the project site shall match the discharge durations of a pre-developed forested condition for the range of pre-developed discharge rates from 50 percent of the 2-year peak flow to the 50-year peak flow.*
References
• Volume 1, Section 5.3 - Flow Control • Volume 3, Section 3.4 – BMP Selection for Flow Control • Volume 3, Section 4.1 – Sizing Approach • Appendix F – Hydrologic Analysis and Design

5.3.3. Pre-developed Pasture Standard

Stormwater Code Language
SMC, 22.805.080.E – *Pre-developed pasture standard. The post-development discharge durations from the project site shall match the discharge durations of a pre-developed pasture condition for the range of pre-developed discharge rates from 50 percent of the 2-year peak flow to the 2-year peak flow.*

References
• Volume 1, Section 5.3 - Flow Control • Volume 3, Section 3.4 – BMP Selection for Flow Control • Volume 3, Section 4.1 – Sizing Approach • Appendix F – Hydrologic Analysis and Design

5.3.4. Existing Condition Standard

Stormwater Code Language
SMC, 22.805.080.F – *Existing condition standard. The post-development discharge durations from the project site shall be limited as follows:* 1. *Match the discharge durations of the existing land cover condition for the range of discharge rates from 50 percent of the 2-year peak flow to the 25-year peak flow; and* 2. *For discharges to a creek or a creek drainage basin or to a small lake or a small lake basin, also match the discharge durations of the existing land cover condition for the range of discharge rates from 50 percent of the 2-year peak flow to the 50-year peak flow.*

References
• Volume 1, Section 5.3 - Flow Control • Volume 3, Section 3.4 – BMP Selection for Flow Control • Volume 3, Section 4.1 – Sizing Approach • Appendix F – Hydrologic Analysis and Design

Existing land cover condition means the existing grade, drainage systems, vegetation, hard surface, land cover, and soils that exist at a site prior to any changes associated with achieving the proposed development conditions. Approved permits and engineering plans may be required. Existing land cover conditions may be verified using aerial photography or other records.

5.3.5. Peak Control Standard

Stormwater Code Language
SMC, 22.805.080.G – *Peak control standard. The post-development release rates from the project site shall be limited as follows:* 1. *The peak flow with a 50 percent annual probability (2-year recurrence flow) shall not exceed 0.07 cubic feet per second per acre;* 2. *The peak flow with a 20 percent annual probability (5-year recurrence flow) shall not exceed 0.10 cubic feet per second per acre; and* 3. *The peak flow with a 4 percent annual probability (25-year recurrence flow) shall not exceed 0.40 cubic feet per second per acre.*

References
• Volume 1, Section 5.3 - Flow Control • Volume 3, Section 3.4 – BMP Selection for Flow Control • Volume 3, Section 4.1 – Sizing Approach • Appendix F – Hydrologic Analysis and Design

Note: The post-development release rates for the Peak Control Standard are based on the full project site. Calculate the allowable release rates using the full project site and include the full project site in the continuous runoff model, including both the pervious and the hard surfaces.

5.4. Water Quality Treatment

Projects triggering this minimum requirement based on the amount of pollution-generating surface must install water quality treatment BMPs, which typically remove pollutants through a combination of gravity settling, filtration, biological uptake, and soil adsorption. General water quality treatment requirements included in SMC, Section 22.805.090 are summarized below.

Note:

- Projects with 35 percent or greater existing hard surface may manage a smaller portion of the project's new and replaced hard surface area to meet water quality treatment requirements if only On-site BMPs are employed. Specifically, if water quality treatment is required and only On-site BMPs are used, the hard surface area requiring management may be reduced by up to 2,000 square feet if On-site BMPs are used to the maximum extent feasible.
- An approved landscape management plan (LMP) can be used as an alternative to the requirement to formally treat (with a water quality treatment BMP) the runoff from pollution-generating pervious surfaces subject to water quality treatment. An LMP is a City-approved plan for defining the layout and long-term maintenance of landscaping features to minimize the use of pesticides and fertilizers, and reduce the discharge of suspended solids and other pollutants. Runoff from a hard surface area that is routed to a pervious area is not included in an LMP and must be addressed separately through applying Minimum Requirements #5, #6, #7, or some combination. LMPs do not apply to artificial turf fields because pesticides and fertilizers are not the associated pollutants of concern. LMPs must be updated if the layout of landscaping features will be substantially modified or if specific maintenance approaches will be altered from the approved LMP. Refer to *Appendix I* for LMP submittal requirements.
- Refer to *Volume 3, Section 4.4* for applicable presettling and pretreatment requirements.

Stormwater Code Language
SMC, 22.805.090 – *Minimum requirements for treatment* A. *Applicability. The requirements of this Section 22.805.090 apply to the extent required in Section 22.805.050 to Section 22.805.060.* B. *Requirements. Water quality treatment facilities shall be installed to the extent allowed by law and maintained pursuant to rules promulgated by the Director to treat flows from the pollution-generating pervious and hard surfaces on the site being developed. When stormwater flows from other areas, including non-pollution generating surfaces (e.g., roofs), dewatering activities, and off-site areas, cannot be separated or bypassed, treatment BMPs shall be designed for the entire area draining to the treatment facility. All projects shall use on-site BMPs identified in subsection 22.805.070.D, or other infiltration BMPs authorized by rule, to the maximum extent feasible to meet the minimum requirements. For pollution-generating pervious surfaces other than artificial turf, a landscape management plan developed according to rules promulgated by the Director may be utilized in lieu of installing water quality treatment facilities.*

References
• Volume 1, Section 4.1.4 – Treatment Requirements for Parcel-based Projects • Volume 1, Section 4.3.4 – Treatment Requirements for Roadway Projects • Volume 1, Section 5.2.2 (SMC 22.805.070.D) – On-site Lists • Volume 1, Section 5.4.1.1 – Runoff Treatment Volume • Volume 1, Section 5.4.1.2 – Runoff Treatment Rates • Volume 1, Section 5.4.1.3 – Infiltration Treatment Requirements • Volume 1, Section 5.4.2 – Water Quality Treatment Standards • Volume 3, Section 4.1.3 – Modeling Approach • Volume 3, Section 4.4 – Presettling and Pretreatment Requirements • Volume 3, Section 5.4 – Infiltration BMPs

Water quality treatment BMPs must be designed based on the stormwater runoff volume from the contributing area or a peak flow rate as outlined in the following subsections.

5.4.1. General Water Quality Treatment Requirements

5.4.1.1. Runoff Treatment Volume

The water quality design treatment volume is determined as follows:

Stormwater Code Language
SMC, 22.805.090.B.1.a – *The daily runoff volume at or below which 91 percent of the total runoff volume for the simulation period occurs, as determined using an approved continuous model. It is calculated as follows:* *1) Rank the daily runoff volumes from highest to lowest.* *2) Sum all the daily volumes and multiply by 0.09.* *3) Sequentially sum daily runoff volumes, starting with the highest value, until the total equals 9 percent of the total runoff volume. The last daily value added to the sum is defined as the water quality design volume.*
References
• Volume 1, Section 5.4 – Water Quality Treatment • Volume 1, Section 5.4.1.3 – Infiltration Treatment Requirements • Volume 3, Section 4.1 – Sizing Approach • Appendix F – Hydrologic Analysis and Design

5.4.1.2. Runoff Treatment Rates

Stormwater Code Language
SMC, 22.805.090.B.1.b – *Different design flow rates are required depending on whether a treatment facility will be located upstream or downstream of a detention facility:* *1) For facilities located upstream of detention or when detention is not required, the design flow rate is the flow rate at or below which 91 percent of the total runoff volume for the simulation period is treated, as determined using an approved continuous runoff model.* *2) For facilities located downstream of detention, the design flow rate shall be the full 2-year release rate, as determined using an approved continuous runoff model.*

References
• Volume 1, Section 5.4 – Water Quality Treatment • Volume 3, Section 4.1 – Sizing Approach • Appendix F – Hydrologic Analysis and Design

5.4.1.3. Infiltration Treatment Requirements

Stormwater Code Language
SMC 22.805.090.B.1.c – *Infiltration facilities designed for water quality treatment must infiltrate 91 percent of the total runoff volume as determined using an approved continuous runoff model. To prevent the onset of anaerobic conditions, an infiltration facility designed for water quality treatment purposes must be designed to drain the water quality design treatment volume (the 91st percentile, 24-hour volume) within 48 hours.*
References
• Volume 1, Section 5.4 – Water Quality Treatment • Volume 1, Section 5.4.1.1 – Runoff Treatment Volume • Volume 3, Section 4.1 – Sizing Approach • Volume 3, Section 4.4 – Presettling and Pretreatment Requirements • Appendix F – Hydrologic Analysis and Design

Note that the "91st percentile, 24-hour volume" referenced above represents the upper limit of the range of daily volumes that accounts for 91 percent of the entire runoff volume over a multi-decade period of record.

5.4.2. Water Quality Treatment Standards

Projects triggering this minimum requirement must install water quality treatment BMPs for the given project type, size, and discharge location as summarized in *Chapter 2*. Refer to *Sections 5.4.2.1* through *5.4.2.4* for oil, phosphorus, metals, and basic water quality treatment standards.

When triggered, water quality treatment BMPs must be installed to treat flows from the pollution-generating hard surface (PGHS) and pollution-generating pervious surface (PGPS) on the site being developed. When stormwater flows from other areas, including non-PGHS (e.g., roofs), dewatering activities, and flows that cannot be separated or bypassed, water quality treatment BMPs must be sized for the combined total flow.

Stormwater Code Language
SMC, 22.805.090.B.6 – *Discharges to groundwater. Direct discharge of untreated drainage water from pollution-generating hard surfaces to groundwater is prohibited.*
References
• Volume 1, Section 5.4 – Water Quality Treatment • Volume 3, Section 4.5.2 – Soil Requirements for Water Quality Treatment

5.4.2.1. Oil Control Treatment

Oil control treatment applies to projects that include "high-use sites" or have NPDES permits that require application of oil control. Oil control treatment is in addition to other water quality treatment requirements (i.e., phosphorus, metals, or basic). The petroleum storage and transfer standard is intended to address regular transfer operations such as gasoline service stations.

The project proponent must develop an Average Daily Traffic (ADT) estimate for approval by the City (http://data-seattlecitygis.opendata.arcgis.com/search?tags=transportation). In addition to the typical sites outlined in the definition for a high-use site, the City may also require oil control treatment to be used on other sites that have the potential to generate high concentrations of oil or have oil handling activity.

Stormwater Code Language
SMC, 22.805.090.B.3 – *Oil control treatment. An oil control treatment facility is required for high-use sites, as defined in this subtitle.*
SMC, 22.801.090 – "*High-use sites" means sites that typically generate high concentrations of oil due to high traffic turnover or the frequent transfer of oil or other petroleum products. High-use sites include:* 1. *An area of a commercial or industrial site subject to an expected average daily traffic (ADT) count equal to or greater than 100 vehicles per 1,000 square feet of gross building area; 300 or more total trip ends per day; or both;* 2. *An area of a commercial or industrial site subject to petroleum storage and transfer in excess of 1,500 gallons per year, not including routinely delivered heating oil;* 3. *An area of a commercial or industrial site subject to parking, storage or maintenance of 25 or more vehicles that are over 10 tons gross weight (trucks, buses, trains, heavy equipment, etc.);* 4. *A road intersection with a measured ADT count of 25,000 vehicles or more on the main roadway and 15,000 vehicles or more on any intersecting roadway, excluding projects proposing primarily pedestrian or bicycle use improvements.*
References
• Volume 3, Section 3.5 – BMP Selection for Water Quality Treatment

5.4.2.2. Phosphorus Treatment

The requirement to provide phosphorus treatment is determined by the discharge location of the project. Phosphorus treatment is required for projects discharging stormwater to or infiltrating within 1/4 mile of a nutrient-critical receiving water or a tributary to that water. If the soil suitability criteria for infiltrating BMPs are met (refer to *Volume 3, Section 4.5.2*) and pre-settling is provided (refer to *Volume 3, Section 4.4*), then it is assumed that the phosphorus treatment performance goal is met.

At the time this Manual was developed, Green Lake was the only nutrient-critical receiving water determined to be impaired due to phosphorus contributed by stormwater. In the future, the City may designate additional waterbodies as nutrient-critical receiving water as defined by the SMC, Section 22.801.150. Refer to the SDCI website to determine if any

nutrient-critical receiving waters have been designated (www.seattle.gov/sdci/codes/codes-we-enforce-(a-z)/stormwater-code).

Stormwater Code Language
SMC, 22.805.090.B.4 – *Phosphorus treatment. A phosphorus treatment facility is required for projects discharging into nutrient-critical receiving waters.*
References
• Volume 1, Section 2.3 – Identify the Receiving Water and Downstream Conveyance • Volume 1, Figure 2.5 – North End Creek and Small Lake Basins • Volume 3, Section 3.5 – BMP Selection for Water Quality Treatment • Volume 3, Section 4.4.3.2 – Pretreatment

Project sites subject to the phosphorus treatment requirement could also be subject to the oil treatment and metals treatment requirements (*Section 5.4.2.1* and *Section 5.4.2.3*).

5.4.2.3. Metals Treatment

The requirement to provide metals treatment (previously known as enhanced treatment) is determined by the discharge location of the project and activities occurring on the project site. If the soil suitability criteria for infiltrating BMPs are met (refer to *Volume 3, Section 4.5.2*) and pre-settling is provided (refer to *Volume 3, Section 4.4*), then it is assumed that the metals treatment performance goal is met.

Stormwater Code Language
SMC, 22.805.090.B.5 – *Metals treatment. Except for landscaped areas (unless containing crumb rubber) and projects that discharge to a basic treatment receiving water, a metals treatment facility for reducing concentrations of dissolved metals is required for projects that discharge, directly or through conveyance systems, to fresh waters designated for aquatic life use or having an existing aquatic life use, or that use infiltration strictly for flow control (not treatment) and discharge within 1/4 mile of fresh waters designated for aquatic life use or having an existing aquatic life use, if the project meets one of the following criteria:* *a. For a parcel-based project, the project is industrial, is commercial, or proposes four or more dwelling units, or the site is subject to industrial activities.* *b. For a roadway project, the site includes a road:* *1) With an expected Annual Average Daily Traffic count of 7,500 or greater; or* *2) That provides on-street parking for commercial or industrial areas.*
References
• Volume 1, Section 5.4.2.4 – Basic Treatment • Volume 3, Section 3.5 – BMP Selection for Water Quality Treatment • Volume 3, Section 4.4.3.2 – Pretreatment

Note: Sites not considered residential, industrial, or road-related are considered commercial for the purposes of applying metals treatment requirements. Examples include fueling stations, transit facilities, parks, churches, schools, light rail guideways and tracks (both elevated and non-elevated), and other rail lines and railways.

Any portion of a project site (e.g., landscaped areas, including sports fields (unless containing crumb rubber)) that is identified as subject to basic treatment requirements only (*Section 5.4.2.4*) are not subject to metals treatment requirements.

Project sites subject to the metals treatment requirement could also be subject to the oil control treatment requirement (*Section 5.4.2.1*) and phosphorus treatment requirement (*Section 5.4.2.2*).

5.4.2.4. Basic Treatment

Projects triggering water quality treatment must install, at a minimum, a BMP that meets the basic treatment requirements. The requirements for oil control treatment (which may also be required if the project includes "high-use sites"; refer to *Section 5.4.2.1*), phosphorus treatment, and metals treatment are in addition to the basic treatment requirement. If the soil suitability criteria for infiltrating BMPs are met (refer to *Volume 3, Section 4.5.2*) and pre-settling is provided (refer to *Volume 3, Section 4.4*), then it is assumed that the basic treatment performance goal is met.

Stormwater Code Language
SMC, 22.805.090.B.2 – *Basic treatment. A basic treatment facility is required for all projects. The requirements of subsection 22.805.090.B.3 (Oil control treatment), subsection 22.805.090.B.4 (Phosphorus treatment), and subsection 22.805.090.B.5 (Metals treatment) are in addition to this basic treatment requirement.*
References
• Section 5.4.2.1 (SMC, Section 22.805.090.B.3) – Oil Control Treatment • Section 5.4.2.2 (SMC, Section 22.805.090.B.4) – Phosphorus Treatment • Section 5.4.2.3 (SMC, Section 22.805.090.B.5) – Metals Treatment • Volume 3, Section 3.5 – BMP Selection for Water Quality Treatment • Volume 3, Section 4.1 – Sizing Approach • Appendix F – Hydrologic Analysis and Design

Project sites subject to the basic treatment requirement per SMC, Chapter 22.805 could also be subject to the oil control treatment requirement (*Section 5.4.2.1*). Areas that provide phosphorus treatment or metals treatment do NOT have to provide additional basic treatment BMPs to meet the basic treatment performance goal.

Basic treatment is required in the following circumstances:

- Project sites that discharge stormwater to the ground (i.e., via infiltration) UNLESS:
  - The soil suitability criteria for infiltration treatment are met (refer to *Volume 3, Section 4.5.2*) and pre-settling is provided (refer to *Volume 3, Section 4.4*), or
  - The project site uses infiltration strictly for flow control — not treatment, or
  - The project site is required to provide metals treatment (refer to *Section 5.4.2.3*).
- Project sites discharging directly (or indirectly through a drainage system) to a Basic Treatment Receiving Water.

Stormwater Code Language
SMC, Section 22.801.030 – *"Basic treatment receiving water* *1. All marine waters, including Puget Sound;* *2. Lake Union;* *3. Lake Washington;* *4. Ship Canal and bays between Lake Washington and Puget Sound; and* *5. Duwamish River.*

- Project sites that drain to fresh waters or to waters tributary to fresh waters that are not designated for aquatic life use and that do not have an existing aquatic life use. As provided in Chapter 173-201A WAC, all surface waters of the State, including but not limited to wetlands, in or near the City are to be protected for designated aquatic life use. For the purposes of the Stormwater Code and this Manual, "fresh waters designated for aquatic life use" include at minimum fresh water wetlands, small lakes, creeks, and fresh water-designated receiving waters.
- Landscaped areas of industrial, commercial, and multifamily project sites per SMC, Subsection 22.805.090.B.5.

CHAPTER 6 – Alternative Compliance

Alternative compliance in creek basins applies only within the City of Seattle.

Stormwater Code Language

SMC, 22.800.080 *Authority*

E. The Director of SPU is authorized, to the extent allowed by law, to develop, review, or approve an Integrated Drainage Plan as an equivalent means of complying with the requirements of this subtitle, in which the developer of a project voluntarily enters into an agreement with the Director of SPU to implement an Integrated Drainage Plan that is specific to one or more sites where best management practices are employed such that the cumulative effect on the discharge from the site(s) to the same receiving water is the same or better than that which would be achieved by a less integrated, site-by-site implementation of best management practices.

F. For projects that do not discharge to the combined sewer system, the Director of SPU is authorized, to the extent allowed by law, to enter into an agreement with the developer to allow a project's flow control, water quality treatment, on-site stormwater management, or wetland protection requirements to be met at an alternative location if the following conditions are met, or if another scenario is approved by Ecology:

1. The developer enters the agreement voluntarily to contribute funds toward the construction of, or to construct, one or more drainage control facilities at an alternative location to mitigate the impacts to the same receiving water that have been identified as a consequence of the project; and

2. The alternative location is for an equivalent area in terms of flow and pollution characteristics when compared with the project, as determined by the Director; and

a. The site of the project has greater than or equal to 35 percent existing hard surface coverage and the project discharges to:

1) A listed creek and the equivalent area is in-basin, which means that the equivalent area is on the same site as the project, the project is located within contributing area to the equivalent area, or the equivalent area discharges from the public drainage system to the receiving water at the same point as (or upstream of) the point where the project area discharges from the public drainage system to the same receiving water; or

2) A receiving water other than a listed creek and the equivalent area discharges to the same receiving water as the project.

G. For projects that discharge to the combined sewer system, the Director of SPU is authorized, to the extent allowed by law, to enter into an agreement with the developer to allow a project's flow control or on-site stormwater management requirements to be met at an alternative location if the developer enters the agreement voluntarily to contribute funds towards the construction of, or to construct, one or more drainage control facilities at an alternative location, determined by the Director, to mitigate the impacts that have been identified as a consequence of the project.

When the consequences of the proposed development are from new hard surfaces, the mitigation should be provided at the same time as completion of the new surfaces. When the consequences of the proposed development are from replaced hard surfaces, there should be a construction plan and schedule that ensure the stormwater control BMP(s) mitigating the impacts are constructed within 5 years of the original development, which may be required by state law.

CHAPTER 7 – Exemptions, Adjustments, and Exceptions

7.1. Exemptions

Exemptions are described in SMC, Subsection 22.800.040.A. Refer to *Volume 1, Sections 2.2.6–2.2.10* for additional information related to exemptions, including Utility, Pavement Maintenance, Remediation, Retrofit, and WSDOT project provisions.

7.2. Adjustments

Stormwater Code Language
SMC, 22.800.040 *Exemptions, adjustments, and exceptions* *B. Adjustments* *1. The Director may approve a request for adjustments to the requirements of this subtitle when the Director finds that:* *a. The adjustment provides substantially equivalent environmental protection; and* *b. The objectives of safety, function, environmental protection, and facility maintenance are met, based on sound engineering practices.* *2. During construction, the Director may require, or the applicant may request, that the construction of drainage control facilities and associated project designs be adjusted if physical conditions are discovered on the site that are inconsistent with the assumptions upon which the approval was based, including but not limited to unexpected soil and/or water conditions, weather generated problems, or changes in the design of the improved areas.* *3. A request by the applicant for adjustments shall be submitted to the Director for approval prior to implementation. The request shall be in writing and shall provide facts substantiating the requirements of subsection 22.800.040.B.1 and, if made during construction, the factors in subsection 22.800.040.B.2. Any such modifications made during the construction of drainage control facilities shall be recorded on the final approved drainage control plan, a revised copy of which shall be filed by the Director.*

An adjustment request must be submitted as a separate, clearly labeled request for the Director's review and decision.

The request must include enough technical information to show how the proposal meets the adjustment criteria in SMC, Subsection 22.800.040.B. The adjustment request and supporting analysis must also be included in the project drainage report.

Example Application

For example, the Director may approve an adjustment to allow the use of an existing water quality treatment facility that does not meet the mass loading ratio requirements of this Manual where the applicant demonstrates that:

1. The project is otherwise required to conduct monitoring and comply with benchmark requirements; and
2. The existing facility will provide substantially equivalent environmental protection compared to the minimum water quality treatment requirements applicable to the project.

7.3. Exceptions

Exceptions for criteria and protocol related to a request for an exception to the requirements of the Stormwater Code are described in SMC, Subsection 22.800.040.C. Note, the criteria for granting an exception are extremely limited and require public notice of the exception application and the Director's decision.

VOLUME 2

CONSTRUCTION STORMWATER CONTROL

City of Seattle | Stormwater Manual

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City of Seattle

Note:

Some pages in this document have been purposely skipped or blank pages inserted so that this document will copy correctly when duplexed.

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CHAPTER 1 – Introduction

1.1. What is the Purpose of this Volume?

This volume is designed to help businesses, individuals, responsible parties, and public agencies in the City of Seattle (City) implement best management practices (BMPs) at project sites to:

- Prevent impacts to the public drainage system or public combined sewer and downstream resources.
- Stop pollutants from contaminating stormwater.

Uncontrolled stormwater can threaten downstream resources, such as public storm drains, real property, and natural habitat. It can also pollute our public drainage system or public combined sewer and receiving waters (e.g., creeks, streams, rivers, lakes, and Puget Sound). The resulting impacts can pose serious risks to the health, safety, and welfare of humans and the environment.

1.2. How Does this Volume Apply to Construction?

This volume applies to all construction projects in Seattle, defined in the Seattle Municipal Code (SMC), Chapter 22.801.170 as the addition or replacement of hard surface or the undertaking of land-disturbing activity.

The construction stormwater BMPs and requirements in this volume have been integrated from many programs and regulations, including the provisions of the:

- Federal Clean Water Act
- Federal Coastal Zone Management Act
- City of Seattle Phase I NPDES Municipal Stormwater Permit
- Puget Sound Partnership Action Agenda
- Washington State Department of Ecology (Ecology) Construction Stormwater General Permit
- City of Seattle Stormwater Code

1.2.1. City of Seattle Requirements

Under current City law, the responsible party is liable for water quality problems and impacts to downstream resources caused by construction work. Many construction projects with land disturbance require a permit from the Seattle Department of Construction and Inspections (SDCI) and most projects that occur in the street right-of-way require a permit from Seattle Department of Transportation (SDOT). Regardless of whether or not a permit is required, all construction stormwater must be controlled to prevent negative impacts.

If you are planning a construction project and need information concerning the applicable stormwater requirements, the first step is reviewing *Volume 1 — Project Minimum Requirements* and the applicable elements of the Stormwater Code. Code sections to review include, but are not limited to, SMC 22.805.020 (particularly subsection D), SMC 22.807.020 (for requirements related to drainage control review), and the definitions in SMC 22.801.

1.2.2. How to Use This Volume

- *Chapter 1* (this chapter) outlines the purpose and content of this volume.
- *Chapter 2* provides Construction Stormwater Control and Soil Management Plan requirements.
- *Chapter 3* provides an explanation for BMP selection based on project category and required BMPs.
- *Chapters 4* and *5* provide the standards and specifications for the BMPs contained in this volume.

Several appendices also support the information contained in this manual. These appendices include:

- *Appendix A* — Definitions
- *Appendix E* — Additional Stormwater Design Requirements
- *Appendix* F — Hydrologic Analysis and Design

1.3. What is Considered "Compliance"?

The City expects that the selection and implementation of appropriate BMPs outlined in this volume and other applicable manuals will result in compliance with the Stormwater Code's minimum requirements for project site stormwater pollution prevention control. If compliance is not achieved, additional measures must be implemented.

Proper implementation and maintenance of appropriate BMPs is critical to control any adverse water quality or downstream resource impacts from construction activity.

1.3.1. Surface Water Quality

Pollutants that might be expected in the discharge from project sites include, but are not limited to, sediment, pH, and petroleum products. Public drainage systems, public combined sewers, and receiving waters can be contaminated by direct discharges of these pollutants or from stormwater discharges that have become contaminated by direct contact with the pollutants or pollutants absorbed into sediment.

Soil erosion, sheet erosion, or downstream channel erosion can cause turbid (muddy) stormwater when the sediment contacts rainwater; this is the most common and visible form of construction stormwater pollution. The resulting high turbidity can adversely impact receiving waters if not properly controlled using the BMPs contained in this volume.

The sources of other commonly encountered pollutants include materials and chemicals used during day-to-day construction activities, such as concrete pouring, paving, truck and heavy equipment operation, and maintenance activities. Low and high pH (acidity) and petroleum products can adversely impact public drainage systems, public combined sewers, and receiving waters in more than one way. One direct impact is reduced water quality by introducing pollutants; another impact is decreased function of the public drainage system or public combined sewer by fouling and spreading pollutants in the pipe network.

Water Quality Standards for Surface Waters of the State of Washington are defined in the Washington Administrative Code (WAC) Chapter 173-201A. Contractors and other responsible parties must be familiar with the current water quality standards, particularly those targeting typical construction-related pollutants. For more information on surface water quality standards and specific criteria, refer to Ecology's website (https://ecology.wa.gov/Water-Shorelines/Water-quality/Water-quality-standards/Criteria).

It is illegal to discharge dirty water to the drainage system; however, the activity may be permitted for disposal in the sanitary sewer if authorized by the City and King County.

If sanitary sewer disposal is not available or not allowed, the contaminated water must be treated or transferred to a holding tank where it must be picked up for offsite disposal.

1.3.2. Groundwater Quality

Water quality standards for groundwaters of the State of Washington are designed to meet the goal of protecting the current and future beneficial uses of groundwater by preventing groundwater contamination. The primary water quality consideration for stormwater discharges to groundwater from project sites is the control of contaminants other than sediments.

For more information on groundwater quality standards, refer to Ecology's website (https://ecology.wa.gov/Water-Shorelines/Water-quality/Groundwater/Groundwater-quality-standards).

1.3.3. Downstream Infrastructure and Resources

The public drainage system or public combined sewer, real property, and natural habitat can be adversely impacted when an uncontrolled discharge leaves a project site. Common negative impacts can include soil erosion, flooding, habitat degradation, subsequent destructive after-effects due to increases in the stormwater volume, velocity, and peak flow rate, or some combination of these impacts.

Regulations and guidelines in the Stormwater Code and this volume may require construction of temporary stormwater retention, detention, or infiltration facilities to protect downstream resources. It is important to note that these facilities must be functioning prior to implementation of land-disturbing activity. If a permanent facility is used to control flows during construction, refer to *Volume 3* for design guidelines and criteria. *Volume 3* also provides design criteria to protect permanent infiltration facilities from siltation during the construction phase of the project. For most parcel-based projects, the temporary BMPs to be implemented from this volume should be sized to accommodate a storm with a 2-year or a 10-year recurrence interval (refer to specific BMPs for additional guidance regarding sizing).

Additional impacts to downstream infrastructure and resources can occur from dewatering activities as well. Projects that are required to comply with the Minimum Requirements for Flow Control must include the dewatering discharge volume as part of the total release rate allowed from the site.

1.3.4. Upstream Analysis of Runoff Entering a Construction Site

The designer must evaluate whether stormwater runoff from any offsite areas could flow onto the project site. If so, any offsite runoff must be re-routed around the construction site in a way that will not alter the water quality of the runoff or alternatively the construction stormwater BMPs must be designed to fully accommodate the offsite runoff. When sizing BMPs to account for offsite runoff entering the project site, determine the full area of the upstream basin that contributes runoff onto the site. If survey information is not available for the upstream basin, use topographic maps provided by the City or King County to determine the size of the basin and use aerial photos or field investigation to determine the existing land cover conditions. Size any sediment traps, tanks, or filtration systems to include the additional upstream flows; additional tanks may be necessary to collect run-on from upstream areas, especially during periods of heavy rain. If re-routing the runoff around the site, verify that the pipes or swales have capacity for the calculated flowrates from the upstream areas.

1.4. What is Considered "Out of Compliance"?

The Stormwater Code outlines compliance requirements for construction stormwater pollution prevention. If the required BMPs implemented do not effectively address erosion issues or the discharge of pollutants, additional BMPs may be required.

Violations are enforceable under the City's Stormwater Code SMC 22.808.030 and *Volume 5 — Enforcement* of this manual.

Examples of when a project would be considered out of compliance with the Stormwater Code include:

- A discharge leaves the project site and causes or contributes to a prohibited discharge, a turbidity or pH that exceeds the benchmarks, a known or likely violation of water quality standards in the receiving water, or violates the Phase I NPDES Municipal Stormwater General Permit (SMC, Chapter 22.805.010).
- A project that has not received all required permits and discharges to the public drainage system or public combined sewer.
- A discharge of oil or other harmful substances leaves the project site and enters the public combined sewer, public drainage system, or receiving waters.
- Sediment is tracked off the project site.
- A project site does not have a Construction Stormwater Control and Soil Management Plan.

This is not a comprehensive list of out of compliance events. If there is a question about compliance, visit the SDCI Applicant Services Center on the 20th floor of the Seattle Municipal Tower, 700 Fifth Avenue, Seattle, Washington 98124, or the City's website (www.seattle.gov/sdci).

1.5. Purpose of Construction Stormwater Best Management Practices (BMPs)

Construction stormwater BMPs are measures implemented to protect the public drainage system, public combined sewer system, and receiving waters from pollution and impacts to downstream resources during land-disturbing and other construction activities (refer to SMC, Chapter 22.801.030). For example:

- Construction activities such as clearing, grading, excavation, and stockpiling disturb established vegetation, trees, and stable soils.
- Concrete, asphalt, treated timber, and other construction materials involve chemicals and contaminants that must be retained on the project site.
- Construction activities can increase the volume and/or peak flow rate of discharges leaving the site. The discharges can increase sediment and pollution in receiving waters.
- Construction equipment introduces the potential for spills involving oil, gasoline, or other petroleum products.

In general, construction BMPs help prevent pollution from leaving the project site, eliminate ponding, flooding, or both in the public right-of-way, and minimize impacts to the public drainage system or public combined sewer. These measures fall into two general categories—erosion and sedimentation control and control of pollutants other than sediment.

Erosion and sediment control BMPs can be grouped according to three methods:

- Cover practices: a temporary or permanent cover designed to stabilize disturbed areas.
- Erosion control practices: physical measures designed and constructed to prevent erosion of project site soils.
- Sediment control practices: prevent eroded soils from leaving the project site by trapping them in a depression, filter, or other barrier.

Pollutants other than sediment are primarily controlled using good “housekeeping” practices and other methods outlined in this volume to reduce the risk of pollutant contact with stormwater or direct discharge to receiving waters.

Refer to *Volume 4 — Source Control*. This volume should be reviewed to ensure that all requirements are being met for each project.

CHAPTER 2 – Construction Stormwater Control and Soil Management Plans

The Construction Stormwater Control and Soil Management Plan applies best management practices (BMPs) that fall within the 19 elements of water quality, air quality, and downstream resource protection and are required by the Stormwater Code (SMC, Chapter 22.805.020.D). These 19 elements (refer to *Chapter 3*) cover general water and air quality protection strategies, including:

- Limiting project site impacts
- Protecting the public drainage system, combined and sanitary sewers, and downstream receiving waters
- Preventing erosion and sedimentation
- Managing activities and sources

Project designers must review the applicable elements of SMC 22.805.020.D and ensure the specific requirements under each of the 19 elements in the code are fully addressed by the project site stormwater pollution prevention controls.

2.1. Small Project Construction Stormwater Control and Soil Management Plan

For Small Projects (i.e., involving less than 5,000 square feet of new plus replaced hard surface or less than10,000 square feet of land-disturbing activity), the applicant must submit a Construction Stormwater Control and Soil Management Plan that demonstrates how the project will cover the required elements by using BMPs contained in this volume.

The first step after reviewing the Stormwater Code requirements is to refer to Attachment 1, Table 1a, Checklist to Select Small Project Construction BMPs. Small Projects are required to implement BMPs as dictated by site conditions. If a required element is not applicable, the reason must be justified briefly on the checklist and in detail in the plan narrative.

The next step is to prepare the Small Project Construction Stormwater Control and Soil Management Plan narrative section that describes the project and selected BMPs.

The narrative, and subsequently prepared plan, must include:

- The name, address, and phone number of the owner or contact person.
- A north arrow, lot number and plat, address, date, and street name fronting the structure.
- A description of all existing and proposed structures on the project site.
- Limits of disturbance, including all clearing, grading, and other land-disturbing activity.
- The location and size of all streams, swales, and drainage channels on or within 25 feet of the project site that may be impacted by or affect the drainage of the project site to be developed.

- A description of all existing stormwater pipes and their diameters and approximate lengths.
- The direction and location of stormwater runoff entering and exiting the project site from all adjacent properties (this may be done with topographic contour lines).
- "Point of discharge" labels for all discharges of stormwater, wastewater, etc. that leave the site or will be infiltrated on site.
- System discharge flowrate limits for construction stormwater, groundwater dewatering, and process water discharges. Refer to SPU Design Standards and Guidelines Appendix 18B Temporary Discharges for allowable discharge rates.
- The types of systems, including On-site BMPs, that will be used to convey runoff away from the proposed structures, if applicable.
- The steps that will be taken to retain native vegetation and minimize hard surfaces to the maximum extent feasible
- The types of wastewater that may be generated during the work and the types of collection or conveyance systems used to manage the waste, including disposal options.
- Location(s) where stormwater discharges are collected from the project site, including individual (point) flow and sheet flow (i.e., overland flow).
- A description of how construction will be phased so that only those areas actively being worked are uncovered.
- The construction entrance(s) and exit(s), as applicable.
- Stockpile and excavation locations.

First complete the narrative followed by the plan sheet. The plan sheet is not required to be prepared by a civil engineer; however, it is required to graphically show the information provided in the narrative, including how BMPs will be implemented.

The Construction Stormwater Control and Soil Management Plan can be obtained from the Seattle Department of Construction and Inspections (SDCI) web page, which has both pdf and CAD formats (www.seattle.gov/sdci/codes/codes-we-enforce-(a-z)/stormwater-code).

The applicant is responsible for modifying the Construction Stormwater Control and Soil Management Plan whenever directed to by the Inspector or when there is a change in design, construction, operation, or maintenance at the project site that has, or could have, a significant effect on the discharge of pollutants.

2.2. Large Project Construction Stormwater Control and Soil Management Plan

For Large Projects (i.e., greater than 5,000 square feet of new plus replaced hard surface or 10,000 square feet and greater of land-disturbing activity), the applicant must submit a Large Project Construction Stormwater Control and Soil Management Plan, including narrative and plan sheet(s), that demonstrate how the project will cover the 19 elements by using BMPs contained in this volume.

The first step is to refer to Attachment 1, Table 1b, Checklist to Select Large Project Construction BMPs. Large Projects are required to implement BMPs from all 19 elements. If a required element is not applicable, the reason must be justified briefly on the checklist and in detail in the plan narrative. The next step is to prepare the Large Project Construction Stormwater Control and Soil Management Plan narrative section and plan sheets that describe the project and selected BMPs. The Large Project Construction Stormwater Control and Soil Management Plan includes the same narrative and plan details required for the Small Project Construction Stormwater Control and Soil Management Plan (*Section 2.1*) plus additional narrative and plan sheet(s), as applicable.

The Large Project Construction Stormwater Control and Soil Management Plan must be prepared by a qualified professional. When the plan includes engineering calculations, it must be stamped and signed by an engineer licensed in the State of Washington.

2.3. Certified Erosion and Sediment Control Lead

2.3.1. Description

The project proponent must have a project representative who is a Certified Erosion and Sediment Control Lead (CESCL). The project proponent designates at least one person as the responsible representative in charge of erosion and sediment control and water quality protection. The designated person must be the CESCL.

2.3.2. Purpose

The purpose of a designated CESCL is to ensure compliance with all city, county, state, and federal erosion and sediment control and water quality requirements.

2.3.3. Conditions Where Practice Applies

A CESCL should be designated and made available on Large Projects. The CESCL must perform all duties and take on all responsibilities listed in this BMP.

2.3.4. Certification Criteria

The training and administrative requirements for the person designated as the CESCL are listed below. The CESCL should:

- Have a current certificate proving attendance in an erosion and sediment control (ESC) training course that meets the minimum ESC training and certification requirements established by the Washington State Department of Ecology (Ecology).
  Ecology maintains a list of ESC training and certification providers on its website (https://ecology.wa.gov/Regulations-Permits/Permits-certifications/Certified-erosion-sediment-control).

  OR

  Be a Certified Professional in Erosion and Sediment Control (CPESC). For additional information on the CPESC certification, refer to the EnvironCert International, Inc., website (www.envirocertintl.org/cpesc/).

- Certification must remain valid for the full duration of construction.

- The CESCL should have authority to act on behalf of the contractor or developer and should be available, on call, 24 hours per day throughout the period of construction.
- The name, telephone number, fax number, and address of the designated CESCL must be recorded in the Large Project Construction Stormwater Control and Soil Management Plan.
- A CESCL may provide inspection and compliance services for multiple construction projects in the same geographic region.

2.3.5. Duties and Responsibilities

The duties and responsibilities of the CESCL should include, but are not limited to, the following:

- Maintain all applicable documentation, permits, and plans on site at all times.
- Direct BMP installation, inspection, maintenance, modification, and removal.
- Update all project drawings and plans with changes made.
- Keep daily logs and inspection reports. Inspection reports should include:
  - Inspection date and time.
  - Weather information: general conditions during inspection and approximate amount of precipitation since the last inspection.
  - A summary or list of all BMPs implemented, including observations of all erosion and sediment control structures or practices. The following should be noted:
    - Locations of BMPs inspected
    - Locations of BMPs that need maintenance
    - Locations of BMPs that failed to operate as designed or intended
    - Locations of where additional or different BMPs are required
- Duties relating to temporary dewatering (BMP E4.20).
- Visual monitoring results, including a description of discharged stormwater. The presence of suspended sediment, turbid water, discoloration, and oil sheen should be noted, as applicable.
- Any water quality monitoring performed during inspection.
- General comments and notes, including a brief description of any BMP repairs, maintenance, or installations made as a result of the inspection.
- Facilitate, participate in, and take corrective actions resulting from inspections performed by outside agencies or the owner.
- Contact, or direct staff to contact, SPU's Operations Response Center (206-386-1800) and other appropriate agencies (e.g., Ecology, at 206-594-0000) if a discharge of turbid or otherwise polluted water enters the City's MS4, a receiving waterbody, or both (Note: MS4 includes streets with drainage assets).

The CESCL is responsible for modifying the Construction Stormwater Control and Soil Management Plan whenever there is a change in design, construction, operation, or maintenance at the project site that has, or could have, a significant effect on the discharge of pollutants, or when directed to by the Inspector.

CHAPTER 3 –Selecting Construction Stormwater Controls

Projects must implement best management practices (BMPs) from the 19 elements of general water quality and downstream resource protection strategies listed in SMC, Chapter 22.805.020.D. Refer to *Section 2.1* and *Section 2.2* for a discussion of Small and Large Project Construction Stormwater Control and Soil Management Plans, including the level of detail required for submittals. Also reference *Volume 1, Minimum Requirements for All Projects - Chapter 3.4* – Construction Site Stormwater Pollution Prevention Control for additional information

Attachment 1, Tables 1a and 1b present each of the 19 elements and required or recommended BMPs for Small and Large Project plans, respectively. Required BMPs must be implemented throughout construction. If a required element is not applicable, the reason must be justified briefly on the checklist and in detail in the plan narrative. The recommended BMPs are intended to provide further guidance for minimizing potential stormwater pollution resulting from activities. Using these additional BMPs is encouraged. BMPs referenced as "Ecology BMPs" can be found in Volume II of the Washington State Department of Ecology (Ecology) Stormwater Management Manual for Western Washington (SWMMWW), 2024 edition.

Refer to Attachment 1, Table 1a or 1b and the pre-application report (PAR) prepared by the City to identify the appropriate required and recommended BMPs for your project. The Small Project Construction Stormwater Control and Soil Management Plan and the Large Project Construction Stormwater Control and Soil Management Plan should document each selected BMP and its implementation, maintenance, and inspection requirements.

Note: The City may require additional measures beyond what are shown on the approved plan depending on Stormwater Code requirements, construction sequencing, and actual site conditions.

Stormwater Code Language

SMC 22.805.020.D – *Minimum Requirements for Construction Stormwater Pollution Prevention Plan. Temporary and permanent construction controls shall be used to accomplish [the 19 construction site stormwater pollution prevention control requirements outlined in SMC 22.805.020.D and Volume 2, Construction Stormwater Control]. All projects are required to meet each of the elements below or document why an element is not applicable. Additional controls may be required by the Director when minimum controls are not sufficient to prevent erosion or transport of sediment or other pollutants from the site.*

1. *Mark clearing limits and environmentally critical areas. Within the boundaries of the project site and prior to beginning land disturbing activities, including clearing and grading, clearly mark all clearing limits, easements, setbacks, all environmentally critical areas and their buffers, and all trees and drainage courses that are to be preserved within the construction area.*
2. *Retain top layer. Within the boundaries of the project site, the duff layer, topsoil, and native vegetation, if there is any, shall be retained in an undisturbed state to the maximum extent feasible. If it is not feasible to retain the top layer in place, it should be stockpiled on-site, covered to prevent erosion, and replaced immediately upon completion of the land disturbing activities to the maximum extent feasible.*
3. *Establish construction access. Limit construction vehicle access, whenever possible, to one route. Stabilize access points and minimize tracking sediment onto public roads. Promptly remove any sediment tracked off site.*

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4. *Protect downstream properties and receiving waters. Protect properties and receiving waters downstream from the development sites from erosion or flooding due to increases in the volume, velocity, duration, and peak flow rate of drainage water from the project site. If it is necessary to construct flow control facilities to meet this requirement, these facilities shall be functioning prior to implementation of other land disturbing activity. If permanent infiltration facilities are used to control flows during construction, these facilities shall be protected from siltation during the construction phase of the project.*
5. *Prevent erosion and sediment transport from the site. Pass all drainage water from disturbed areas through a sediment trap, sediment pond, or other appropriate sediment removal BMP before the water leaves the site or prior to discharge to an infiltration facility. Sediment controls intended to trap sediment on site shall be constructed as one of the first steps in grading and shall be functional before other land disturbing activities take place. BMPs intended to trap sedimentation shall be located in a manner to avoid interference with the movement of juvenile salmonids attempting to enter off-channel areas or drainages. Provide and maintain natural buffers around surface waters, direct stormwater to vegetated areas to increase sediment removal and maximize stormwater infiltration where feasible.*
6. *Prevent erosion and sediment transport from the site by vehicles. Whenever construction vehicle access routes intersect paved roads, the transport of sediment onto the paved road shall be minimized. If sediment is transported onto a paved road surface, the roads shall be cleaned thoroughly at the end of each day. Sediment shall be removed from paved roads by shoveling or sweeping and shall be transported to a controlled sediment disposal area. If sediment is tracked off site, roads shall be cleaned thoroughly at the end of each day, or at least twice daily during wet weather. Street washing is allowed only after sediment is removed, and street wash wastewater shall be prevented from entering the drainage system and receiving waters.*
7. *Stabilize soils. Prevent on-site erosion by stabilizing all exposed and unworked soils, including stock piles and earthen structures such as dams, dikes, and diversions. From October 1 to April 30, no soils shall remain exposed and unworked for more than two days. From May 1 to September 30, no soils shall remain exposed for more than seven days. Soils shall be stabilized at the end of the shift before a holiday or weekend if needed based on the weather forecast. Soil stockpiles shall be stabilized from erosion, protected with sediment trapping measures, and be located away from storm drain inlets, waterways, and drainage channels. Before the completion of the project, permanently stabilize all exposed soils that have been disturbed during construction.*
8. *Protect slopes. Erosion from slopes shall be minimized. Cut and fill slopes shall be designed and constructed in a manner that will minimize erosion. Off-site stormwater run-on or groundwater shall be diverted away from slopes and undisturbed areas with interceptor dikes, pipes, and/or swales. Pipe slope drains or protected channels shall be constructed at the top of slopes to collect drainage and prevent erosion. Excavated material shall be placed on the uphill side of trenches, consistent with safety and space considerations. Check dams shall be placed at regular intervals within constructed channels that are cut down a slope.*
9. *Protect storm drains. Prevent sediment from entering all storm drains, including ditches that receive drainage water from the project. Storm drain inlets protection devices shall be cleaned or removed and replaced as recommended by the product manufacturer, or more frequently if required to prevent failure of the device or flooding. Storm drain inlets made operable during construction shall be protected so that drainage water does not enter the drainage system without first being filtered or treated to remove sediments. Storm drain inlet protection devices shall be removed at the conclusion of the project. When*

Stormwater Code Language

manufactured storm drain inlet protection devices are not feasible, inlets and catch basins must be cleaned as necessary to prevent sediment from entering the drainage control system.

10. *Stabilize channels and outlets. All temporary on-site drainage systems shall be designed, constructed, and stabilized to prevent erosion. Stabilization shall be provided at the outlets of all drainage systems that is adequate to prevent erosion of outlets, adjacent stream banks, slopes, and downstream reaches.*
11. *Control pollutants. Measures shall be taken to control potential pollutants and shall include, but not be limited to, the following measures:*
    a. *All pollutants, including sediment, waste materials, and demolition debris, that occur on site shall be handled and disposed of in a manner that does not cause contamination of drainage water and pursuant to all applicable disposal laws.*
    b. *Containment, cover, and protection from vandalism shall be provided for all chemicals, liquid products, petroleum products, and other materials that have the potential to pose a threat to human health or the environment.*
    c. *On-site fueling tanks shall include secondary containment.*
    d. *Maintenance, fueling, and repair of heavy equipment and vehicles involving oil changes, hydraulic system drain down, solvent and de-greasing cleaning operations, fuel tank drain down and removal, and other activities which may result in discharge or spillage of pollutants to the ground or into drainage water runoff shall be conducted using spill prevention and control measures.*
    e. *Contaminated soils shall be removed and surfaces shall be cleaned immediately following any discharge or spill incident.*
    f. *Wheel wash or tire bath wastewater shall be discharged to a separate on-site treatment system that prevents discharge to surface water, or to the sanitary sewer or combined sewer system with approval of the Director of SPU. Temporary discharges or connections to the public sanitary and combined sewers shall be made in accordance with Chapter 21.16 (Side Sewer Code).*
    g. *Application of fertilizers and pesticides shall be conducted in a manner and at application rates that will not result in loss of chemical to drainage water. Manufacturers' label requirements for application rates and procedures shall be followed.*
    h. *BMPs shall be used to prevent or treat contamination of drainage water by pH-modifying sources. These sources include, but are not limited to, recycled concrete stockpiles, bulk cement, cement kiln dust, fly ash, new concrete washing and curing waters, waste streams generated from concrete grinding and sawing, exposed aggregate processes, and concrete pumping and mixer washout waters. Construction site operators may be required to adjust the pH of drainage water if necessary to prevent a violation of water quality standards.*
    i. *Construction site operators must obtain written approval from Ecology prior to using chemical treatment other than carbon dioxide (CO_2) dry ice, or food grade vinegar, to adjust pH.*
    j. *Uncontaminated water from water-only based shaft drilling for construction of building, road, and bridge foundations may be infiltrated provided the wastewater is managed in a way that prevents discharge to surface waters. Prior to infiltration, water from water-only based shaft drilling that comes into contact with curing concrete must be neutralized until pH is in the range of 6.5 to 8.5 (su).*
    k. *Train all employees on proper BMPs for preventing illicit discharges, including spills.*
12. *Control dewatering. When dewatering devices discharge on site, to a public drainage system, or to the public combined sewer, dewatering devices shall discharge into a sediment trap, sediment pond, gently sloping vegetated area of sufficient length to remove sediment contamination, or other sediment removal BMP. Foundation, vault, and trench dewatering waters must be discharged into a controlled drainage*

Stormwater Code Language

system prior to discharge to a sediment trap or sediment pond. Clean, non-turbid dewatering water, such as unpolluted well-point groundwater, that is discharged to systems tributary to surface waters must not cause erosion or flooding. Highly turbid or contaminated dewatering water shall be handled separately from drainage water. For all projects with an excavation depth of 12 feet or more below the existing grade, all projects with an excavation depth of less than 12 feet located in an area expected to have shallow groundwater depths, and all projects with 5,000 square feet or more of new plus replaced hard surface or one acre or more of land disturbing activity, a dewatering analysis must be performed to determine dewatering flows and to verify that there is sufficient capacity in the downstream system (e.g., public drainage system or public combined sewer) for review and approval or disapproval by the Director.

13. *Maintain BMPs. All temporary and permanent erosion and sediment control BMPs shall be maintained and repaired as needed to assure continued performance of their intended function. All temporary erosion and sediment controls shall be removed within five days after final site stabilization is achieved or after the temporary controls are no longer needed, whichever is later. Trapped sediment shall be removed or stabilized on site. Disturbed soil areas resulting from removal shall be permanently stabilized.*
14. *Inspect BMPs. BMPs shall be periodically inspected. For projects with 5,000 square feet or more of new plus replaced hard surface or 7,000 square feet or more of land disturbing activity, site inspections shall be conducted by a Certified Erosion and Sediment Control Lead who shall be identified prior to construction and shall be present on-site or on-call at all times.*
15. *Execute construction stormwater control plan. Construction site operators shall maintain, update, and implement their construction stormwater control plan. Construction site operators shall modify their construction stormwater control plan to maintain compliance whenever there is a change in design, construction, operation, or maintenance at the site that has, or could have, a significant effect on the discharge of pollutants to waters of the state.*
16. *Minimize open trenches. In the construction of underground utility lines, where feasible, no more than 150 feet of trench shall be opened at one time, unless soil is replaced within the same working day, and where consistent with safety and space considerations, excavated material shall be placed on the uphill side of trenches. Trench dewatering devices shall discharge into a sediment trap or sediment pond.*
17. *Phase the project. Development projects shall be phased to the maximum extent feasible in order to minimize the amount of land disturbing activity occurring at the same time and shall take into account seasonal work limitations.*
18. *Install flow control and water quality facilities. Development projects required to comply with Section 22.805.080 (Minimum requirements for flow control) or Section 22.805.090 (Minimum requirements for treatment) shall install permanent flow control and water quality facilities to prevent erosion or transport of sediment or other pollutants from the site during construction.*
19. *Protect stormwater BMPs*
    a. *Protect all stormwater BMPs from sedimentation through installation and maintenance of erosion and sediment control BMPs. Restore the BMPs to their fully functioning condition if they accumulate sediment during construction. Restoring the stormwater BMP must include removal of sediment and any sediment-laden stormwater BMP soils, and replacing the removed soils with soils meeting the design specification.*
    b. *Prevent compacting infiltration BMPs by excluding construction equipment and foot traffic. Protect completed lawn and landscaped areas from compaction due to construction equipment.*

Stormwater Code Language
c. Control erosion and avoid introducing sediment from surrounding land uses onto permeable pavements. Do not allow muddy construction equipment on the base material or pavement. Do not allow sediment-laden runoff onto permeable pavements or base materials. *d. Permeable pavements fouled with sediments or no longer passing an initial infiltration test must be cleaned until infiltrating per design or replaced.* *e. Keep all heavy equipment off existing soils under infiltration BMPs, especially those that have been excavated to final grade, to retain the infiltration rate of the soils.*

CHAPTER 4 – Standards and Specifications for Construction Erosion, Sediment, and Flow Control Practices

This chapter contains the standards and specifications for erosion and sediment control practices that form the foundation of erosion and sediment control planning in the City of Seattle (City). These best management practices (BMPs) are grouped according to their method of controlling erosion and sedimentation at project sites:

- Cover Practices (*Section 4.1*)
- Erosion Control Practices (*Section 4.2*)
- Sediment Control Practices (*Section 4.3*)

Refer to these sections for a list of BMPs in each category.

All temporary erosion and sediment control BMPs must be removed within 5 business days after final site stabilization is achieved or after they are no longer needed, whichever is later. In either case, trapped sediment must be removed or stabilized on site and the disturbed areas permanently stabilized.

The standards and specifications for each BMP have been divided into six sections to facilitate the selection process and implementation:

1. Definition
2. Purpose
3. Conditions Where Practice Applies
4. Planning Considerations
5. Design Criteria
6. Maintenance

Note that “Conditions Where Practice Applies” always refers to site conditions. As site conditions change, BMPs must be changed to remain in compliance with the Stormwater Code.

4.1. Cover Practices

The cover BMPs for erosion and sedimentation control are divided into two categories:

1. Temporary cover practices, such as temporary seeding and clear plastic covering (refer to *Section 4.1.1*)
2. Permanent cover practices, such as sodding and planting (refer to *Section 4.1.5*)

The requirements for maintaining permanent BMPs are included with each description; however, all temporary and permanent erosion and sediment control practices should be maintained and repaired as needed to ensure continued performance of their intended function.

4.1.1. Temporary Cover Practices

Temporary cover BMPs are implemented to provide a cover to soils exposed during the life of the project. Soil stockpiles must be stabilized from erosion; protected with sediment trapping measures; and where possible, located away from storm drain inlets, waterways, and drainage channels. From October 1 to April 30, no soils should remain exposed and unworked for more than 2 days. From May 1 to September 30, no soils should remain exposed and unworked for more than 7 days.

More than one BMP may be required for effective protection of steeper slopes or where the soils are more erodible.

The standards and specifications for temporary cover BMPs are described in the sections below and include:

- BMP E1.10: Temporary Seeding (*Section 4.1.1.1*)
- BMP E1.15: Mulching, Matting, and Compost Blankets (*Section 4.1.1.2*)
- BMP E1.20: Clear Plastic Covering (*Section 4.1.1.3*)
- Polyacrylamide for soil erosion protection (refer to Washington State Department of Ecology [Ecology] BMP C126)

4.1.1.1. BMP E1.10: Temporary Seeding

Description

The establishment of temporary vegetative cover on disturbed areas by seeding with appropriate rapidly growing annual plants.

Purpose

To provide temporary soil stabilization by planting grasses and legumes to areas that would remain bare for more than 7 days where permanent cover is not necessary or appropriate (Figure 1).

Figure 1. Hydroseeding Method.

Conditions Where Practice Applies

- Permanent structures are to be installed or extensive re-grading will occur prior to the establishment of permanent vegetation.
- Areas that will not be subjected to heavy wear by construction traffic.
- Areas sloping up to 15 percent for 100 feet or less (where temporary seeding is the only BMP used).

Planning Considerations

Sheet erosion, caused by the impact of rain on bare soil, is the source of most fine particles in sediment. To reduce this sediment load in runoff, the soil surface itself should be protected. The most efficient and economical means of controlling sheet and rill erosion is to establish vegetative cover. Annual plants that sprout rapidly and survive for only one growing season

are suitable for establishing temporary vegetative cover. Temporary seeding is effective when combined with construction phasing so that bare areas of the site are minimized at all times.

Temporary seeding may prevent costly maintenance operations on other erosion control systems. For example, sediment basin cleanouts will be reduced if the drainage area of a basin is seeded where grading and construction are not taking place. Perimeter dikes will be more effective if not clogged with sediment.

Temporary seeding is essential to preserve the integrity of earthen structures used to control sediment, such as dikes, diversions, and the banks and dams of sediment basins.

Proper seedbed preparation and the use of quality seed are important in this practice just as in permanent seeding. Failure to carefully follow sound agronomic recommendations will often result in an inadequate stand of vegetation that provides little or no erosion control.

Design Criteria

- Time of Seeding: Seeding should preferably be done between April 1 and June 30, and September 1 through October 31. If seeding is done in the months of July and August, irrigation will be required until 75 percent grass cover is established. If seeding is done between October 1 and March 31, mulch immediately after seeding.
- Site Preparation: Before seeding, install needed surface runoff control measures such as gradient terraces, earth dike or drainage swales, level spreaders, and sediment basins.
- Seedbed Preparation: The seedbed should be firm with a fairly fine surface. All soil should be roughened no matter what the slope. If compaction is required for engineering purposes, slopes must be track-walked before seeding. Perform all cultivating operations across or at right angles to the slope. A minimum of 2 to 4 inches of tilled topsoil is required.
- Fertilization: Apply fertilizers as per suppliers or Natural Resources Conservation Service (NRCS) recommendations, or apply a 10:4:6 ratio of nitrogen-phosphorus-potassium (N-P-K) fertilizer at a rate of 90 pounds per acre. Developments adjacent to receiving waters must use non-phosphorus fertilizer.
- Seeding: Seeding mixtures will vary depending on the exact location, soil type, slope, etc. Information on mixes may be obtained from local suppliers, the Washington State Department of Transportation, or the NRCS. The seed mix in Table 2 is supplied as guidance. Hydroseed applications should include a minimum of 1,500 pounds per acre of mulch with 3 percent tackifier. Refer to City of Seattle Standard Specification 9-14.4(7).
- Mulching: Mulch is required for seeding. Mulch can be applied on top of the seed or simultaneously by hydroseeding. Refer to BMP E1.15 Mulching, Matting, and Compost Blankets for more information on mulching.
- Tackifier: Apply a tackifier with a tracer to indicate where the seeding has been applied.

Table 2. Temporary Erosion Control Seeding Mixture.[a]

Name	Proportion by Weight
Turf-type perennial rye (blend of 3 approved varieties)[b]	50 percent
Creeping red fescue[b]	20 percent
Chewings fescue[b]	20 percent
Hard fescue	10 percent

[a] Hydroseeding applications with approved seed-mulch-fertilizer mixtures may also be used. Mixture must be no less than 98 percent pure and have a minimum germination rate of 90 percent.

[b] Refer to City of Seattle Standard Specification 9-14.2(1) for approved varieties.

Maintenance

- Seeding should be supplied with adequate moisture. Supply water as needed, especially in abnormally hot or dry weather or on adverse sites. Water application rates should be controlled to prevent runoff.
- Re-seed areas that fail to establish at least 80 percent vegetative cover as soon as such areas are identified. If re-seeding is ineffective, use an alternate method, such as sodding, mulching, or nets or mats.
- If vegetative cover is inadequate to prevent rill erosion, apply other BMPs.

4.1.1.2. BMP E1.15: Mulching, Matting, and Compost Blankets

Description

Application of plant residues or other suitable materials to the soil surface.

Purpose

To provide immediate protection to exposed soils during the period of short construction delays or over winter months through the application of plant residues or other suitable materials to exposed soil areas.

Mulches also enhance plant establishment by conserving moisture and moderating soil temperatures. Mulch helps hold fertilizer, seed, and topsoil in place in the presence of wind, rain, and runoff and maintains moisture near the soil surface.

Conditions Where Practice Applies

- Areas that cannot be seeded because of the season or are otherwise unfavorable for plant growth.
- Areas that have been seeded as specified in Temporary Seeding (BMP E1.10).
- In an area of greater than 25 percent slope, mulching should immediately follow seeding.

Planning Considerations

Mulches are applied to the soil surface to conserve a desirable soil property or to promote plant growth. Surface mulch is one of the most effective means of controlling runoff and erosion on disturbed land (refer to Table 3 for a comparison of pollutant loading reductions for various mulches).

Mulches can increase the infiltration rate of the soil, reduce soil moisture loss by evaporation, prevent crusting and sealing of the soil surface, modify soil temperatures, and provide a suitable microclimate for seed germination.

Organic mulch materials, such as compost, straw, wood chips, bark, and wood fiber, have been found to be the most effective. Compost has the advantage of being reusable by tilling it in to meet the City's soil amendment requirement at the end of the project. A variety of nets and mats have been developed for erosion control in recent years, and these are also used as mulches, particularly in critical areas such as waterways. They may be used to hold other mulches to the soil surface.

The choice of materials for mulching will be based on the type of soil to be protected, site conditions, season, and economics. It is especially important to mulch liberally in mid-summer and prior to winter, and on cut slopes and southern slope exposures.

Table 3. Guide to Mulch Materials, Rates, and Uses.

Mulch Material	Quality Standards	Application Depth	Remarks[a]
Gravel, slag, or crushed rock	• Washed • 0.75 to 1.5 inch size	3 inches	• Excellent mulch for short slopes and around woody plants and ornamentals. • Use where subject to foot traffic. Approximately 2,000 pounds per cubic yard.
Straw	• Air dried • Free from unwanted seeds and coarse material	Minimum 2 inches	• Use for immediate protection. Hand application generally requires greater thickness than blown straw. • Thickness of straw may be reduced by half when used in conjunction with seeding. • Most common and widely used mulching material. Can be used in critical erosion areas.
Wood fiber cellulose (partially digested wood fibers)	• Should not contain growth-inhibiting factors	Minimum 2 inches	• If used on critical areas, double the normal application rate. • Apply with a hydro-mulcher with seed and tackifier. No tie-down required. • Fibers should be less than 0.75 inch and packaged in 100-pound bags. • Recycled cellulose may contain polychlorinated biphenyls (PCBs); products should be evaluated for PCBs prior to use.
Compost blanket, mulch, and compost	• No visible water or dust during handling	Minimum 2 inches	• Excellent mulch for protecting final grades until landscaping. • Can be directly seeded or tilled into soil as an amendment. • A 3-inch layer provides superior protection.
Chipped site vegetation	• Average size should be several inches • Gradations from fines to 6 inches	Minimum 2 inches	• Cost-effective way to dispose of clear and grubbing debris. • Should not be used on slopes above 10 percent. Not recommended within 200 feet of receiving waters.
Wood-based mulch	• No visible water or dust during handling • Must be purchased from supplier with Solid Waste Handling Permit (unless exempt)	Minimum 2 inches	• Often called hog (or hogged) fuel or wood straw and is useful organic matter. • Typically does not provide any weed seed control. • Prevent introduction of weed plants or seeds with application.

[a] All mulches will provide some degree of (1) erosion control, (2) moisture conservation, (3) weed control, and (4) reduction of soil crusting.

Compost Blankets

Compost for use as a mulch layer (i.e., a compost blanket) should meet the definition of "composted materials," including contaminant limits, in WAC 173-350---220. Coarsely screened compost (1--inch minus screen) provides superior protection in higher rainfall and on steeper slopes and may be tilled in later for tree and shrub planting areas. A finer compost (1/2-- or 5/8--inch minus screen) may be preferred where it will be tilled in later before planting lawn areas. A 2–inch-thick compost blanket is usually sufficient, but 3 inches provides superior protection.

Compost blankets are a preferred cover practice because they:

- Provide superior ground contact compared to rolled mats.
- Are more effective at filtering both sediment and pollutants such as oil.
- May be seeded when placed and promote superior seed germination.
- Can be reused as compost at the end of the project by tilling it in to soils to meet the City's Soil Amendment BMP (*Volume 3*).

Chemical Mulches and Soil Binders

The use of synthetic, spray-on materials (except tacking agents used with hydroseeding) is not recommended because they can create impervious surfaces and, possibly, adverse effects on water quality. Research shows they can cause more erosion than bare exposed soil when used.

Nets and Mats

Used alone, netting does not retain soil moisture or modify soil temperature. It stabilizes the soil surface while grasses are being established and is useful in grassed drainage channels and on slopes. Light netting may also be used to hold other mulches in place. Its relatively high cost makes it most suitable for small sites.

The most critical part of installing nets and mats is obtaining firm, continuous contact between material and soil. Without such contact, the material is useless and erosion occurs. It is important to use an adequate number of staples and to roll the material after laying it to ensure soil is protected.

Design Criteria

- Site Preparation — Same as Temporary Seeding (BMP E1.10).
- Mulch Materials, Application Rates, and Specifications — refer to Table 3.
- Erosion nets and mats may be used on level areas, on slopes (Figure 2a) up to 25 percent, and in channels (Figure 2b). Where soil is highly erodible, nets should only be used in connection with organic mulch such as straw and wood fiber. Jute nets should be heavy, uniform cloth woven of single jute yarn and should weigh an average of 1.2 pounds per linear yard if 36 to 48 inches wide. It must be applied so that it is in complete contact with the soil. Netting should be securely anchored to the soil with No. 11 gauge wire staples at least 6 inches long and overlap 2 inches across and 6 inches down.

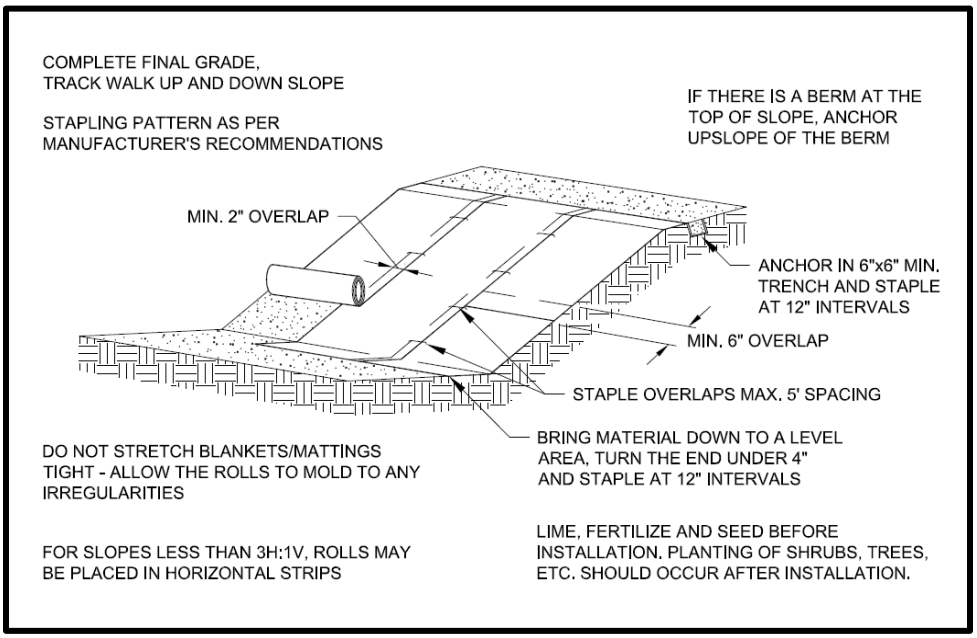


Figure 2a. Mat Installation on Slope.

- To install mats on slopes:
  - First complete the final grade and track walk up and down the slope. Install hydromulch with seed and fertilizer.
  - Dig a small trench, approximately 6 inches wide by 6 inches deep, along the top of the slope.
  - Install the leading edge of the mat into the small trench and staple approximately every 12 inches (metal, U-shaped, and a minimum of 6 inches long). Longer staples should be used in sandy soils. Biodegradable stakes are also available.
  - Roll the mat slowly down the slope as the installer walks backwards, with the mat resting against the installer's legs.
  - Install staples as the mat is unrolled. Do not allow the mat to roll down the slope unattended. Do not allow anyone to walk on the mat after it is in place. If the mat is not long enough to cover the entire slope length, the trailing edge of the upper mat should overlap the leading edge of the lower mat and be stapled.
  - On steeper slopes, this overlap should be installed in a small trench, stapled, and covered with soil.
- Excelsior blankets are considered protective mulches and may be used alone on erodible soils and during all times of year.
- Ecology has also approved technologies that are functionally equivalent to mulching. Refer to the Functionally Equivalent Technologies section of Ecology's TAPE website for approved BMPs: https://ecology.wa.gov/regulations-permits/guidance-technical-assistance/stormwater-permittee-guidance-resources/emerging-stormwater-treatment-technologies.

Maintenance

Mulched areas must be checked periodically, especially following severe storms. Damaged areas of mulch or tie-down material must be repaired.

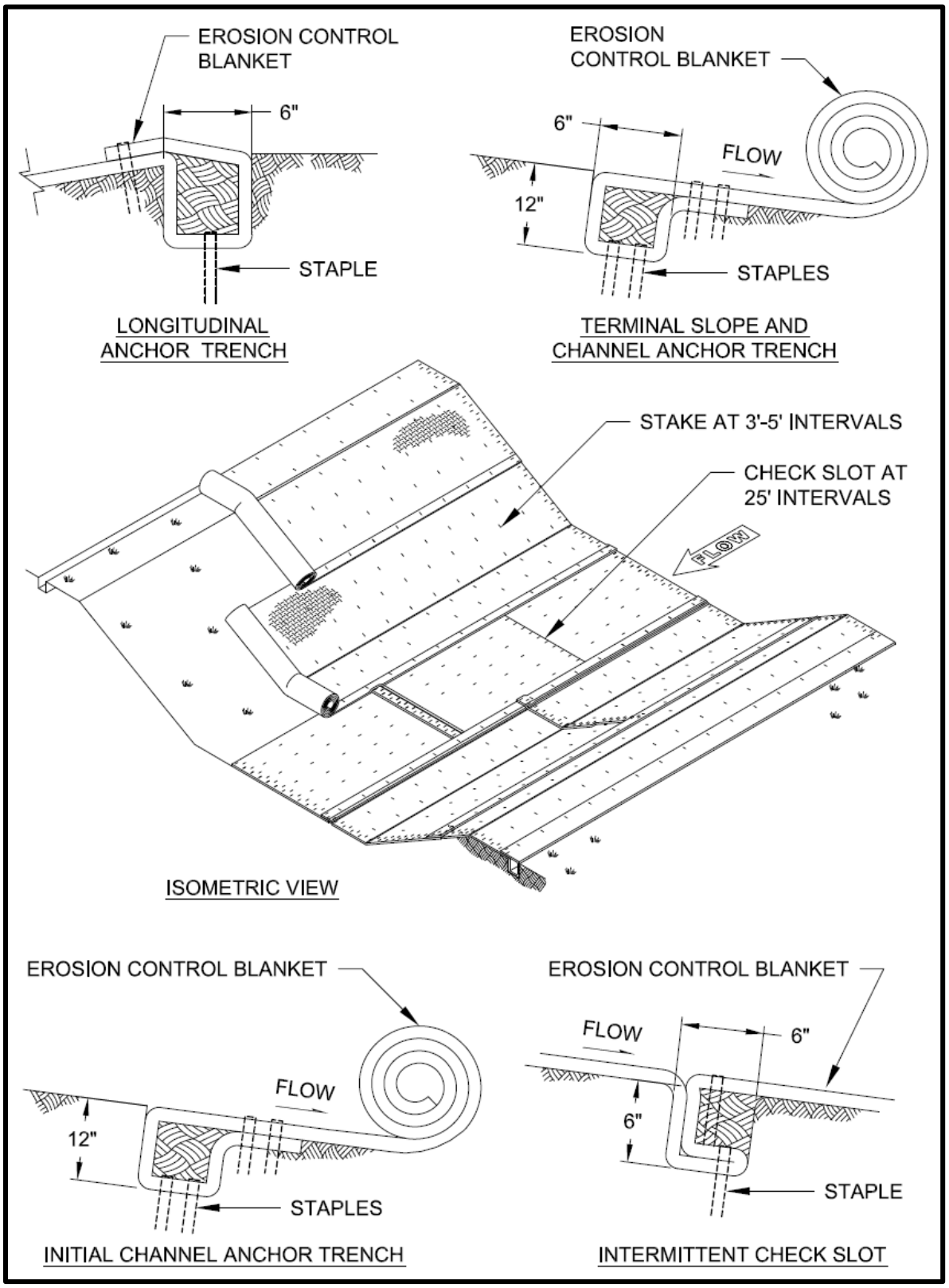


Figure 2b. Mat Installation on a Channel.

4.1.1.3. BMP E1.20: Clear Plastic Covering

Description

The covering of bare areas that need immediate protection from erosion with clear plastic sheeting.

Purpose

To provide immediate temporary erosion protection to slopes and disturbed areas that cannot be covered by mulching, to provide protection to plantings during winter, or to cover stockpiles. Clear plastic also is used to protect disturbed areas that must be covered during short periods of inactivity to meet November 1 through March 31 cover requirements. Because of many disadvantages, clear plastic covering is the least preferred cover practice (Figure 3).

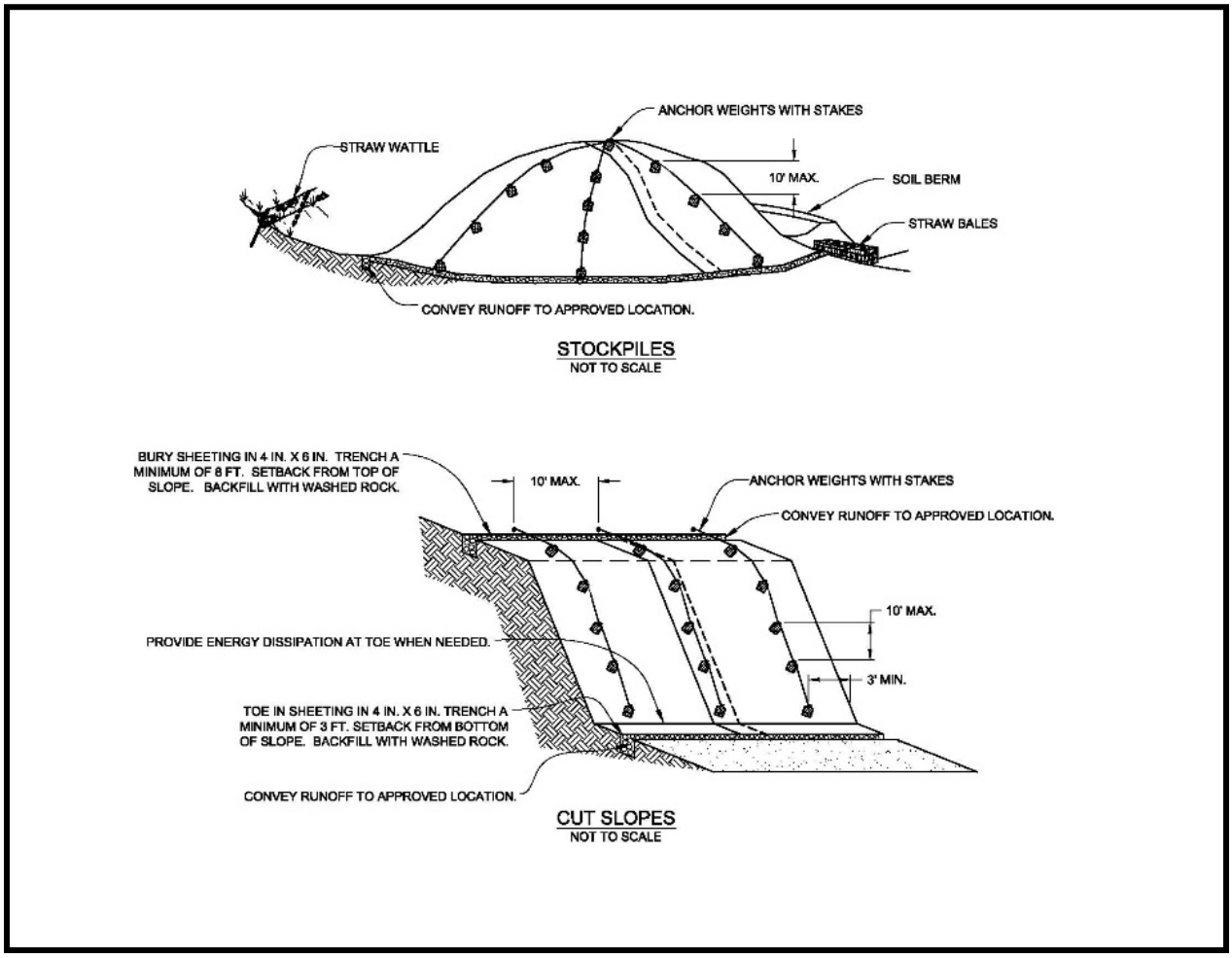


Figure 3. Stockpile Covered with Plastic Sheeting.

Conditions Where Practice Applies

- Disturbed areas that require immediate erosion protection for less than 30 days.
- Areas seeded during the time period from November 1 to March 31.

Planning Considerations

Plantings at this time require clear plastic covering for germination and protection from heavy rains.

Design Criteria

- Clear plastic sheeting must have a minimum thickness of 6 mil and must meet the requirements of the City of Seattle Standard Specifications Section 9-14.5.
- Toe in sheeting by placing plastic into a small (12--inch wide by 6--inch deep) slot trench at the top of the slope and backfill with soil to keep water from flowing underneath the plastic.
- Install covering and maintain tightly in place by using sandbags or tires on ropes with a maximum 10-foot grid spacing in all directions. Tape or weigh down all seams full length with at least a 1- to 2--foot overlap of all seams. Then roll, stake, or tie all seams.
- Immediately install covering on areas seeded between November 1 and March 1, and keep covering in place until vegetation is firmly established.
- When the covering is used on unseeded slopes, leave in place until the next seeding period.
- If erosion at the toe of a slope is likely, install a gravel berm, riprap, or other suitable protection at the toe of the slope in order to reduce the velocity of runoff.
- Remove sheeting as soon as possible once vegetation is well established to prevent burning the vegetation through the plastic sheeting, which acts as a greenhouse.
- Install drainage collection at the toe of the covered slope to collect and route runoff to the approved discharge point, if needed.

Maintenance

Check regularly for rips and places where the plastic may be dislodged. Contact between the plastic and the ground must always be maintained. Any air bubbles found must be removed immediately or the plastic may rip during the next windy period. Re-anchor or replace the plastic as necessary.

4.1.2. Permanent Cover Practices

Permanent cover BMPs are implemented both during and upon completion of construction activities. Permanent cover reduces erosion wherever practical and can be achieved by limiting site disturbance during construction. For example, by preserving existing conifers, approximately 50 percent of all rain that falls onto the trees will be retained during a storm. Up to 20 to 30 percent of this rain may never reach the ground but is taken up by the tree or lost to evaporation. Another benefit of permanent cover is that rain held in permanent vegetation (plantings, grass, trees) can be released slowly into the ground after a rain event.

Note: Equipment access and soil compaction is not allowed in areas where permanent cover is established.

The City requires that all new, replaced, and disturbed topsoil is amended prior to completion of the project. Refer to *Volume 3 — Project Stormwater Control* for guidance on soil amendment BMP requirements.

The standards and specifications for permanent cover BMPs are described below and include:

- BMP E1.30: Preserving Natural Vegetation (*Section 4.1.2.1*)
- BMP E1.35: Buffer Zones (*Section 4.1.2.2*)
- BMP E1.40: Permanent Seeding and Planting (*Section 4.1.2.3*)
- BMP E1.45: Sodding (*Section 4.1.2.4*)
- BMP E1.50: High-Visibility Fence (*Section 4.1.2.5*)

4.1.2.1. BMP E1.30: Preserving Natural Vegetation

Description

Phase construction activities to minimize exposed soils and resulting erosion by clearing only where construction will occur.

Purpose

To reduce erosion by preserving natural vegetation wherever practical (Figure 4).

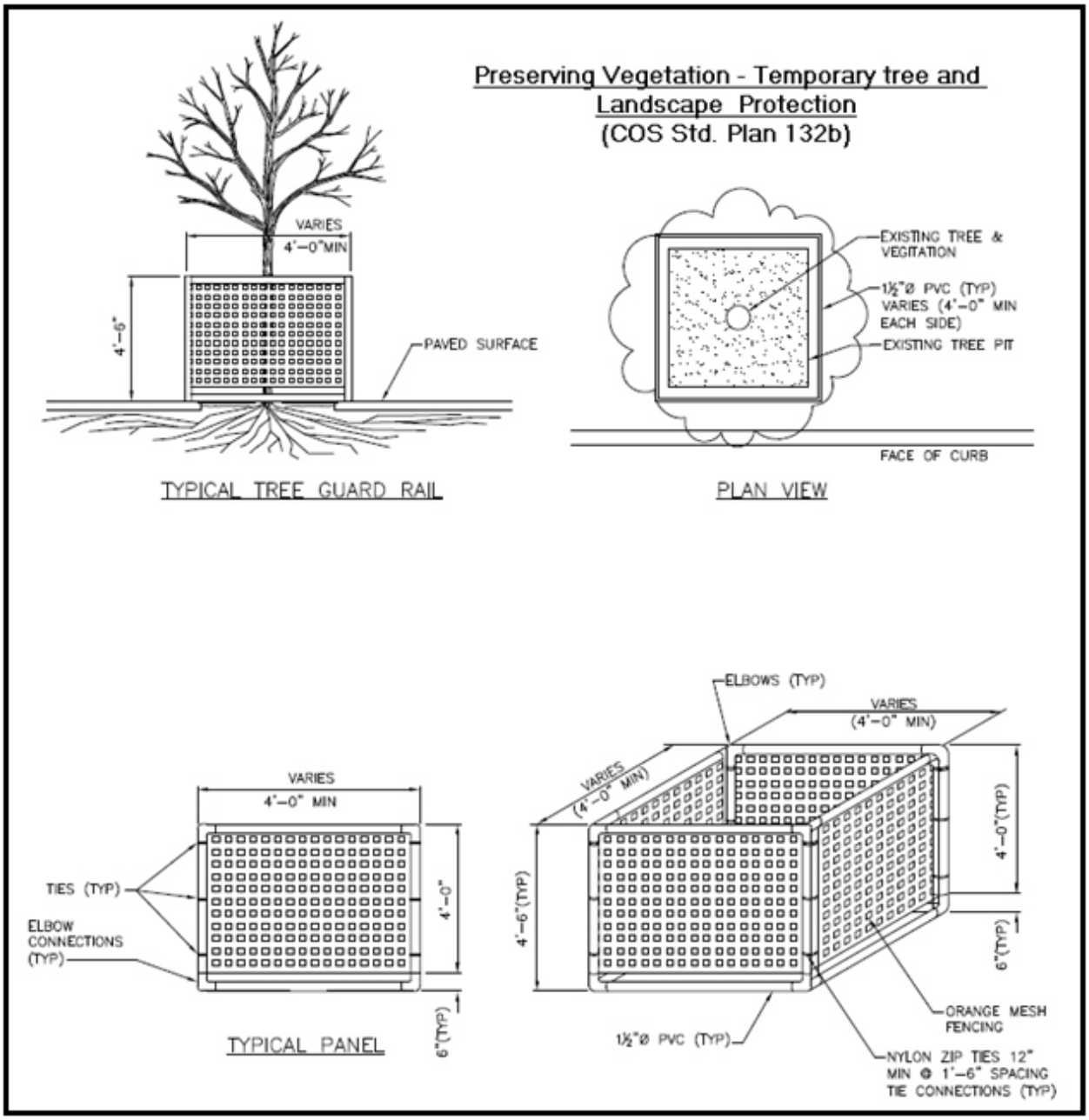


Figure 4. Preserving Vegetation.

Conditions Where Practice Applies

Natural vegetation should be preserved everywhere and must be preserved within certain Environmentally Critical Areas (ECAs) pursuant to SMC, Chapter 25.09. Natural vegetation should be preserved especially on steep slopes, near perennial and intermittent watercourses or swales, and on building sites in wooded areas.

Planning Considerations

Refer to SMC, Section 25.09 Trees and Vegetation and SMC, Section 25.11 Tree Protection for additional requirements for vegetation and tree protection and for requirements within ECAs. See the Seattle Department of Construction and Inspections (SDCI) Trees & Codes website for tree protection requirements on parcels at https://www.seattle.gov/sdci/codes/codes-we-enforce-(a-z)/trees-and-codes#treeprotectiononprivateproperty. The Seattle Department of Transportation (SDOT), Urban Forestry section, has additional information regarding general tree and vegetation protection as well as requirements for tree protection in the right-of-way on the City's website (www.seattle.gov/transportation/projects-and-programs/programs/trees-and-landscaping-program).

Design Criteria

It can be worthwhile to preserve natural vegetation both in the form of vegetated communities of trees and related understory plants and in the form of individual trees retained along with the soil that supports them. The preservation of individual trees can be particularly challenging given the typical use of heavy construction equipment on site. Clear field marking is essential to guard against incidental impacts to the soil and or to the trunk, branches, and roots of the tree itself.

Design considerations include:

- Establish a monetary value for the tree or vegetated area and post this in some visible manner on protective fencing to help ensure care on the part of the site contractors. Monetary value is typically established by a professional in the tree care, landscape, or nursery industry. This professional should have value assessment experience in accordance with the 9th Edition of the "Guide for Plant Appraisal" (Council of Tree and Landscape Appraisers 2000). An aspect of appraisal includes application of local standards to help ensure the protection of plants that are desirable native or non-native species.
- Prior to beginning land-disturbing activities, including clearing and grading, clearly mark all clearing limits, critical areas, and their buffers. Clearly flag and provide a rigid (chain link or similar) fence to protect areas around trees and vegetated areas to be retained. In addition, provide high-visibility fencing where required by Section 4.1.5. BMP E1.50. Where protection of all surfaces within the drip line of the tree or vegetated area is not possible, consult a tree care professional with qualifications in urban forestry, landscape architecture, or a related field to develop an appropriate plan. On parcels, the plan must apply the SDCI tree protection requirements. In the right-of-way, the plan must apply the requirements defined in City of Seattle Standard Plans 132a, 132b and 133.
- The duff layer, native topsoil, and natural vegetation should be retained in an undisturbed state to the maximum degree practical.

- Trees and other plants need protection from three types of impacts:
  - Construction Equipment: Impacts from construction equipment can occur above or below the ground level. Damage results from scarring, cutting of roots, and compaction of the soil. Roping or fencing a buffer zone around plants to be saved can prevent such injuries.
  - Grade Change: Any grade change affecting areas within the drip line of an existing tree should be reviewed and approved by a tree care professional with local construction experience. Local experience is needed to ensure familiarity with the tree species and local conditions associated with soil, drainage, and pests or disease that may be factors. Where appropriate, systems may be designed utilizing structural or engineered soil mixes and/or "rootways" to ensure the circulation of air to roots impacted by fill.
  - Excavation: Excavation within the drip line of trees commonly requires exploratory work utilizing hand equipment, including the use of an air spade to fracture soil and reveal root locations without damage. Identifying the location of existing roots allows construction to occur within areas where roots are expected with minimal damage to critical root systems.
- For trees required to be preserved, any activities within the drip line requires oversight by a certified arborist or professional. For specific information about preserving mature trees and/or large plants, refer to references listed on the Seattle Department of Construction and Inspections (SDCI) Tree and Landscaping Guidance and Requirements web page (www.seattle.gov/sdci/codes/codes-we-enforce-(a-z)/tree-protection-code).
- In all situations involving vegetation preservation, it is fundamentally important to involve a qualified tree or vegetation care professional to assess the specific site issues. The above guidelines are designed to capture the major common issues associated with vegetation preservation; however, each site will be unique and would benefit from the input of a dedicated professional.

Maintenance

Inspect tree and protection areas regularly to make sure fencing has not been removed. If the fencing has been damaged, repair or replace immediately. If tree roots have been exposed or injured, "prune" cleanly with an appropriate pruning saw or loppers directly above the damaged roots and re-cover with native soils (with arborist oversight). Mechanical treatment of sap-flowing trees (i.e., fir, hemlock, pine, soft maples) is not advised as sap forms a natural healing barrier.

4.1.2.2. BMP E1.35: Buffer Zones

Description

An undisturbed area or strip of natural vegetation or an established suitable planting that will provide a living filter to reduce soil erosion and stormwater runoff velocities.

Purpose

Buffer zones are used along streams and other receiving waters that need protection from erosion and sedimentation (Figure 5).

Figure 5. Vegetated Buffer Zone.

Conditions Where Practice Applies

Contractors can use vegetative buffer zone BMPs to protect natural swales, and they can incorporate them into the natural landscaping of an area. Do not use critical area buffer zones as sediment treatment areas; these areas should remain completely undisturbed.

Planning Considerations

The City's ECA regulations require undisturbed vegetative buffer zones for wetlands (SMC, Section 25.09.160), steep slope areas (SMC, Section 25.09.090), and fish and wildlife habitat

conservation areas (SMC, Section 25.09.200). Refer to the appropriate code section(s) for site-specific requirements.

Design Criteria

- Preserve natural vegetation or plantings in clumps, blocks, or strips. This is generally the easiest and most successful method.
- Leave all critical areas in a naturally vegetative condition.
- Fence clearing limits and keep all equipment and construction debris out of the natural vegetation.
- Keep all excavations outside of critical areas and the drip line of trees and shrubs.
- Do not push debris or extra soil into the buffer zone area because it will cause damage to vegetation from burying and smothering.

Maintenance

Inspect the area frequently to make sure flagging remains in place and the area remains undisturbed.

4.1.2.3. BMP E1.40: Permanent Seeding and Planting

Description

The establishment of perennial vegetative cover on disturbed areas.

Purpose

- To establish permanent vegetation (i.e., grasses, legumes, trees, and shrubs) as rapidly as possible to prevent soil erosion by wind or water and to improve wildlife habitat and site aesthetics.
- To provide pollutant filtration (biofiltration) in vegetation-lined channels and to establish constructed wetlands as required.

Conditions Where Practice Applies

- Graded, final graded, or cleared areas where permanent vegetative cover is needed to stabilize the soil.
- Areas that will not be brought to final grade for 1 year or more.
- Vegetation-lined channels.
- Retention or detention ponds as required.

Planning Considerations

Vegetation controls erosion by reducing the velocity and the volume of overland flow and protecting the bare soil surface from raindrop impact.

Land that has been disturbed requires vegetative cover. The most common and economical means of establishing this cover is by seeding grasses and legumes.

Advantages of seeding over other means of establishing plants include the small initial establishment cost, the wide variety of grasses and legumes available, low labor requirement, and ease of establishment in difficult areas.

Disadvantages that must be dealt with are the potential for erosion during the establishment stage, a need to reseed areas that fail to establish, limited periods during the year suitable for seeding, and a need for water and appropriate climatic conditions during germination.

Consider the microclimate(s) within the development area. Low areas may have frost pockets and require hardier vegetation because cold air tends to sink and flow toward low spots. South-facing slopes may be more difficult to re-vegetate because they tend to be sunnier and drier.

There are so many variables in plant growth that an end product cannot be guaranteed. Much can be done in the planning stages to increase the chances for successful seeding. Selection of the right plant materials for the site, good seedbed preparation, timing, and conscientious maintenance are important. Whenever possible, native species of plants should be used for landscaping. These plants are already adapted to the area and survivability should be higher than with exotic species.

Native species are also less likely to require irrigation. Irrigation can require extensive maintenance, is not cost-effective, and is not an ecologically sound practice.

Design Criteria

- Vegetation cannot be expected to supply an erosion control cover and prevent slippage on a soil that is not stable due to its texture, structure, water movement, or excessive slope.
- Seeding should be done immediately after final shaping, except during the period of November 1 through March 1 when the site should be protected by mulching or plastic covering until the next seeding period. Seeding completed between July 1 and August 30 will require irrigation until 75 percent grass cover is established.
- Permanent vegetation may be in the form of grass-type growth by seeding or sodding, or it may be trees or shrubs, or a combination of these. Establishing this cover may require the use of supplemental materials, such as mulch or jute netting (refer to BMP E1.15).
- Prepare the site by installing temporary surface runoff control measures prior to seeding or planting to protect the surface from erosion until the vegetation is established. Temporary measures include gradient terraces, berms, dikes, level spreaders, drainage channels, and sediment basins.
- Soil amendments should be used to achieve organic matter and permeability performance defined in engineered soil and landscape systems. Compost used should meet City of Seattle Standard Specifications 9-14.4(5) or 9-14.4(8). Refer to *Volume 3 — Project Stormwater Control, Section 5.1* for additional requirements regarding soil amendments.
- Prepare seedbed for seeding of grasses and legumes. If infertile or coarse textured subsoil will be exposed during land shaping, it is best to stockpile topsoil and re-spread it over the finished slope at a minimum 2-- to 6--inch depth and roll it to provide a firm seedbed. If construction fills have left soil exposed with a loose, rough, or irregular surface, smooth with blade and roll. If cuts or construction equipment have left a tightly compacted surface, break with chisel plow or other suitable implement. Perform all cultivating operations across or at right angles to the slope (contoured), such as with cat tracks on the final pass. The seedbed should be firm with a fairly fine surface. All soil should be roughened before seeding. If compaction is required for engineering purposes, slopes must be track walked before seeding.
- Apply an appropriate seed mixture to the prepared seedbed at a rate of 120 pounds per acre. The erosion seeding mixture for application is presented in Table 4.

Table 4. Permanent Seeding Mixture.[a]

Name	Percent by Weight
Turf-type perennial rye[b]	50 percent
Creeping red fescue[b]	20 percent
Chewings fescue[b]	20 percent
Hard fescue	10 percent

Notes:

[a] Hydroseeding applications with approved seed-mulch-fertilizer mixtures may also be used. Mixture must be no less than 98 percent pure and have a minimum germination rate of 90 percent.

[b] Refer to City of Seattle Standard Specification 9-14.2(1) for approved varieties.

- Cover the seed with topsoil or mulch no deeper than 0.5 inch. It is better to work topsoil into the upper soil layer rather than spread a layer of it directly on top of the native soil.
- "Hydroseeding" applications with approved seed-mulch-fertilizer mixtures may also be used. Hydroseed applications should include a minimum of 1,500 pounds per acre of mulch with 3 percent tackifier.
- Mulch is always required for seeding. Mulch can be applied on top of the seed or simultaneously by hydroseeding.
- Seeding and planting should be supplied with adequate moisture. Supply water as needed. Water application rates should be controlled to prevent runoff.
- Re-seed and re-plant any areas that fail to establish at least 80 percent cover or experience erosion.
- Control erosion in areas with other BMPs, such as mulching, netting, or matting as necessary to prevent soil loss.
- A wetlands specialist should design plantings and seed mixtures for newly created wetlands to provide the best chance of success. Refer to *Volume 3 — Project Stormwater Control* for more information on constructed wetlands.
- Noxious weeds such as reed canary grass (*Phalaris arundinacea*) or purple loosestrife (*Lythrum salicaria*) are not allowed.
- Trees and shrubs provide natural beauty and wildlife benefits in addition to their erosion and sediment control values. When used for beauty and wildlife benefits, they are usually more effective when planted in clumps or blocks. These procedures should be followed:
    - Trees and shrubs will do best in topsoil. If no topsoil is available, they can be established in subsoil with proper amendment. If trees and shrubs are to be planted in subsoil, particular attention should be paid to amending the soil with generous amounts of organic matter. Mulches should also be used.
    - Good quality planting stock should be used. Normally, 1-to 2--year-old deciduous seedlings, and 3-to 4--year-old coniferous transplants, when properly produced and handled, are adequate. Stock should be kept cool and moist from time of receipt and planted as soon as possible.
    - Competing vegetation, if significant, should be pulled out of the area where the plant or plants are to be placed.

Maintenance

Inspect seeded areas for failure, make necessary repairs, and re-seed areas with less than 80 percent cover immediately. Conduct a follow-up survey after 1 year and replace failed plants where necessary.

- If vegetative cover is inadequate to prevent rill erosion, apply other BMPs, assuming vegetation was successful.
- If a stand has less than 40 percent cover, re-evaluate choice of plant materials and quantities of lime and fertilizer. Re-establish the stand following recommendations for seedbed preparation and seeding, omitting lime and fertilizer in the absence of soil test results. If the season prevents re-sowing, mulch or jute netting is an effective temporary cover.

4.1.2.4. BMP E1.45: Sodding

Description

The stabilizing of fine-graded disturbed areas by establishing permanent grass stands with sod.

Purpose

To establish permanent turf for immediate erosion protection or to stabilize drainage channels where concentrated overland flow will occur.

Conditions Where Practice Applies

- Disturbed areas that require immediate vegetative cover.
- Drainage channels carrying intermittent flow where immediate stabilization or aesthetics are factors and other locations particularly suited to stabilization with sod.

Planning Considerations

Sod can initially be more costly than seeding, but the advantages often justify the increased initial costs. Sod provides immediate erosion control and a green surface; however, it must be protected from disturbance while it takes root. Sod is preferable to seed due to the following:

- Reduced failure, as compared to seed, and the lack of weeds.
- Can be established nearly year-round.
- Immediate protection of the drainage channel after application.

Design Criteria

- Shape and smooth the surface to final grade in accordance with the approved grading plan. Over excavate the swale 4 to 6 inches below design elevation to allow room for placing soil amendment and sod.
- Soil amendments should be used to achieve organic matter and permeability performance defined in engineered soil and landscape systems. Compost used should meet City of Seattle Standard Specifications 9-14.4(5) or 9-14.4(8) for Grade A quality compost. Refer to *Volume 3, Section 5.1* for additional requirements regarding soil amendments.
- Add lime to reach a soil pH value of 6.5 (based on soil tests).
- Fertilize according to a soil test or in the absence of a test use available nitrogen, phosphorus, and potash as prescribed for permanent seeding. Use fertilizers that are not highly soluble.
- Work lime and fertilizer into the soil 1 to 2 inches deep and smooth the surface.
- Lay strips of sod beginning at the lowest area to be sodded and perpendicular to the direction of water flow. Wedge strips securely in place. Square the ends of each strip to provide for a close, tight fit. Stagger joints at least 12 inches. Staple the upstream edge of each sod strip if installed on slopes steeper than 18 percent.
- Roll the sodded area and irrigate.
- When sodding is carried out in alternating strips or other patterns, seed the areas between the sod immediately after sodding.

- Sod should be free of weeds and be of uniform thickness (approximately 1 inch) and should have a dense root mat for mechanical strength.

Maintenance

Inspect sodded areas regularly, especially after large storm events. Re-tack, re-sod, or re-seed and protect with a net or mat as necessary.

4.1.2.5. BMP E1.50: High-Visibility Fence

Description

Limit access to portions of the site not undergoing construction.

Purpose

Fencing is intended to:

- Restrict clearing to approved limits.
- Prevent disturbance of sensitive areas, their buffers, and other areas required to be left undisturbed.
- Limit construction traffic to designated construction entrances, exits, or internal roads.
- Protect areas where marking with survey tape may not provide adequate protection.

Conditions Where Practice Applies

High-visibility fence is required:

- to establish clearing and grading limits at the boundary of sensitive areas, their buffers, and other areas required to be left uncleared or undisturbed. It is also recommended to establish clearing limits and grading limits in general
- necessary to control vehicle access to and on the site

Design Criteria

- High-visibility plastic fence should be composed of a high-density polyethylene material and should be at least 4 feet in height. Posts for the fencing should be steel or wood and placed every 6 feet on center (maximum) or as needed to ensure rigidity. The fencing should be fastened to the post every 6 inches with a polyethylene tie. On long continuous lengths of fencing, a tension wire or rope should be used as a top stringer to prevent sagging between posts. The fence color should be high-visibility orange. The fence tensile strength should be 360 pounds per foot using the ASTM D4595 testing method.
- If appropriate, install fabric filter fence in accordance with BMP E3.10 to act as a high-visibility fence. Filter fence should be at least 3 feet high and must be highly visible to meet the requirements of this BMP.
- Metal fences must be designed and installed according to the manufacturer's specifications.
- Metal fences should be at least 3 feet high and must be highly visible.
- Fences must not be wired or stapled to trees.

Maintenance

If the fence has been damaged or visibility reduced, it must be repaired or replaced immediately and visibility restored.

4.2. Erosion Control Practices

Naturally occurring (undisturbed) soil and vegetation provide important stormwater management functions, including:

- Water infiltration
- Nutrient, sediment, and pollutant adsorption
- Sediment and pollutant biofiltration
- Water interflow storage and transmission
- Pollutant decomposition

These functions are largely lost when construction practices erode native soil and vegetation.

This section presents BMPs that temporarily and permanently address erosion, including measures for project site stabilization, slope protection, and drainage channel protection. The BMPs in this section have been divided into three basic groups based on these characteristics:

1. Temporary erosion control practices, such as road stabilization, check dams, and dust control (beginning at *Section 4.2.1*).
2. Permanent erosion control practices, such as gradient terraces and riprap channel lining (refer to Ecology's *Stormwater Management Manual for Western Washington* [SWMMWW]).
3. Temporary or permanent erosion control practices, such as subsurface drains, earth dikes and drainage swales, and outlet protection (beginning at *Section 4.2.3)*.

The requirements for maintaining permanent erosion control BMPs are included with each description; however, all temporary and permanent erosion and sediment control practices should be maintained and repaired as needed to ensure continued performance of their intended function.

The City requires that all new, replaced, and disturbed topsoil is amended prior to completion of the project. Refer to *Volume 3 — Project Stormwater Control Section 5.1* for guidance on soil amendment requirements.

Permanent erosion control BMPs may need to be designed by an engineer and may have additional criteria for flow and water quality treatment requirements. Variations or alterations to the minimum BMP requirements typically require an engineer's approval. Refer to *Volume 1* for thresholds and standards.

4.2.1. Temporary Erosion Control BMPs

Although temporary erosion control BMPs are emphasized in this section, they may be combined with permanent control facilities to provide protection of downstream properties during construction. Temporary facilities provide siltation control, but downstream erosion protection must also be provided. Refer to *Volume 3 — Project Stormwater Control* for flow control requirements.

Temporary cover BMPs are described in the sections below and include:

- BMP E2.10: Stabilized Construction Access (*Section 4.2.1.1*)
- BMP E2.15: Tire Wash (*Section 4.2.1.2*)
- BMP E2.20: Construction Road Stabilization (*Section 4.2.1.3*)
- BMP E2.35: Check Dams (*Section 4.2.1.4*)
- BMP E2.40: Triangular Silt Dike (Geotextile-encased Check Dam) (*Section 4.2.1.5)*
- BMP E2.45: Dust Control (*Section 4.2.1.6*)
- Level Spreader — refer to *Appendix E*
- Water Bars — refer to Ecology BMP C203

4.2.1.1. BMP E2.10: Stabilized Construction Access

Description

A temporary rock-stabilized pad located at all points of vehicular entrance and exit on a construction project or site.

Purpose

To reduce the amount of mud, dirt, rocks, etc. transported onto public roads by motor vehicles or runoff by constructing a stabilized pad of rock spalls at entrances to and exits from project sites and washing of tires during egress (Figure 6 and Figure 7).

Figure 6. Stabilized Construction Access.

Figure 7. Stabilized Construction Access.

Conditions Where Practice Applies

Whenever traffic leaves a project site and moves onto a public road or other paved area. Also refer to BMP E3.70 Street Sweeping and Vacuuming.

Planning Considerations

Construction entrances and exits provide an area where mud can be removed from vehicle tires before they enter a public road. Construction entrances and exits should be used in conjunction with the stabilization of construction roads to reduce the amount of mud picked up by vehicles. Construction vehicle entrance and exit should be limited to one route, if possible.

It is important to note that this BMP will only be effective if sediment control is used throughout the rest of the project site.

Design Criteria

- A geotextile should be placed under the spalls to prevent fine sediment from pumping up into the rock pad. The geotextile should meet the standards presented in City of Seattle Standard Specification 9--37.

- Material should be quarry spalls (where possible), 4 to 8 inches in size. Do not use crushed concrete, recycled concrete, cement, or calcium chloride for construction access stabilization, because these products raise pH levels in stormwater runoff.
- Alternative materials to quarry spalls may be used with increased offsite inspections. For an alternative specification used by the Washington State Department of Transportation (WSDOT), refer to BMP C105 Stabilized Construction Access in Volume II of the SWMMWW.
- The rock pad should be at least 12 inches thick and 100 feet in length for sites more than 1 acre and may be reduced to the maximum practical size when the size or configuration of the site does not allow the full 100-foot length.
- The access width should be the full width of the vehicle entrance and exit area.
- Additional rock should be added periodically to maintain proper function of the pad.
- Fencing should be installed as necessary to restrict traffic to the construction access.
- Whenever possible, the access point should be constructed on level ground with a firm, compacted subgrade. This can substantially increase the effectiveness of the pad and reduce the need for maintenance.
- Ecology has also approved technologies that are functionally equivalent to stabilized construction access. Refer to the Functionally Equivalent Technologies section of Ecology's TAPE website for approved BMPs (https://ecology.wa.gov/regulations-permits/guidance-technical-assistance/stormwater-permittee-guidance-resources/emerging-stormwater-treatment-technologies).

Maintenance

- If the access point is not preventing sediment from being tracked onto pavement, then alternative measures are required to keep the streets free of sediment. This may include an increase in the dimensions of the entrance or the installation of a tire wash (BMP E2.15). Until the entrance is functioning property, street sweeping may be required.
- Maintain the access point in a condition that will prevent tracking or flow of mud onto public rights-of-way. This may require periodic top dressing with 2--inch rock, as conditions demand, and repair, cleanout, or both, of any structures used to trap sediment. Thoroughly clean all materials spilled, dropped, washed, or tracked from vehicles onto roadways at the end of each day or more frequently during wet weather.
- Remove any sediment that is tracked onto pavement by shoveling or street sweeping. Remove or stabilize onsite sediment collected by sweeping.
- Street washing is allowed only after sediment is removed in accordance with the previous bullet. Do not allow street washwater to enter the public drainage system or systems tributary to waters of the state. All street washwater must be collected and discharged either back onto the site or into the sanitary sewer (if permitted).
- Immediately remove any quarry spalls loosened from the pad that end up on the roadway or sidewalk.

4.2.1.2. BMP E2.15: Tire Wash

Description

A system that uses water to wash motor vehicle tires and is located at exit points from a project site.

Purpose

A tire wash is used to remove mud, dirt, rocks, etc. from tires and under carriages, and to prevent sediment from being transported onto public roads.

Conditions Where Practice Applies

When a stabilized construction entrance or exit (refer to BMP E2.10) is not preventing sediment from being tracked onto pavement.

Planning Considerations

If approval by King County for wastewater discharge to the sanitary or combined sewer is not obtained, process wastewater can be collected and taken off site to an approved location. Indicate the ultimate discharge point or collection point on the Construction Stormwater Control and Soil Management Plan sheet that clearly identifies the location(s) of stormwater discharges.

Tire washes provide an area where mud can be removed from vehicle tires before they enter a public road. Tire washes and construction entrance points should be used in conjunction with the stabilization of construction roads to reduce the amount of mud picked up by vehicles.

It is important to note that this BMP will only be effective if sediment control is used throughout the rest of the project site.

Design Criteria

- Suggested details are shown in Figure 8. A minimum of 6 inches of asphalt-treated base (ATB) over crushed base material or 8 inches over a good subgrade is recommended to pave the tire wash.
- Use a low clearance truck to test the tire wash before paving. Either a belly dump or lowboy will work well to test clearance.
- Keep the water level from 12 to 14 inches deep to avoid damage to truck hubs and filling the truck tongues with water.
- Midpoint spray nozzles are only needed in extremely muddy conditions.
- Tire wash systems should be designed with a small change in grade—6 to 12 inches for a 10-foot wide pond—to allow sediment to flow to the low side of the pond to help prevent re-suspension of sediment. A drain pipe with a 2- to 3-foot riser should be installed on the low side of the pond to allow for easy cleaning and refilling. Polymers may be used to promote coagulation and flocculation in a closed-loop system. Refer to Ecology BMP C126 for additional information on polyacrylamide (PAM) polymers.

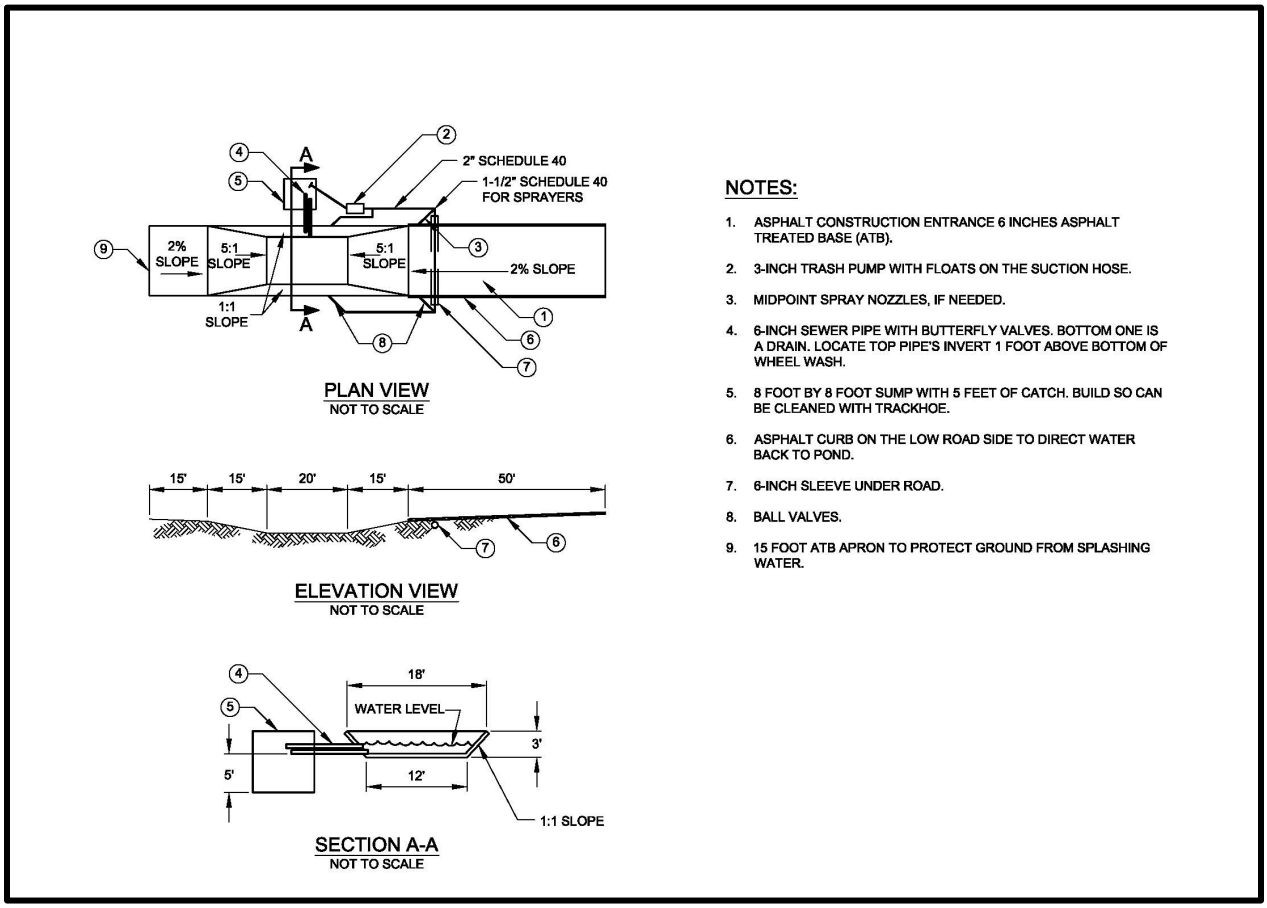


Figure 8. Tire Wash Details.

- Ecology has also approved technologies that are functionally equivalent to tire wash. Refer to the Functionally Equivalent Technologies section of Ecology's TAPE website for approved BMPs (https://ecology.wa.gov/regulations-permits/guidance-technical-assistance/stormwater-permittee-guidance-resources/emerging-stormwater-treatment-technologies).

Maintenance

- The washwater should be changed a minimum of once per day. On large earthwork jobs where more than 10 to 20 trucks per hour are expected, the washwater will need to be changed more often.
- Wheel wash or tire bath wastewater should be discharged to a separate onsite treatment system that prevents discharge to receiving waters, such as closed-loop recirculation or upland land application, or to the sanitary sewer with prior approval by King County.

4.2.1.3. BMP E2.20: Construction Road Stabilization

Description

The temporary stabilization with rock on access roads, subdivision roads, parking areas, and other onsite vehicle transportation routes immediately after grading.

Purpose

- To reduce erosion of temporary roadbeds by construction traffic during wet weather.
- To reduce the erosion and therefore re-grading of permanent roadbeds between the time of initial grading and final stabilization.
- To minimize the amount of dirt tracked off site by vehicular traffic.

Conditions Where Practice Applies

Wherever rock-base roads or parking areas are constructed, whether permanent or temporary, for use by construction traffic.

Planning Considerations

Areas graded for construction vehicle transport and parking purposes are especially susceptible to erosion. The exposed soil surface is continually disturbed, leaving no opportunity for vegetative stabilization. Such areas also tend to collect and transport runoff waters along their surfaces. During wet weather, they often become muddy quagmires that generate significant quantities of sediment that may pollute nearby streams or be transported off site on the wheels of construction vehicles. Dirt roads can become so unstable during wet weather that they are virtually unusable.

Immediate stabilization of such areas with rock may cost money at the outset, but it may actually save money in the long run by increasing the usefulness of the road during wet weather.

Permanent roads and parking areas should be paved as soon as possible after grading. As an alternative, the early application of rock may solve potential erosion and stability problems and eliminate later re-grading costs. Some of the rock will also likely remain in place for use as part of the final base course of the road.

Design Criteria

- Immediately after grading or the completion of utility installation within the right-of-way, apply a 6--inch course of 2- -to 4--inch crushed rock, gravel base, or crushed surfacing base course. A 4--inch course of asphalt-treated base (ATB) may be used in lieu of the crushed rock.
- Temporary roads should not exceed 15 percent, should minimize cuts in existing slopes, and be carefully graded to drain crosswise. Provide drainage swales to carry flow to a sediment control BMP (*Section 4.3*).
- Protect installed inlets to prevent sediment-laden water from entering the drain sewer system (refer to BMP E3.25).
- Maintain undisturbed buffer areas at all stream crossings.

- Seed, mulch, or cover areas adjacent to culvert crossings and steep slopes.
- Use dust control when necessary (refer to BMP E2.45).
- If the stabilized construction access does not adequately reduce the amount of tracked material, install one or more tire wash BMPs (refer to BMP E2.15).
- Install fencing to limit the access of vehicles to only those roads and parking areas that are stabilized.

Maintenance

- Inspect stabilized areas regularly, especially after large storm events. Add crushed rock if necessary and re-stabilize any areas found to be eroding.

4.2.1.4. BMP E2.35: Check Dams

Description

Small dams constructed across a swale or drainage ditch.

Purpose

To reduce the effective slope of the channel and, therefore, the velocity of concentrated flows; reduce erosion of the swale or ditch; and slow water velocity to allow retention of sediments.

Conditions Where Practice Applies

Where temporary channels or permanent channels are not yet vegetated or riprap channel lining is infeasible and, therefore, velocity checks are required. Check dams should be placed at regular intervals within constructed channels that are cut down a slope.

Planning Considerations

The City's ECA regulations require protection for high flow refuge habitat for overwintering juvenile salmonids and emergent salmonid fry. Check dams cannot be placed below the expected backwater from any of these areas during specific times of the year. Refer to SMC 25.09 for site-specific requirements.

No check dams may be placed in streams (unless approved by the Washington Department of Fish and Wildlife as appropriate). Other permits may also be necessary.

Check dams can be constructed of either rock or gravel-filled sandbags. If rock check dams are used in grass-lined channels that will be mowed, care should be taken to remove all the rock from the channel when the dam is removed. This should include any rock that has washed downstream.

Design Criteria

- Check dams can be constructed of rock or pea-gravel-filled bags. Where high velocity flow is not a concern, compost socks may be used. If necessary, compost socks may be stacked.
- Place check dams perpendicular to the flow of water.
- The dam should form a triangle when viewed from the side. This prevents undercutting as water flows over the face of the dam rather than falling directly onto the ditch bottom.
- Before installing check dams, impound and bypass upstream flow away from the work area. Options for bypassing include pumps, siphons, or temporary channels.
- Check dams in association with sumps work more effectively at slowing flow and retaining sediment than just a check dam alone. Provide a deep sump immediately upstream of the check dam.
- In some cases, if carefully located and designed, check dams can remain as permanent installations with very minor re-grading. They may be left as either spillways—in which case accumulated sediment would be graded and seeded—or as check dams to prevent further sediment from leaving the site.

- Keep the maximum spacing between the dams such that the toe of the upstream dam is at the same elevation as the top of the downstream dam (Figure 9).

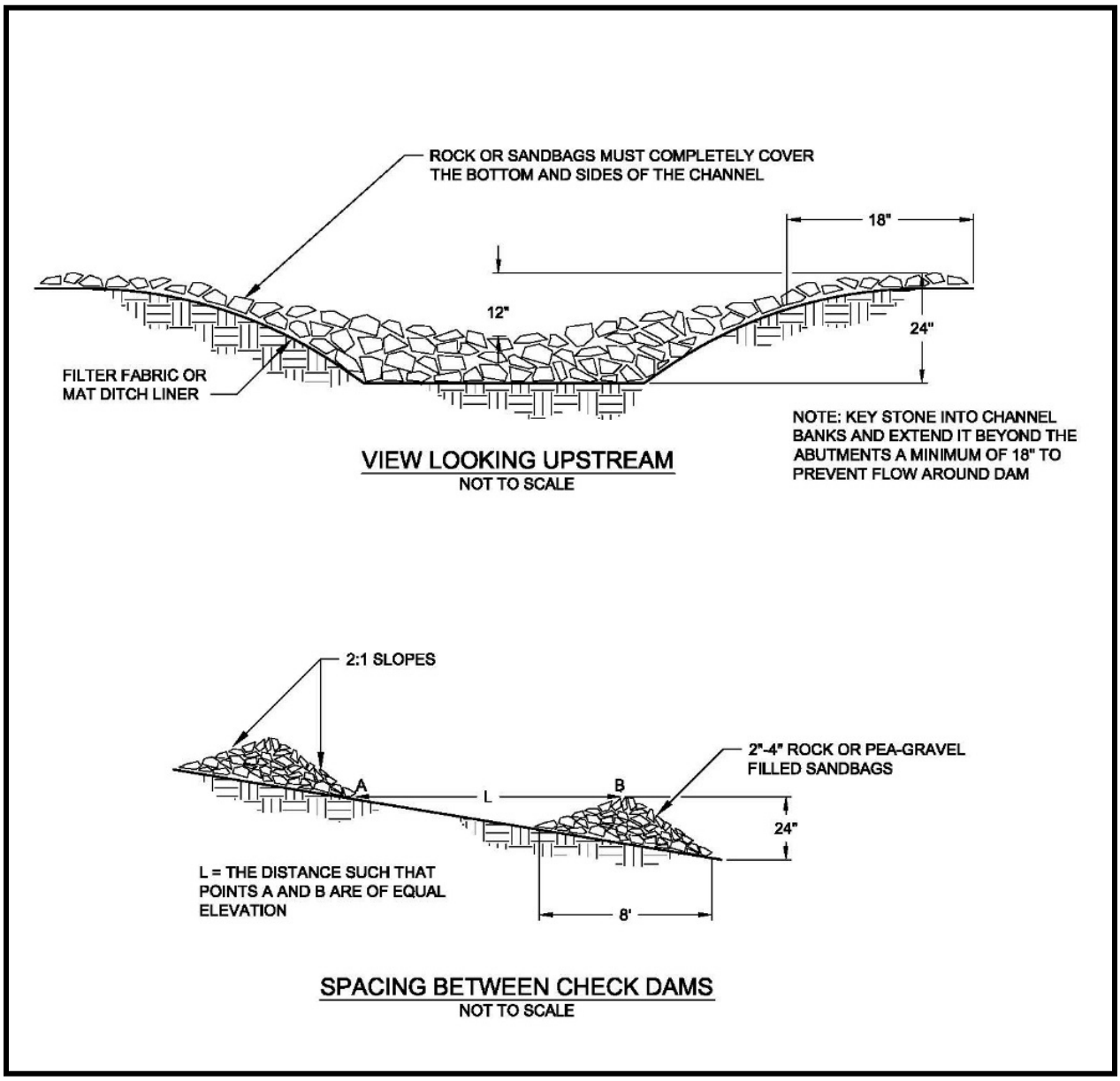


Figure 9. Check Dams.

- Keep the maximum height at 2 feet at the center of the dam.
- Keep the center of the check dam at least 12 inches lower than the outer edges at natural ground elevation.
- Keep the side slopes of the check dam at 2H:1V or flatter.
- Key the rock into the ditch banks and extend it beyond the abutments a minimum of 18 inches to avoid washouts from overflow around the dam.
- Rock check dams should be constructed of appropriately sized rock. The rock used must be large enough to stay in place given the expected design flow through the

channel. Place the rock by hand or by mechanical placement (no dumping of rock to form dam) to achieve complete coverage of the ditch or swale and to ensure that the center of the dam is lower than the edges.

- Use filter fabric foundation under a rock or sandbag check dam. This is not necessary if a mat ditch liner is used. A piece of organic or synthetic mat cut to fit will also work for this purpose.
- In the case of grass-lined ditches and swales, remove check dams when the grass has matured sufficiently to protect the ditch or swale, unless the slope of the swale is greater than 4 percent. Immediately after dam removal, seed and mulch the area beneath the check dams.
- Ensure that channel appurtenances, such as culvert entrances below check dams, are not subject to damage or blockage from displaced rocks.
- Ecology has also approved technologies that are functionally equivalent to check dams. Refer to the Functionally Equivalent Technologies section of Ecology's TAPE website for approved BMPs: https://ecology.wa.gov/regulations-permits/guidance-technical-assistance/stormwater-permittee-guidance-resources/emerging-stormwater-treatment-technologies.

Maintenance

- Monitor check dams for performance and sediment accumulation during and after each runoff-producing rainfall. Remove sediment when it reaches one-half the sump depth.
- If significant erosion occurs between dams, install a protective riprap liner in that portion of the channel.

4.2.1.5. BMP E2.40: Triangular Silt Dike (TSD)

Description

A triangular dike made of urethane foam sewn into a woven geosynthetic fabric.

Purpose

TSDs may be used as check dams, perimeter protection, temporary soil stockpile protection, drop inlet protection, or as a temporary earth dike (Figure 10).

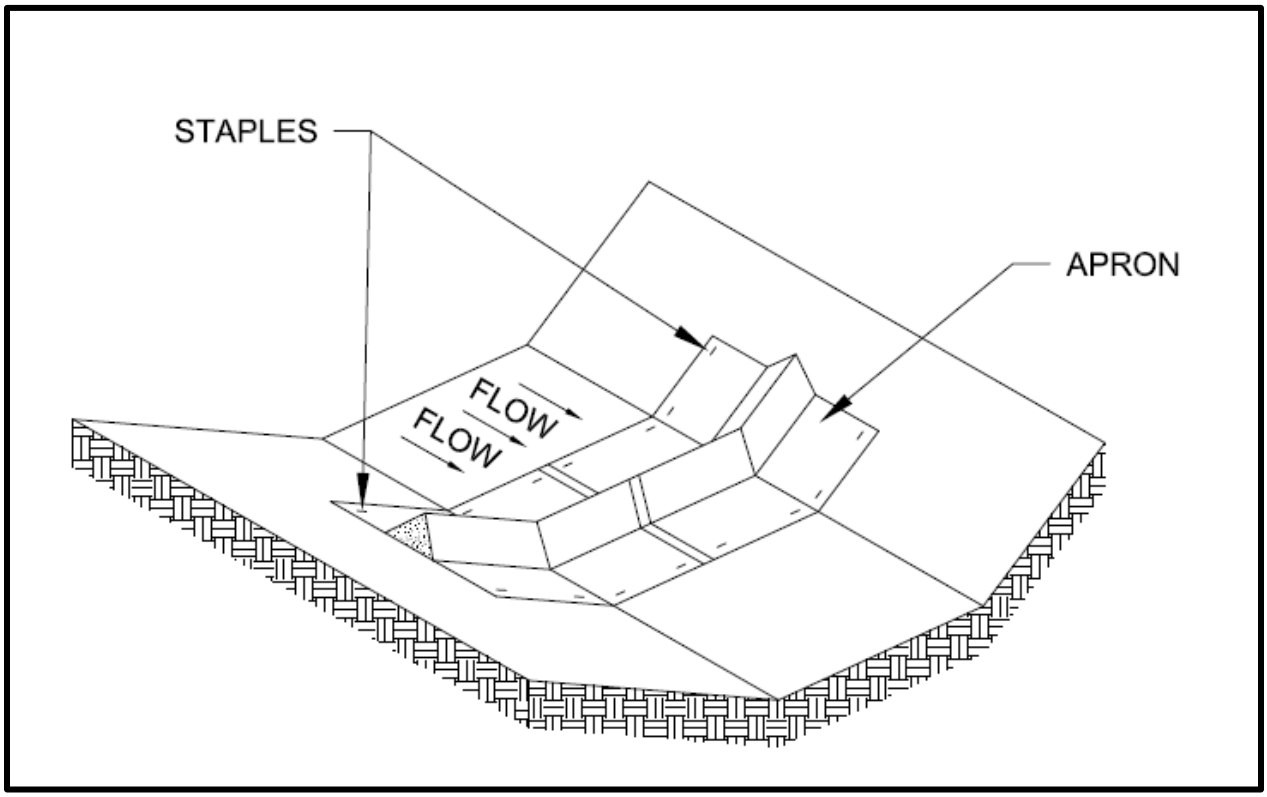


Figure 10. Triangular Silt Dike Cut Section.

Conditions Where Practice Applies

- May be used as temporary check dams in ditches of any dimension.
- May be used on soil or pavement with adhesive or staples.
- TSDs have been used to build temporary:
  - Sediment ponds
  - Diversion ditches
  - Concrete washout facilities
  - Curbing
  - Water bars
  - Level spreaders
  - Berms

Planning Considerations

- When used as check dams:
  - TSDs should be located and installed as soon as construction will allow.
  - TSDs should be placed perpendicular to the flow of water.
  - Anticipate submergence and deposition above the TSD and erosion from high flows around the edges of the dam.

Design Criteria

This BMP is typically made of urethane foam sewn into a woven geosynthetic fabric. It is triangular, 10 inches to 14 inches high in the center, with a 20- to 28-inch base. A 2--foot apron extends beyond both sides of the triangle along its standard section of 7 feet. A sleeve at one end allows attachment of additional sections as needed.

- Install with ends curved up to prevent water from flowing around the ends.
- The fabric flaps and check dam units are attached to the ground with wire staples. Wire staples should be No. 11 gauge wire and should be 200 millimeters (mm) to 300 mm in length.
- When multiple units are installed, the sleeve of fabric at the end of the unit should overlap the abutting unit and be stapled.
- When used as check dams, secure the leading edge with rocks, sandbags, or a small key slot and staples.
- Ecology has also approved technologies that are functionally equivalent to triangular silt dikes. Refer to the Functionally Equivalent Technologies section of Ecology's TAPE website for approved BMPs: https://ecology.wa.gov/regulations-permits/guidance-technical-assistance/stormwater-permittee-guidance-resources/emerging-stormwater-treatment-technologies.

Maintenance

- Inspect TSDs for performance and sediment accumulation during and after each runoff-producing rainfall. Remove sediment when it reaches one-half the height of the TSD.
- In the case of grass-lined ditches and swales, remove check dams and accumulated sediment when the grass has matured sufficiently to protect the ditch or swale, unless the slope of the swale is greater than 4 percent. Seed and mulch the area beneath the check dams immediately after dam removal.
- Immediately repair any damage or any undercutting of the TSD.

4.2.1.6. BMP E2.45: Dust Control

Description

Reducing surface and air movement of dust during land-disturbing, demolition, and construction activities.

Purpose

To prevent surface and air movement of dust from exposed soil surfaces onto roadways, adjoining properties, and into drainage channels and receiving waters (Figure 11).

Figure 11. Using a Water Truck for Dust Control.

Conditions Where Practice Applies

In areas (including roadways) subject to surface and air movement of dust where onsite and offsite damage is likely to occur if preventive measures are not taken.

Planning Considerations

Research at project sites has established an average dust emission rate of 1.2 tons/acre/month for active construction.

Construction activities result in the exposure and disturbance of soil. Fugitive dust is emitted both during the activities (i.e., excavation, demolition, vehicle traffic, human activity) and as a result of wind erosion over the exposed earth surfaces. Large quantities of dust are typically generated by “heavy” construction activities, such as road and street construction, and subdivision, commercial, and industrial development, which involve disturbance of significant areas of soil surface. Earthmoving activities are the major source, but traffic and general disturbance of the soil also generate significant dust emissions.

In planning for dust control, remember that the less soil is exposed at any one time, the less potential there will be for dust generation. Therefore, phasing a project and using temporary

stabilization practices upon the completion of grading can significantly reduce dust emissions. Also, limit traffic on areas off the site roadways.

Design Criteria

- Minimize the period of soil exposure through use of temporary ground cover and other temporary stabilization practices (refer to Seeding and Mulching, BMPs E1.10 and E1.15, respectively).
- Construct natural or artificial windbreaks or windscreens. These may be designed as enclosures for small dust sources.
- Sprinkle the site with water until surface is wet. Repeat as needed. To prevent carryout of mud onto street, refer to Stabilized Construction Access (BMP E2.10) and Tire Wash (BMP E2.15).
- Spray exposed soil areas with approved dust palliative. Oil should not be used for dust suppression. Refer to Ecology BMP C250 for information on chemical treatment.
- Building demolition should use sufficient water, such as from a hydrant or water truck(s), to thoroughly wet buildings and debris for dust suppression, and control for water runoff from the site. Repeat as needed. To prevent carryout of mud onto the street, refer to Stabilized Construction Access (BMP E2.10) and Tire Wash (BMP E2.15).

Maintenance

Re-spray area as necessary to keep dust to a minimum.

4.2.2. Permanent Erosion Control BMPs

Permanent erosion control BMPs are implemented both during and upon completion of construction activities. Permanent erosion control reduces erosion wherever practical and can be achieved primarily by installing permanent stabilizing structures or materials to new construction or existing sites. For example, by adding gradient terraces to an existing or newly constructed slope, erosion will be significantly reduced by creating a set of ridges and channels that intercept runoff and direct it to a controlled outlet. The benefit is that rill and gully formation will be minimized and toe of slope erosion will decrease as a result. Another benefit of permanent erosion control is that some of the following BMPs include using vegetation, which may be incorporated into permanent cover BMPs described in *Section 4.1.2*.

Permanent erosion control BMPs should be designed by an engineer and may have additional criteria for flow control and water quality treatment requirements. Refer to *Volume 3 — Project Stormwater Control*.

The standards and specifications for permanent erosion control BMPs include:

- Riprap Channel Lining — refer to Ecology BMP C202
- Gradient Terracing — refer to Ecology BMP C131

4.2.3. Temporary or Permanent Erosion Control BMPs

There is a subset of erosion control BMPs that may be used as temporary controls during construction, then remain as a permanent erosion control measure. For example, an earth dike and drainage swale would provide siltation control during construction and remain as permanent protection of downstream properties after construction.

Temporary measures that may also remain as a permanent erosion control are typically implemented during construction activities.

The BMPs in this section include:

- BMP E2.70: Subsurface Drains (*Section 4.2.2.2*)
- BMP E2.80: Earth Dike and Drainage Swale (*Section 4.2.3.2*)
- Outlet Protection — refer to *Appendix E*
- Pipe Slope Drains — refer to *Appendix E*
- Surface Roughening — refer to Ecology BMP C130
- Grass-lined Channels — refer to Ecology BMP C201

The requirements for maintaining permanent BMPs are included with each description; however, all temporary and permanent erosion and sediment control practices should be maintained and repaired as needed to ensure continued performance of their intended function.

4.2.3.1. BMP E2.70: Subsurface Drains

Description

A perforated conduit such as a pipe, tubing, or tile installed beneath the ground to intercept and convey groundwater.

Purpose

To provide a dewatering mechanism for draining excessively wet, sloping soils that usually consists of an underground-perforated pipe that will intercept and convey groundwater.

Conditions When Practice Applies

Wherever excessive water must be removed from the soil. The soil must be deep and permeable enough to allow an effective system to be installed. This standard does not apply to subsurface drains for building foundations or deep excavations.

Planning Considerations

Subsurface drainage systems are of two types: relief drains and interceptor drains. Relief drains are used either to lower the water table in order to improve the growth of vegetation or to remove ponded water. They are installed along a slope and drain in the direction of the slope. They can be installed in a gridiron pattern, a herringbone pattern, or a random pattern.

Interceptor drains are used to remove water as it seeps down a slope to prevent the soil from becoming saturated and subject to slippage. They are installed across a slope and drain to the side of the slope. They usually consist of a single pipe or series of single pipes instead of a patterned layout.

Design Criteria

- Temporary measures that may also remain as permanent erosion control are typically implemented during construction activities. The depth of an interceptor drain is determined primarily by the depth to which the water table is to be lowered or the depth to a confining layer. For practical reasons, the maximum depth is usually limited to 6 feet with a minimum cover of 2 feet to protect the conduit.
- The soil should be deep enough and have sufficient permeability to permit installation of an effective drainage system at a depth of 2 to 6 feet.
- An adequate outlet for the drainage system must be available either by gravity or by pumping.
- The quantity and quality of discharge needs to consider the ultimate receiving water (additional detention and/or treatment may be required).
- The capacity of an interceptor drain is determined by calculating the maximum rate of groundwater flow to be intercepted. Therefore, it is good practice to make completed subsurface investigations, including hydraulic conductivity of the soil, before designing a subsurface drainage system.
- Subsurface drains are sized for the required capacity without pressure flow. The minimum diameter for a subsurface drain is 4 inches.

- The minimum velocity required to prevent silting is 1.4 feet per second (ft/sec). Grade the line to achieve at least this velocity. The maximum allowable velocity using a sand-gravel filter or envelope is 9 feet per second.
- Use filter material and fabric around all drains for proper bedding and filtration of fine materials. Envelopes and filters should surround the drain to a minimum thickness of 3--inches.
- Install the outlet of the subsurface drain such that it empties into a sediment trap or pond. If free of sediment, it can empty into a receiving water, swale, or stable vegetated area adequately protected from erosion and undermining.
- The strength and durability of the pipe must meet the requirements of the site in accordance with the manufacturer's specifications.
- Secure an animal guard to the outlet end of the pipe to keep out rodents.
- Use outlet pipe of corrugated metal, cast iron, or heavy-duty plastic without perforations that is at least 10 feet long. Do not use an envelope or filter material around the outlet pipe and bury at least two-thirds of the pipe length.
- When outlet velocities exceed those allowable for the receiving water, provide outlet protection.

Construction Specifications

- Construct the trench on a continuous grade with no reverse grades or low spots.
- Stabilize soft or yielding soils under the drain with gravel or other suitable material.
- Do not use deformed, warped, or otherwise unsuitable pipe.
- Place filter material as specified with at least 3 inches of material on all sides of the pipe.
- Backfill immediately after placement of the pipe. Do not allow sections of pipe to remain uncovered overnight or during a rainstorm. Place backfill material in the trench in such a manner that the drain pipe is not displaced or damaged.

Maintenance

- Periodically check subsurface drains to ensure they are free-flowing and not clogged with sediment.
- Keep the outlet clean and free of debris.
- Keep surface inlets open and free of sediment and other debris.
- Trees located too close to a subsurface drain often clog the system with their roots. If a drain becomes clogged, relocate the drain to minimize this problem. As a last resort, the trees may need to be removed. Tree removal may require prior approval by SDCI and SDOT.
- Where heavy vehicles cross drains, check the line to ensure that it is not crushed.

4.2.3.2. BMP E2.80: Earth Dike and Drainage Swale

Description

A ridge of compacted soil or a swale with vegetative lining located at the top or base of a sloping disturbed area.

Purpose

To intercept stormwater runoff from drainage areas above unprotected slopes and direct it to a stabilized outlet.

Conditions Where Practice Applies

Wherever the volume and velocity of runoff from exposed or disturbed slopes must be reduced. When an earth dike or drainage swale is placed above a disturbed slope, it reduces the volume of water reaching the disturbed area by intercepting runoff from above (Figure 12). When it is placed horizontally across a disturbed slope, it reduces the velocity of runoff flowing down the slope by reducing the distance that the runoff can flow directly downhill.

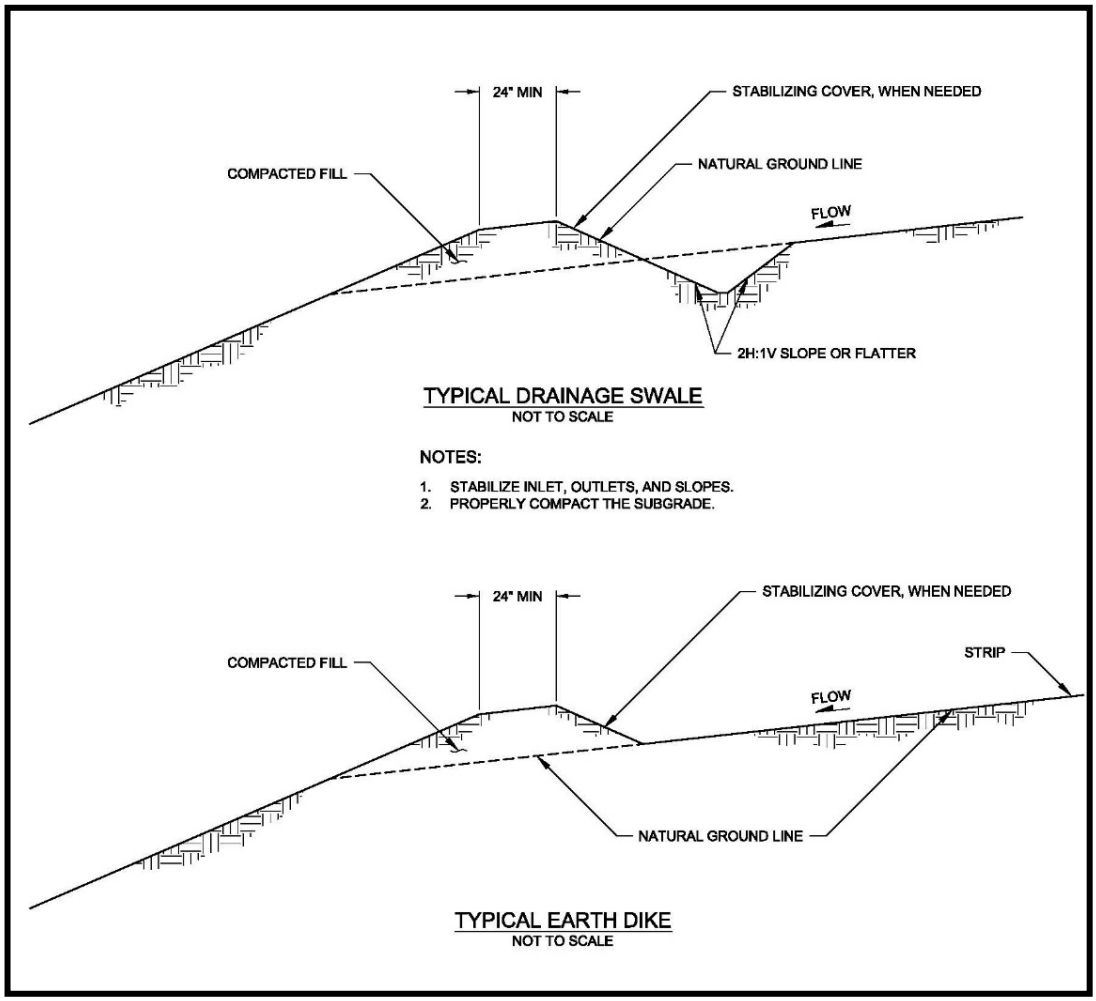


Figure 12. Earth Dike and Drainage Swale.

Planning Considerations

A temporary diversion dike or swale is intended to divert overland sheet flow to a stabilized outlet or a sediment trapping facility during establishment of permanent stabilization on a sloping disturbed area. When used at the top of a slope, the structure protects exposed slopes by keeping upland runoff away. When used at the base of a slope, the structure protects adjacent and downstream areas by diverting sediment-laden runoff to a sediment trapping facility.

If the dike or swale is going to remain in place for longer than 15 days, it must be stabilized with temporary or permanent vegetation. The slope behind the dike or swale is also an important consideration. The dike or swale must have a positive grade to ensure drainage, but if the slope is too great, precautions, including channel protection and check dams, must be taken to prevent erosion due to high velocity of flow.

This practice is considered an economical one because it uses material available on the site and can usually be constructed with equipment needed for site grading. Stabilizing the dike or swale with vegetation can extend the useful life of the BMP.

Design Criteria

- Temporary measures that may also remain as permanent erosion control are typically implemented during construction activities. Review construction for areas where overtopping may occur.
- Subbasin tributary area should be 1 acre or less.
- Earth dikes must meet the criteria in Table 5.
- Drainage swales must meet the criteria in Table 6.
- An 8- or 12-inch diameter compost sock may also be used.
- Design the dike or swale to contain flows calculated by one of the following methods:
    - Single Event Hydrograph Method: The peak flow rate from a 10--year, 24--hour frequency storm with a 10--minute time step.
    - Continuous Simulation Method: The 10--year peak flow rate as determined by an approved continuous runoff model with a 15--minute time step or less.

Maintenance

Inspect the measure after every major storm and make repairs as necessary. Repair damage caused by construction traffic or other activity before the end of each working day.

Table 5. Design Criteria for Earth Dike.

Feature	Requirement
Top Width	2-foot minimum.
Height	18-inch minimum measured from upslope toe and at a compaction of 90 percent ASTM D698 standard proctor.
Side Slopes	25 percent or flatter.
Grade	Topography dependent, except that the dike should be limited to grades between 0.5 and 1.0 percent.
Horizontal Spacing of Earth Dikes	● Slopes less than 5 percent = 300 feet ● Slopes 5–10 percent = 200 feet ● Slopes 10–40 percent = 100 feet
Stabilization	● Slopes = less than 5 percent. Seed and mulched construction (refer to BMPs E1.10 and E1.15). ● Slopes = 5 to 40 percent. Dependent on runoff velocities and dike materials. ● Stabilization should be done immediately using either sod or riprap to avoid erosion.
Outlet	The upslope side of the dike should provide positive drainage to the dike outlet. No erosion should occur at the outlet. Provide energy dissipation measures as necessary. Sediment-laden runoff must be released through a sediment trapping facility.
Other	Minimize construction traffic over temporary dikes.

Table 6. Design Criteria for Drainage Swale.

Feature	Requirement
Bottom Width	2-foot minimum. Bottom should be level.
Depth	1-foot minimum.
Side Slopes	25 percent or flatter.
Grade	5 percent maximum with positive drainage to suitable outlet such as a sediment trap.
Stabilization	Seed as per BMP E1.10 temporary seeding or Ecology BMP C130. Riprap 12 inches thick pressed into bank and extending at least 8 inches vertical from the bottom.
Stabilization	Slope of disturbed area: Less than 5 percent = 300 feet 5–10 percent = 200 feet 10–40 percent = 100 feet
Outlet	Level spreader or riprap to stabilized outlet or sedimentation pond.

4.3. Sediment Control Practices

Sediment retention practices for construction activities are temporary controls only. Permanent sediment retention requires a separate process for flow control and treatment facilities as outlined in *Volume 3 — Project Stormwater Control*.

Temporary sediment retention BMPs are described in the sections below and include:

- BMP E3.10: Filter Fence (*Section 4.3.1*)
- BMP E3.20: Gravel Filter Berm (*Section 4.3.2*)
- BMP E3.25: Inlet Protection (*Section 4.3.3*)
- BMP E3.30: Vegetated Strip (*Section 4.3.4*)
- BMP E3.35: Straw Wattles, Compost Socks, and Compost Berms (*Section 4.3.5*)
- BMP E3.40: Sediment Trap (*Section 4.3.6*)
- BMP E3.50: Portable Sediment Tank (*Section 4.3.7*)
- BMP E3.60: Construction Stormwater Filtration (*Section 4.3.8*)
- BMP E3.65: Cleaning Inlets and Catch Basins (*Section 4.3.9*)
- BMP E3.70: Street Sweeping and Vacuuming (*Section 4.3.10*)
- Brush Barrier — refer to Ecology BMP C231
- Sediment Pond (Temporary) — refer to Ecology BMP C241
- Construction Stormwater Chemical Treatment — refer to Ecology BMP C250

The requirements for maintaining these BMPs are included with each description. All temporary sediment retention practices should be maintained and repaired as needed to ensure continued performance of their intended function.

Temporary BMPs must be removed within 5 business days after final site stabilization is achieved, or after they are no longer needed, whichever is later. In either case, trapped sediment must be removed or stabilized on site and the disturbed areas permanently stabilized.

4.3.1. BMP E3.10: Filter Fence

Description

A temporary sediment barrier consisting of a filter fabric stretched across and attached to supporting posts and entrenched. The filter fence is constructed of stakes and synthetic filter fabric with a rigid wire fence backing where necessary for support.

Purpose

Filter fence is used during construction operations to intercept and detain small amounts of sediment under sheet flow conditions from disturbed areas in order to prevent sediment from leaving the site and to decrease the velocity of sheet flows (Figure 13).

Figure 13. Filter Fence Installed on a Slope.

Conditions Where Practice Applies

Filter fence may be used downslope of all disturbed areas and must be provided just upstream of the point(s) of runoff discharge from a site before the flow becomes concentrated. They may also be used below disturbed areas where runoff may occur in the form of sheet and rill erosion, and wherever runoff has the potential to impact downstream resources.

Planning Considerations

Laboratory work at the Virginia Highway and Transportation Research Council has shown that filter fence can trap a much higher percentage of suspended sediments than can straw bales, which have been disallowed by Ecology. The fence must be properly installed to fully function. The installation methods outlined here can improve performance.

Design Criteria

Refer to Figure 14 for design details.

- The drainage area must be 1 acre or less. On larger sites, the fence must be used in combination with sediment basin(s).
- Maximum slope steepness on the site (perpendicular to fence line) is 45 percent.
- Maximum sheet or overland flow path length to the fence is 100 feet.
- Concentrated flows must not be greater than 0.5 cubic feet per second (cfs).
- Selection of a filter fabric is based on soil conditions at the project site. Soil conditions affect the apparent opening size (AOS) fabric specification. Soils also affect the characteristics of the support fence, which depend on the choice of tensile strength. The designer should specify a filter fabric that retains the soil found on the project site yet will have openings large enough to permit drainage and prevent clogging. Refer to Table 7 for selection of the AOS.
- The material used in a filter fabric fence must have sufficient strength to withstand various stress conditions. The ability to pass flow through must be balanced with the material's ability to trap sediments.
- Support non-woven and regular strength slit film fabrics with wire mesh, chicken wire, 2-inch x 2-inch wire, safety fence, or jute mesh to increase the strength of the fabric. Filter fence materials are available that have synthetic mesh backing attached.
- Filter fabric material must contain ultraviolet ray inhibitors and stabilizers to provide a minimum of 6 months of expected usable construction life at a temperature range of 0°F to 120°F.
- One hundred percent biodegradable filter fence is available that is strong, long lasting, and can be left in place after the project is completed.
- The following design criteria must be used with a Large Project Construction Stormwater Control and Soil Management Plan (*Section 2.2*):
    - Purchase filter fabric in a continuous roll cut to the length of the barrier to avoid use of joints. When joints are necessary, splice filter cloth together only at a support post, with a minimum 6-inch overlap. Securely fasten both ends to the post.
    - Space posts a maximum of 6 feet apart and drive securely into the ground a minimum of 30 inches (where physically possible).
    - Excavate a trench approximately 8 inches wide and 12 inches deep along the line of posts and upslope from the barrier. Construct the trench to follow the contour.
    - When slit film filter fabric is used, fasten a wire mesh support fence securely to the upslope side of the posts using heavy-duty wire staples at least 1-inch long, tie

wires, or hog rings. Extend the wire into the trench a minimum of 4 inches and not more than 36 inches above the original ground surface.

- Wire the slit film filter fabric to the fence. Extend 20 inches of the fabric into the trench. Extend the fabric not more than 36 inches above the original ground surface. Filter fabric should not be stapled to existing trees. Other types of fabric may be stapled to the fence.
- When extra-strength or monofilament fabric and closer post spacing are used, the wire mesh support fence may be eliminated. In this case, staple or wire the filter fabric directly to the posts. Use extra care when joining or overlapping these stiffer fabrics.
- Use properly compacted native material. This is the preferred alternative because the soil forms a more continuous contact with the trench below, and use of native materials reduces the number of trips that must be made on and off site.
- Remove filter fabric fences when they have served their useful purpose but not before the upslope area has been permanently stabilized. Remove retained sediment and properly dispose of or mulch and seed.

Table 7. Geotextile Standards.

Geotextile Property	Test Method	Geotextile Property Requirements
Polymeric Mesh AOS	ASTM D4751	0.60 mm max. for slit film woven (#30 sieve) 0.30 mm max. for all other geotextile types (#50 sieve) 0.15 mm min. for all fabric types (#100 sieve)
Water Permittivity	ASTM D4491	0.02 sec-1 min.
Grab Tensile Strength	ASTM D4632	180 lbs. min. for extra strength fabric 100 lbs min. for standard strength fabric
Grab Tensile Strength	ASTM D4632	30% max.
Ultraviolet Resistance	ASTM D4355	70% min.

- Ecology has also approved technologies that are functionally equivalent to filter fences. Refer to the Functionally Equivalent Technologies section of Ecology's TAPE website for approved BMPs: https://ecology.wa.gov/regulations-permits/guidance-technical-assistance/stormwater-permittee-guidance-resources/emerging-stormwater-treatment-technologies.

Maintenance

- Inspect immediately after each rainfall and at least daily during prolonged rainfall. Repair as necessary.
- Remove sediment when it reaches approximately one-third the height of the fence.
- Spread any sediment deposits remaining in place after the filter fence is no longer required to conform to the existing grade and prepare and seed.
- Repair any damage immediately.
- Intercept and convey all evident concentrated flows uphill of the filter fence to a sediment pond.
- Check the uphill side of the fence for signs of the fence clogging and acting as a barrier to flow and causing channelization of flows parallel to the fence. If this occurs, replace the fence or remove the trapped sediment.

- Replace filter fabric that has deteriorated due to ultraviolet breakdown.

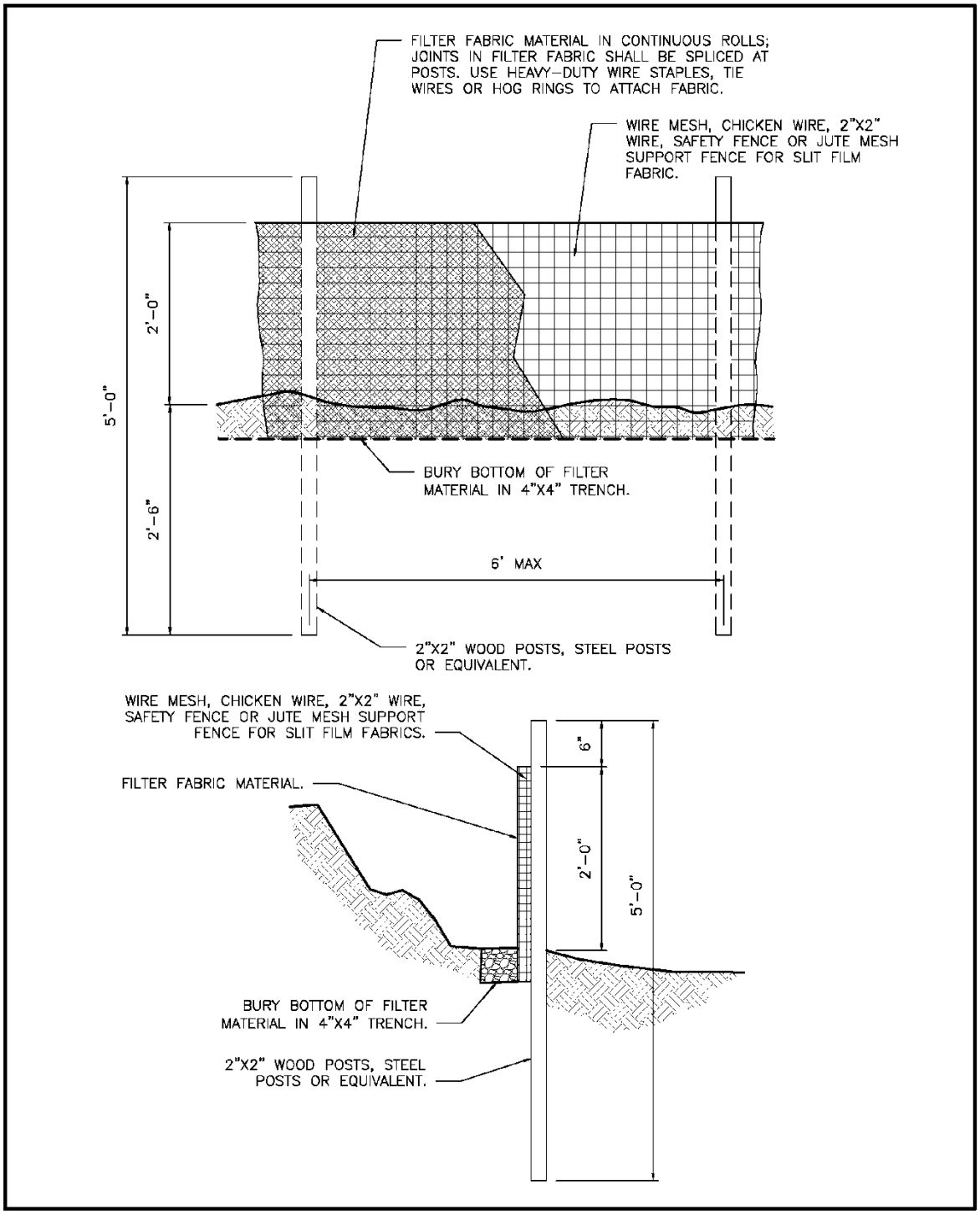


Figure 14. Filter Fence Details.

4.3.2. BMP E3.20: Gravel Filter Berm

Description

A raised gravel berm or mound constructed in traffic areas.

Purpose

To keep sediment away from traffic areas by filtering runoff through gravel or crushed rock.

Conditions Where Practice Applies

- On private property only. This BMP is not allowed in the public right-of-way.
- Where a temporary measure is needed to retain sediment from traffic areas within the project site.

Design Criteria

- Berm material must be 3/4 to 3 inches, washed, well-graded gravel or crushed rock with less than 5 percent fines.
- Spacing of berms, perpendicular to the flow of traffic:
  - Every 300 feet on slopes less than 5 percent.
  - Every 200 feet on slopes between 5 and 10 percent.
  - Every 100 feet on slopes greater than 10 percent.
- Berm dimensions:
  - 1-foot high with 18 percent side slopes.
  - 8 linear feet per 1 cfs runoff based on the 10--year, 24--hour design storm.

Maintenance

- Inspect regularly. Remove sediment and replace filter material when it becomes clogged.

4.3.3. BMP E3.25: Inlet Protection

Description

A sediment filter or an excavated impounding area around a storm drain or catch basin.

Purpose

To prevent sediment from entering storm drainage systems prior to permanent stabilization of the disturbed area.

Conditions Where Practice Applies

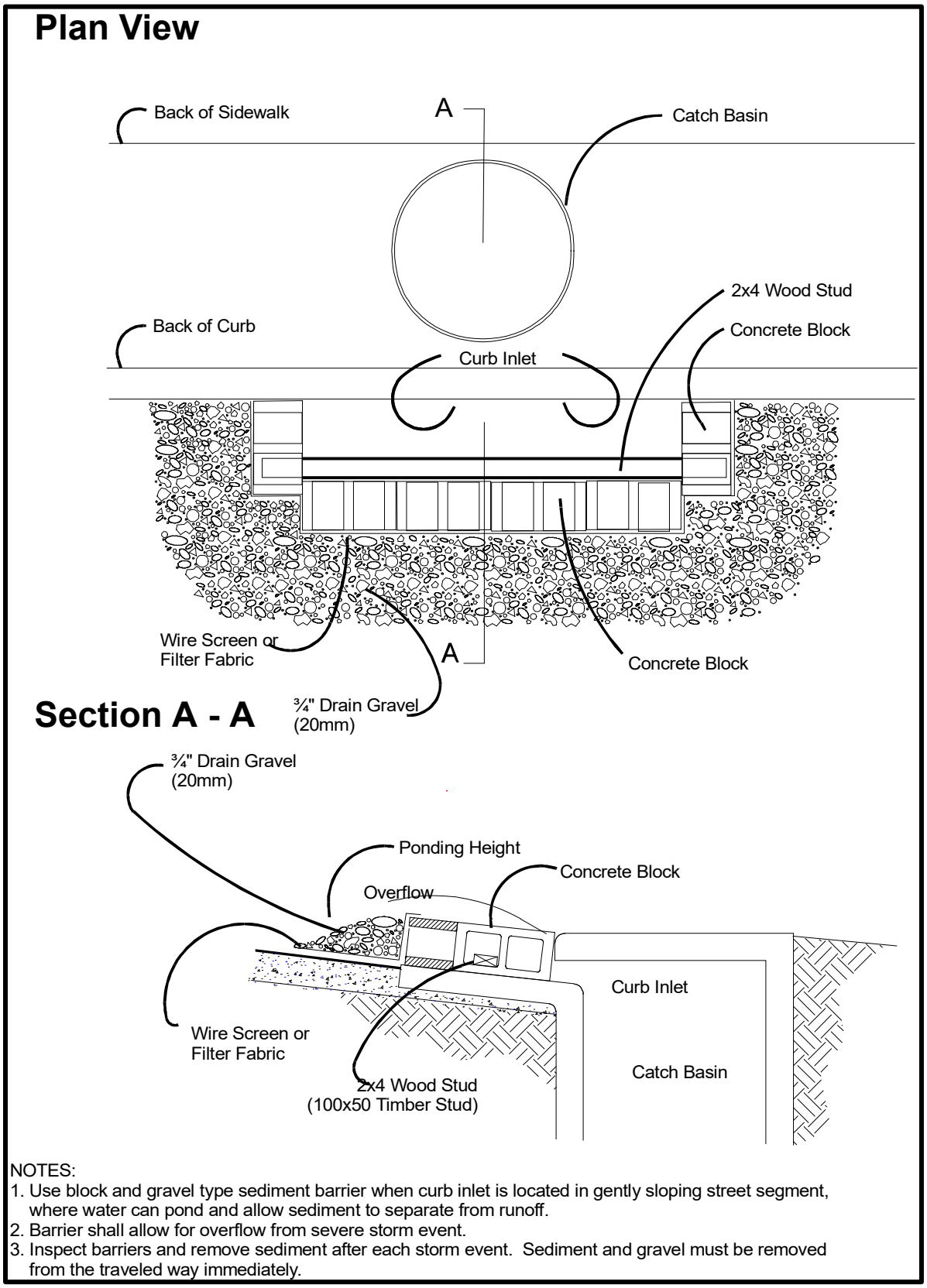
Where downslope inlets are operational prior to permanent stabilization of the disturbed drainage area. Within the project site, protection should be provided for all inlets downslope and within 500 feet to a block of a disturbed or construction area, whichever is further, unless the runoff that enters the catch basin will be conveyed to a sediment pond or trap.

Drainage areas should be limited to 1 acre or less per inlet. Emergency overflows may be required where stormwater ponding would cause a hazard. If an emergency overflow is provided, additional end-of-pipe treatment may be required. Different types of structures are applicable to different conditions:

- Structures less than 12 inches deep — use other methods to protect the inlet (BMP E3.70 Street Sweeping and Vacuuming).
- Storm drain or catch basin filter sock — applicable on private properties or within the public right-of-way for structures greater than 12 inches deep.
- Block and gravel curb inlet protection — applicable for private properties only, on a paved surface. Sturdy, but limited filtration. Consists of a barrier formed around an inlet with concrete blocks and gravel (Figure 15).
- Curb and gutter barrier — applicable for private properties only, using a sandbag or rock berm (riprap and aggregate) 3 feet high and 3 feet wide in a horseshoe shape (Figure 16). An 8- or 12---inch diameter compost sock may also be used in temporary, low-velocity applications.

Planning Considerations

- The best way to prevent sediment from entering the storm drain is to stabilize the site as quickly as possible, preventing erosion and stopping sediment at its source. Proper implementation of other BMPs, such as filter fence (BMP E3.10), straw wattles (BMP E3.35), and covering practices, can eliminate or reduce the need for downstream inlet protection, and their implementation is mandatory. Clean out the stormwater drain or catch basin prior to implementing this BMP (refer to BMP E3.65 Cleaning Inlets and Catch Basins).
- Within the project site, remove BMP within 5 business days after final site stabilization is achieved or after it is no longer needed, whichever is longer. Daily removal is required when the BMP is necessary and approved to be installed in the street inlets and catch basins for short durations to protect the public drainage system or public combined sewer from pollution-generating activities, such as sawcutting, utility excavation, or paving.



NOTES:
1. Use block and gravel type sediment barrier when curb inlet is located in gently sloping street segment, where water can pond and allow sediment to separate from runoff.
2. Barrier shall allow for overflow from severe storm event.
3. Inspect barriers and remove sediment after each storm event. Sediment and gravel must be removed from the traveled way immediately.

Figure 15. Block and Gravel Curb Inlet Protection.

Figure 16. Curb and Gutter Barrier.

- All methods for inlet protection are prone to plugging and require a high frequency of maintenance.
- Storm drains made operational before their drainage area is stabilized can convey large amounts of sediment to natural drainage channels. In cases of extreme sediment loading, the storm drain itself may clog and lose a major portion of its capacity. To avoid these problems, it is necessary to prevent sediment from entering the system at the inlets.
- Several types of inlet filters and traps have different applications that depend on site conditions and type of inlet. Other innovative techniques for accomplishing the same purpose are encouraged, but only after specific plans and details are submitted to and approved by the SDCI. Note that these various inlet protection devices are for drainage areas of less than 1 acre. Runoff from larger disturbed areas should be routed through a temporary sediment pond or trap (refer to Ecology BMPs C241 and E3.40).

Design Criteria

- Secure grates and spaces of all inlets to prevent seepage of sediment-laden water.
- All catch basin protection measures should include sediment sumps of 1 to 2 feet in depth with 25 percent side slopes.
- Installation procedure for a drain or catch basin filter sock:
  - For structures greater than 12 inches deep, the filter sock can be laid into the inlet as long as the overflow opening is in the direction of the outlet pipe.
  - Trim and remove filter sock material that extends beyond the grate.
  - Make provisions to decant accumulated sediment.
  - Install a high-flow bypass that will not clog under normal use at a project site.
- Installation procedures for block and gravel curb inlet protection:
  - Place two concrete blocks on their sides abutting the curb at either side of the inlet opening—these are spacer blocks.
  - Place a piece of lumber through the outer holes of each spacer block to align the front blocks.
  - Place blocks on their sides across the front of the inlet and abutting the spacer blocks.
  - Place wire mesh with 1/2--inch openings over the outside vertical face.
  - Pile coarse aggregate against the wire to the top of the barrier.
- Installation procedures for curb and gutter sediment barrier:
  - Construct a horseshoe shaped berm.
  - If using riprap, create a face with coarse aggregate 3 feet high and 3 feet wide and at least 2 feet from the inlet.
- Ecology has also approved technologies that are functionally equivalent to storm drain inlet protection. Refer to the Functionally Equivalent Technologies section of Ecology's TAPE website for approved BMPs: https://ecology.wa.gov/regulations-permits/guidance-technical-assistance/stormwater-permittee-guidance-resources/emerging-stormwater-treatment-technologies.

Maintenance

- Inspections should be made on a regular basis, especially after large storm events. Inlet protection devices should be cleaned or removed and replaced when sediment has filled one-third of the available storage (unless a different standard is specified by the product manufacturer.
- Do not wash sediment into storm drains while cleaning. Spread all excavated material evenly over the surrounding land area or stockpile and stabilize as appropriate.

4.3.4. BMP E3.30: Vegetated Strip

Description

A vegetated area located downslope of a disturbed area that is capable of filtering coarse sediment from runoff and slowing runoff velocities.

Purpose

Vegetated strips reduce the transport of coarse sediment from a project site by providing a temporary physical barrier to sediment and reducing the runoff velocities of overland flow.

Conditions Where Practice Applies

- Vegetated strips may be used downslope of all disturbed areas and placed parallel to the toe of the slope.
- Vegetated strips are not intended to treat concentrated flows, nor are they intended to treat substantial amounts of overland flow. Any concentrated flows must be conveyed through the drainage system to a sediment pond. The only circumstance where overland flow can be treated solely by a strip, rather than by a sediment pond, is when the strip flow path length can be achieved with the associated average slope (Table 8).

Table 8. Vegetated Strip Implementation Criteria.

Average Slope	Slope Percent	Flowpath Length
1.5H:1V or less	67% or less	100 feet
2H:1V or less	50% or less	115 feet
4H:1V or less	25% or less	150 feet
6H:1V or less	16.7% or less	200 feet
10H:1V or less	10% or less	250 feet

Design Criteria

- The vegetated strip must consist of a minimum of a 25--foot-wide continuous strip of dense vegetation with permeable topsoil. Grass-covered landscaped areas are generally not adequate because the volume of sediment overwhelms the grass. Ideally, vegetated strips should consist of undisturbed native growth with a well-developed soil that allows for infiltration of runoff.
- The slope within the strip must not exceed 25 percent.
- Delineate the uphill boundary of the vegetated strip with clearing limits.

Maintenance

- Immediately seed and mulch any areas damaged by erosion or construction activity.
- Install sod if more than 5 feet of the original vegetated strip width has had vegetation removed or is being eroded.
- If there are indications that concentrated flows are traveling across the buffer, install stormwater controls to reduce the flows entering the buffer or install additional perimeter protection.

4.3.5. BMP E3.35: Straw Wattles, Compost Socks, and Compost Berms

Description

Temporary erosion and sediment control barriers consisting of encased straw, encased compost, or a compost berm.

Straw wattles consist of straw that is wrapped in biodegradable tubular plastic or similar encasing material. Straw wattles are typically 8 to 10 inches in diameter and 25 to 30 feet in length. The wattles are placed in shallow trenches and staked along the contour of disturbed or newly constructed slopes (Figure 17). Compost socks consist of a net tube, similar to straw wattles, filled with compost, and available in biodegradable mesh or non-biodegradable mesh for installations longer than 6 months. Compost berms are rows of compost with a triangular cross section that can serve a similar function as wattles or socks. Compost socks and berms typically do not require trenching.

Figure 17. Straw Wattles or Compost Sock for Inlet Protection.

Purpose

To reduce the velocity, spread the flow of rill and sheet runoff, and capture and retain sediment.

Conditions Where Practice Applies

- Disturbed areas that require immediate erosion protection.
- Exposed soils during short construction delays or over winter months.
- On slopes requiring stabilization until permanent vegetation can be established.
- For inlet protection or elsewhere on top of pavement to filter or direct flow.
- As an alternative to filter fence for perimeter control.

Planning Considerations

- Compost socks and straw wattles are effective for 1 to 2 seasons. Berms are effective for 1 to 2 weeks, or longer if vegetated, protected by fencing, or both.
- If conditions are appropriate, straw wattles and compost socks can be staked to the ground using willow cuttings for added re-vegetation. Compost socks can also be filled with a compost and seed mix to provide temporary or permanent vegetation. Use biodegradable socks for permanent installations.

Design Criteria

- It is critical that straw wattles and compost socks are installed perpendicular to the flow direction and parallel to the slope contour (Figure 18). Rilling can occur beneath straw wattles if not properly entrenched and water can pass between straw wattles and compost socks if not tightly abutted together.
- In most conditions, compost socks do not require trenching because of their superior ground contact. Straw wattles do require trenching.
- For straw wattles, dig narrow trenches across the slope on contour to a depth of 3 to 5 inches on clay soils and soils with gradual slopes. Construct trenches at contour intervals of 3 to 30 feet apart depending on the steepness of the slope, soil type, and rainfall. The steeper the slope the closer together the trenches.
- Start building trenches and installing wattles from the base of the slope and work up. Spread excavated material evenly along the uphill slope and compact using hand tamping or other methods.
- Install straw wattles snugly into the trenches and abut tightly end to end. Do not overlap the ends. Install stakes at each end of the wattle and at 4-foot centers along entire length of wattle. If required, install pilot holes for the stakes using a straight bar to drive holes through the wattle and into the soil.
- On loose soils, steep slopes, and areas with high rainfall, dig the trenches to a depth of 5 to 7 inches or one-half to two-thirds of the thickness of the wattle.
- At a minimum, use wooden stakes that are approximately ¾ inches square and 24 inches long. Willow cuttings or 3/8-inch rebar can also be used for stakes. Drive stakes through the middle of the straw wattle or compost sock, leaving 2 to 3 inches of the stake protruding above the wattle or sock.
- Compost socks are usually placed on the prepared surface, without trenching, so long as no rilling exists on that surface. If the surface is sloped, stake through the sock at 10-foot intervals or more closely on steeper slopes. After staking, walk down the top of the sock to press it onto the ground surface.

- Compost berms are typically 1 foot high by 2 feet wide at the base, or 18 inches high and 3 feet wide.
- Protect compost berms from foot or vehicle traffic by a fence or otherwise immediately seed to provide stability. Short-term (1 to 2 week) applications may not require protection and stabilization.

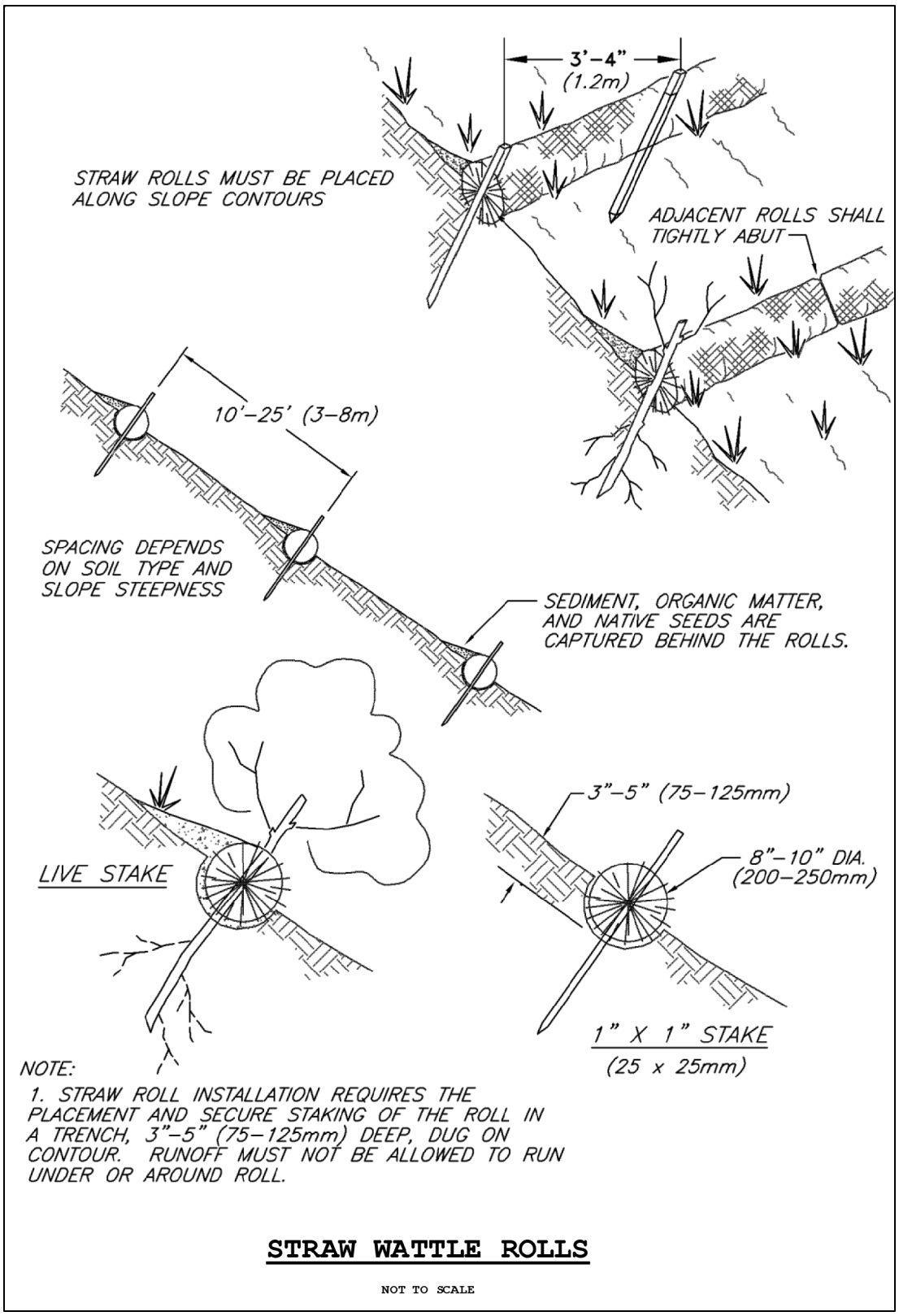


Figure 18. Straw Wattle Details.

Ecology has also approved technologies that are functionally equivalent to wattles. Refer to the Functionally Equivalent Technologies section of Ecology's TAPE website for approved BMPs: https://ecology.wa.gov/regulations-permits/guidance-technical-assistance/stormwater-permittee-guidance-resources/emerging-stormwater-treatment-technologies.

Maintenance

- Inspect wattles to ensure they are in contact with soil and thoroughly entrenched, especially after significant rainfall on steep sandy soils. Repair as necessary.
- Straw wattles and compost socks can be compressed by vehicle traffic, creating an overflow point. Repair immediately.
- Inspect the slope after significant storms and repair any areas where wattles are not tightly abutted or water has scoured beneath the wattles.

4.3.6. BMP E3.40: Sediment Trap

Sizing is less important than constant maintenance for this BMP because it is a temporary control. Inspections must be made and sediment removed regularly for sediment traps to function well.

Description

A small temporary ponding area with a gravel outlet formed by excavation or by constructing an earthen embankment.

Purpose

To collect and store sediment from project sites cleared, graded, or both during construction. It is intended for use in relatively small drainage basins with no unusual drainage features, and a projected quick build-out time. It should help in reducing silt-laden runoff that clogs offsite conveyance systems and destroys habitat, particularly in streams.

Conditions Where Practice Applies

Proposed building sites where the tributary drainage basin is less than 3 acres.

Planning Considerations

- Prior to leaving a project site where the tributary drainage is 3 acres or less, stormwater runoff must pass through a sediment pond or other appropriate sediment removal BMP (refer to Attachment 1, Table 1a and Table 1b for other approved stormwater controls).
- If the contributing drainage area is greater than 3 acres, refer to Ecology BMP C241 Sediment Pond (Temporary) or subdivide the tributary drainage area.
- The trap is a temporary measure (with a design life of approximately 6 months) and is to be maintained until the project site is permanently protected against erosion by vegetation, structures, or both.
- Sediment must be periodically removed from the trap. Plans should detail how this sediment is to be disposed of, such as by use in fill areas on site or removed to an approved offsite dump. Sediment traps, along with other perimeter controls, must be installed before any land disturbance takes place in the drainage area.
- Alternative Methods: Consider using a temporary aboveground storage tank (e.g., Baker Tank) for temporary storage. If a tank cannot be used, consider using a pond with pumping capabilities to another temporary holding structure. Refer to BMP E3.50 Portable Sediment Tank.
- Wherever possible, sediment-laden water should be discharged into onsite, relatively level, vegetated areas (refer to BMP E3.30 Vegetated Strip).
- Projects that are constructing permanent flow-control BMPs or runoff treatment BMPs that use ponding for treatment may use the rough-graded or final-graded permanent BMP footprint for the temporary sediment trap. Refer to *Volume 3 — Project Stormwater Control* for additional requirements.

Safety

Sediment traps and ponds should be limited to project sites where failure of the structure would not result in loss of life, damage to homes or buildings, or interruption of use or service of public roads or utilities.

Sediment traps and ponds are attractive to children and can be very dangerous. Local ordinances regarding health and safety must be adhered to. If fencing of the pond is required, the type of fence and its location must be shown in the Construction Stormwater Pollution Control Plan.

Design Criteria

To determine the sediment trap geometry, first calculate the design surface area (SA) of the trap, measured at the invert of the weir (Figure 19). Use the following equation:

$$SA = FS(Q/Vs)$$

Where:

Q = Peakflow rate

The peak flow rate must be calculated by one of the following methods:

- Single Event Hydrograph Method: The peak flow rate from a 2--year, 24--hour design storm with a 10--minute time step. The 10--year peak flow rate must be used if the project size, expected timing and duration of construction, or downstream conditions warrant a higher level of protection, including but not limited to the following situations:
  - The site is within 1/4 mile of an open creek or a wetland.
  - There will be more than 1 acre of clearing and grading or land disturbance that is likely to occur during the wet season.
  - There is a known erosion or sediment problem downstream of the site.
  - When the downstream system is considered capacity constrained.
- Continuous Simulation Method: The 50 percent annual probability or 10 percent annual probability flows (2-year or 10---year recurrence interval, respectively) as outlined above with a 15--minute time step or less.
- Rational Method: If no hydrologic analysis is required for the other portions of the site design (conveyance, flow control, water quality control, or some or all of these) and the site is less than 1 acre, the Rational Method may be used for sediment trap design. Refer to *Appendix F* for additional guidelines.

When calculating the peak flow rate, the land use cover used in the calculations must represent the conditions during construction that result in the most runoff (e.g., 100 percent impervious for sites that will not have any vegetated areas that are protected during construction) unless multiple sizes are given for different stages of the construction.

Vs = the settling velocity of the soil particle of interest. The 0.02-millimeter (mm) (medium silt) particle with an assumed density of 2.65 grams per cubic centimeter (g/cm^3) has been selected as the particle of interest and has a settling velocity (Vs) of 0.00096 ft/sec.

FS = A safety factor of 2 to account for non-ideal settling.

Therefore, the equation for computing sediment trap surface area becomes:

SA = 2 x *Q*/0.00096 or
2,080 square feet per cfs of inflow

Note: Even if permanent facilities are used, they must still have a surface area that is at least as large as that derived from the above formula. If they do not, the pond must be enlarged.

The outlet riser or pipe should be 3.5 feet minimum above bottom to draw clean water and avoid discharging sediment that is still suspended in the lower part of the water column.

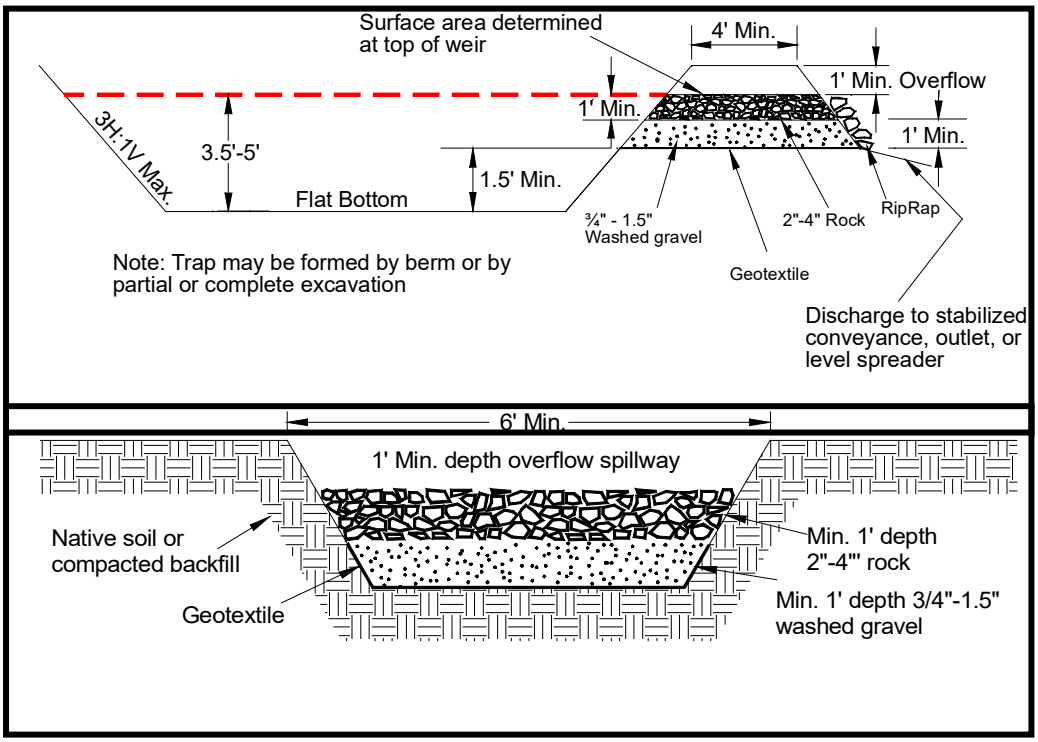


Figure 19. Cross Section of Sediment Trap and Outlet.

To aid in determining sediment depth, all sediment traps should have a staff gauge with a prominent mark 1 foot above the bottom of the trap.

Maintenance

- The sediment trap must be continually monitored and regularly maintained. The size of the trap is less important to its effectiveness than is regular sediment removal. Remove sediment from the trap when it reaches approximately 1 foot in depth

(assuming a 1.5 foot sediment accumulation depth). Conduct regular inspections and additional inspections after each large runoff-producing storm.

- Maintain and repair all temporary and permanent erosion and sediment control practices as needed to ensure continued performance of their intended function.
- Remove all temporary erosion and sediment control measures within 5 business days after final site stabilization is achieved, or after the temporary BMPs are no longer needed, whichever is longer. Remove trapped sediment or stabilize on site. Permanently stabilize disturbed soil areas resulting from removal.

4.3.7. BMP E3.50: Portable Sediment Tank

Description

A compartmental tank brought temporarily to a project site. Sediment-laden water is pumped into the tank to trap and retain sediment.

Purpose

A portable sediment tank is used for temporary storage of sediment-laden water and to trap and retain sediment prior to discharging to an appropriate discharge point.

Conditions Where Practice Applies

A portable sediment tank should be used on sites where excavations are deep and space is limited, or wherever the tank can be located per the manufacturer's specifications with an appropriate discharge point.

Planning Considerations

Using a portable sediment tank is the preferred method to minimize potential impacts to the project site. The tank configuration, size, location, and discharge point must be presented in the Construction Stormwater Control and Soil Management Plan and approved by the City.

Follow the manufacturer's or vendor's specifications for choosing the appropriate location. In addition, the tank should be located for ease of clean-out and disposal of trapped sediment, and to minimize the interference with construction activities and pedestrian traffic.

If a permit is obtained for discharge to a combined sewer system, conduct all discharge activities in accordance with permit requirements, including when it can be discharged and the discharge flow rate.

Design Criteria

Sediment tanks must have a minimum depth of 2 feet and be designed to allow for emergency flow to an approved discharge point. Outlet riser or pipe should be 1.5 feet minimum above bottom to draw clean water and avoid discharging sediment that is still suspended in the lower part of the water column.

As noted above, tank configuration and size must be presented in the Construction Stormwater Control and Soil Management Plan and approved by the City. For planning purposes, use the following formula to determine the minimum storage volume of the sediment tank. This formula is equivalent to 120 minutes of residence time. Additional storage volume may be required by the City.

Peak flow rate in gallons per minute (gpm) x 16 = cubic feet storage,

or

Peak flow rate in gallons per minute (gpm) x 120 minutes = gallons of storage.

Refer to *Section 4.3.6* for BMP E3.40 Sediment Traps for design peak flow rate selection requirements.

In some cases, it may be necessary to hold drainage on site and truck it off site to discharge in a different location. Examples include when no off-site point of discharge is available for drainage or the construction stormwater runoff or groundwater needing discharge is contaminated. In this case, the following is required:

- The sediment tanks must be sized to store the full volume from a 2-year, 24-hour storm event. These tanks must always be available on the site. Additional volume may be required during the rainy season (November through April).
- The discharge water and sediment must be taken to a discharge facility that is permitted and authorized to accept the type of discharges present in the sediment tanks. For example, if there are contaminants in the discharge, the facility must be permitted and authorized to accept the volume of discharge and the type of any contaminants present. Discharge tickets provided by the facility must be presented to the City inspector for approval.
- Special Inspections by a third party may be required, as determined by the Director.

Container designs can vary from cylindrical tanks to rectangular boxes, depending on the manufacturer. Any tank configuration can be used if the storage volume is adequate and approval is obtained from the City.

Effectiveness

The pollution removal efficiency of the sediment tank can be increased by using flocculation chemicals, such as alum (aluminum sulfate) in the tank. Flocculation will allow very small, suspended particles to settle out and decrease the time it takes for larger particles to settle out. Flocculation tank setup is considerably more complicated because the rate of flocculent addition must be carefully monitored.

For sites that do not require coverage under Ecology's Construction Stormwater General Permit, formal written approval from the City is required to use chemical treatment such as flocculation chemicals, regardless of site size. Any proposed chemicals and the method of use must also be formally approved by Ecology. Refer to Ecology BMP C250 for more information on chemical treatment.

Alternatives

An alternative to a portable sediment tank is a tank constructed using steel drums, sturdy wood, or other material suitable for handling the pressure exerted by the volume of the water.

- Sediment tanks must have a minimum depth of 2 feet.
- The tank must be located for easy clean-out and disposal of the trapped sediment and to minimize the interference with construction activities.
- Once the water level nears the top of the tank, the pump must be shut off while the tank drains and additional capacity is made available.
- Clean out the tank as soon as one-third of the original capacity is depleted due to sediment accumulation. The tank must be clearly marked showing the cleanout point.
- An appropriate discharge point must be selected and approved by the City.

Maintenance

- Follow the manufacturer's or vendor's specifications.
- During construction, inspect BMPs daily during the work week with additional inspections scheduled during storm events. Make any required repairs immediately.
- Inspect filtering or control devices frequently. Repair or replace them to ensure that the structure functions as designed.
- Clean out the tank as soon as one-third of the original capacity is depleted due to sediment accumulation. The tank must be clearly marked showing the clean-out point. Removed sediment may be disposed of on site if no contamination is present. Contaminated sediment must be disposed of according to local governing agency requirements.
- Systems should be filled in or otherwise removed when permanent dewatering controls are in place and connected to an approved treatment and receiving system.

4.3.8. BMP E3.60: Construction Stormwater Filtration

Description

Use of a filter to remove sediment from stormwater runoff.

Purpose

Filtration removes sediment from runoff originating from disturbed areas of the site.

Conditions Where Practice Applies

Construction stormwater filtration should be used when traditional construction stormwater BMPs used to control soil erosion and sediment loss from construction sites may not be adequate to ensure compliance with the water quality standard for turbidity in the receiving water. Filtration may be used in conjunction with gravity settling to remove sediment as small as fine silt (0.5 micrometers [µm]). The reduction in turbidity will be dependent on the particle size distribution of the sediment in the stormwater. In some circumstances, sedimentation and filtration may achieve compliance with the water quality standard for turbidity.

Unlike chemical treatment, the use of construction stormwater filtration does not require approval from Ecology. Filtration may also be used in conjunction with polymer treatment in a portable system to ensure capture of the flocculated solids. Filtration in conjunction with polymer treatment requires testing under the Chemical Technology Assessment Protocol — Ecology (CTAPE) before it can be initiated. Approval from Ecology must be obtained at each site where chemical use is proposed prior to use. For more guidance on stormwater chemical treatment, refer to Ecology BMP C250.

Filtration with sand media has been used for over a century to treat water and wastewater. The use of sand filtration for treatment of stormwater has developed recently, generally to treat runoff from streets, parking lots, and residential areas. The application of filtration to construction stormwater treatment is currently under development.

Design Criteria

Two types of filtration systems may be applied to construction stormwater treatment: rapid and slow.

- Rapid filtration systems are the typical system used for water and wastewater treatment. These systems can achieve relatively high hydraulic flow rates, on the order of 2 to 20 gallons per minute per square foot (gpm/sf), because they have automatic backwash systems to remove accumulated solids.
- Slow filtration systems have very low hydraulic rates, on the order of 0.02 gpm/sf, because they do not have backwash systems. Slow filtration systems have generally been used as postconstruction BMPs to treat stormwater. Slow filtration is mechanically simple compared to rapid filtration but requires a much larger filter area.

Filter Type and Efficiencies

Sand media filters are available with automatic backwashing features that can filter to 50 µm particle size. Screen or bag filters can filter down to 5 µm. Fiber wound filters can remove particles down to 0.5 µm. Filters should be sequenced from the largest to the smallest pore opening. Sediment removal efficiency will be related to particle size distribution in the stormwater.

Treatment Process and Description

Stormwater is collected at interception point(s) on the site and is diverted to an untreated stormwater sediment pond or tank for removal of large sediment and storage of the stormwater before it is treated by the filtration system. In a rapid filtration system, the untreated stormwater is pumped from the pond or tank through the filtration media. Slow filtration systems are designed using gravity to convey water from the pond or tank through the filtration media. If large volumes of concrete are being poured, pH adjustment may be necessary (refer to BMPs C1.56, C1.58, and C1.59).

Sizing for Flow-through Treatment Systems for Discharges to Designated Receiving Waters:

Filtration treatment systems must be designed to control the velocity and peak flow rate that is discharged from the system and consequently the project site. Refer to *Element 4 Protect Downstream Properties and Receiving Waters* (SMC 22.805.020.D) for further detail on this requirement.

The untreated stormwater storage pond or tank must be sized to hold 1.5 times the runoff volume of the 10--year, 24--hour storm event minus the treatment system flow rate for an 8-hour period.

$V_s = (1.5 \text{ X } V_{10}) - (Q_t \text{ X } 60 \text{ minutes/hour X } 8 \text{ hours})$ where:

V_s = volume of storage pond or tank (gallons)

V_{10} = runoff volume of the 10-year, 24-hour storm in (gallons)

Q_t =filtration treatment system flow rate (gpm)

If groundwater dewatering will be conducted and will be treated with filtration, the capacity of the filtration treatment system must be sized to account for the groundwater dewatering rate plus the peak flow rate from the 2-year, 24-hour storm at a minimum. In addition, the storage pond or tank size must be confirmed to provide at least 2 hours (120 minutes) of residence time for the combined groundwater dewatering rate and the 2-year, 24-hour storm.

$Q_t = Q_{gw}+Q_2$

and

Check that $V_s \geq (Q_{gw} + Q_2) \text{ X } 120$ minutes

where:

V_s = volume of storage pond or tank (gallons)

Q_{gw} = groundwater dewatering rate (gpm)

Q_2 = peak runoff flowrate from 2-year, 24-hour storm (gpm)

For a chitosan-enhanced sand filtration system, the treatment system flow rate must be sized using a hydraulic loading rate between 6 and 8 gpm/sf. Other hydraulic loading rates may be more appropriate for other systems.

Bypass must be provided around the filtration treatment system to accommodate extreme storms. Runoff volume must be calculated using the methods presented in *Volume 3, Chapter 4*. Worst-case land cover conditions (i.e., producing the most runoff) must be used for analyses (in most cases, this would be the land cover conditions just prior to final landscaping).

Sizing for Listed Creek Basins and Non-listed Creek Basins:

Sites that must implement flow control for developed site conditions must also control stormwater release rates during construction. See Section 4.4.1 BMP E4.10 Temporary Flow Control During Construction.

Maintenance

- Rapid sand filters typically have automatic backwash systems triggered by a pre-set pressure drop across the filter. If the backwash water volume is not large or substantially more turbid than the stormwater stored in the holding pond or tank, return of backwash to the pond or tank may be appropriate. However, land application or another means of treatment and disposal may be necessary.
- Screen, bag, and fiber filters must be cleaned or replaced when they become clogged.
- Sediment should be removed from the storage and treatment ponds as necessary. Typically, sediment removal is required once or twice during a wet season and at the decommissioning of the ponds.

4.3.9. BMP E3.65: Cleaning Inlets and Catch Basins

Description

Removal of debris from existing inlets, catch basins, and connecting pipelines to protect and maintain private facilities and the public drainage system.

Purpose

The purpose of cleaning inlets and catch basins is to restore the function of the drainage collection system and reduce sediment transfer through the public drainage system or public combined sewer system.

Conditions Where Practice Applies

- Whenever other sediment control BMPs are not feasible or have failed.
- Whenever the public drainage collection facilities immediately downstream are not functioning.
- Whenever there is ponding in the travel lanes of the public roadway.

Planning Considerations

Large amounts of sediment can be conveyed through inlets, catch basins, and the public drainage system or public combined sewer. Sediment can also plug these facilities, causing a flooding hazard or a hazard to traffic and pedestrians in the public roadway. Protection from sediment and debris is not always possible or effective; therefore, cleaning is the last action taken.

The best ways to prevent sediment from entering the storm drain are:

- Control the discharge points.
- Stabilize the site to control pollution at its source.
- Good housekeeping such as sweeping, vacuuming, and cleaning (BMP E3.70).
- Identify which BMP is feasible at each point of drainage collection and discharge and during each construction phase. Inlet and catch basin cleaning must be performed when other protection methods are not possible or fail.

Design Criteria

- Identify the drainage flow path(s) on site and downstream for a minimum distance of 500 feet or one block, whichever is further, in the public roadway.
- Identify the location of all existing inlets and catch basins within the project area that may be impacted. Identify whether they will remain, be removed, or abandoned during construction.
- When an inlet or catch basin is to be removed or abandoned, plug that path to the public drainage system or public combined sewer prior to demolition of the immediate surroundings.
- Inlet protection (BMP E3.25) is required when feasible. When it is not feasible or fails, clean affected inlets, catch basins, and connecting pipe.

- Use a vacuum truck or shovels with proper disposal for cleaning. Jetting material downstream into the public drainage system or public combined sewer is not allowed.
- Protect new inlets and catch basins from onsite sediment and clean after site stabilization as necessary.

Maintenance

- Regularly inspect inlets and catch basins on site and within a distance of 500 feet or one block, whichever is further, in the public roadway. Increase inspections as necessary, especially after street sweeping.
- Clean inlets when sediment, debris, or both are visible.
- Clean catch basins whenever debris, sediment, or both occupy more than one--half the capacity or are within 18 inches of the outlet pipe invert.
- Always clean inlets and catch basins after site stabilization.

4.3.10. BMP E3.70: Street Sweeping and Vacuuming

Description

Use of human-powered or mechanical equipment to collect sediment on paved surfaces to minimize sediment accumulation in private systems and the public drainage system. This BMP may also be used to clean paved surfaces in preparation for final paving.

Purpose

Sweeping and vacuuming minimizes project area sediment from entering the public drainage system or public combined sewer. Targeted pollutants include sediment, nutrients, trash, metals, bacteria, oil and grease, and organics.

Conditions Where Practice Applies

Sweeping and vacuuming are suitable on any paved surface and, in particular, anywhere sediment is tracked from the project site onto public or private paved streets and roads, typically at the stabilized construction access (BMP E2.10) and other construction access points. Sweeping and vacuuming are also applicable during preparation of paved surfaces for final paving.

Planning Considerations

Sweeping and vacuuming may not be effective when sediment is wet or when tracked soil is caked (caked soil may need to be scraped loose). Washing is not an alternative to sweeping and vacuuming because of the risk of pollutant transport.

Design Criteria

- Control the number of points where vehicles can leave the site to allow focused sweeping and vacuuming efforts.
- Do not use kick brooms or sweeper attachments.
- Consider incorporating the removed sediment back into the project if not mixed with debris or trash.

Maintenance

- After initiating sweeping, vacuuming, or both, inspect the potential sediment tracking locations daily to ensure they are clean of any sediment.
- Visible sediment tracking must be swept or vacuumed on a daily basis.
- Be careful not to sweep up any unknown substance or any object that may be potentially hazardous.
- Adjust brooms frequently; maximize efficiency of sweeping operations.
- After sweeping is finished, properly dispose of sweeper wastes at an approved disposal site.

4.4. Flow Control & Dewatering Practices

4.4.1. BMP E4.10: Temporary Flow Control During Construction

Description

Projects that meet the criteria in Section 4.4.1.3 below must provide flow control BMPs during construction to detain stormwater runoff and dewatering flow before it leaves the construction site. The BMPs used for sediment control (e.g. sediment traps, sediment tanks) may also be used for flow control, but they must be sized using a continuous runoff model to meet the temporary flow control standard. Note: the sizing of BMPs in the Sediment Control section of this Manual do not necessarilyf meet the flow control standard.

Purpose

The purpose of temporary flow control during construction is to protect properties and waterways downstream of development sites from flooding and erosion due to increases in the velocity, duration, and flow rate of stormwater runoff that occur during construction as a result of clearing vegetation, compacting the soil, and adding impervious surface.

Flow control during construction consists of three main elements:

1. Interception of runoff and dewatering flow.
2. Conveyance of the flow to a flow control BMP as required. This can be a modified sediment BMP that is designed to provide the required flow control.
3. Controlled release of the runoff downstream of any disturbed areas at the approved point of discharge.

Conditions Where Practice Applies

Large projects that include more than 10,000 square feet of new plus replaced hard surface area AND that meet any of the following criteria must implement flow control during construction:

- The site discharge is within 1/4 mile of an open creek or a wetland.
- There is a known flooding, erosion, or sediment problem downstream of the site.
- The site discharges to a capacity constrained system or its basin.

If the criteria above apply, construction site stormwater plus dewatering discharges must not exceed the discharge durations of the existing condition for the range of existing discharge rates from one-half of the 2-year flow through the 10-year flow as predicted by an approved continuous runoff model. In addition, if there will be groundwater dewatering, the peak flowrates from the existing condition for the 2-year and 10-year recurrence intervals must not be exceeded during construction, including both the construction stormwater and groundwater discharges.

The existing condition to be matched must be the landcover condition immediately prior to the development project. This restriction on release rates can affect the size of the sediment trap or sediment tank, the filtration system, and the flow rate through the filter system. It may also require additional BMPs.

For all other scenarios and project sizes, discharges from projects sites will be limited by the SPU allowable discharge rates, unless otherwise approved by the Director. Refer to SPU Design Standards and Guidelines Appendix 18B Temporary Discharges for allowable discharge rates.

Flow control must be installed or otherwise provided prior to any clearing, or grading of the site, except as required to construct the flow control facilities.

Planning Considerations

Flow control measures must be planned and accounted for on the site early on. Flow control BMP configuration, size, location, and discharge point must be presented in the Construction Stormwater Control and Soil Management Plan and approved by the City.

Design Criteria

Construction site stormwater discharges, including dewatering, must not exceed the discharge durations of the pre-developed condition for the range of existing condition discharge rates from one-half of the 2-year flow through the 10-year flow as predicted by an approved continuous runoff model. The existing condition to be matched must be the landcover condition immediately prior to the development project. In addition, if there will be groundwater dewatering, the peak flowrates from existing condition for the 2-year and 10-year recurrence intervals must not be exceeded during construction, including both the construction stormwater and groundwater discharges.

If the developed site requires flow control and the permanent flow control does not include infiltration, the permanent flow control must be constructed first and used during construction to control flow from the site if feasible.

The following is how the Western Washington Hydraulic Model (WWHM) can be used to size flow control, including when a chemical treatment system is used. The same design steps can generally be used for MGSFlood:

1. Determine the pre-project flow durations to be matched by entering the existing land use area under the “Pre-developed” scenario in WWHM. The default flow range is from one-half of the 2-year flow through the 10-year flow.
2. Enter the land cover scenario during construction that will result in the most stormwater runoff for land use area in the “Mitigated” scenario in WWHM. The “Mitigated” land use is typically 100% impervious for projects in Seattle unless there are portions of the site that are vegetated and will be preserved throughout construction.
3. While in the “Mitigated” scenario, add a pond or vault element under the basin element.
    a. If using multiple tanks for detention, the stage/storage/discharge (SSD) relationship must consider the relative elevation of each tank or the plans must stipulate that all tanks are set at the same elevation.
    b. Provide 2 feet of dead storage below the lower orifice of the flow control riser.

c. In cases where the discharge is controlled by a pump, a stage/storage/discharge (SSD) table representing the pond or vault must be generated outside WWHM and imported into WWHM. WWHM can route the runoff from the post-developed condition through this SSD table (the pond or tank) and determine compliance with the flow duration standard. This would be an iterative design procedure where, if the initial SSD table proved to be inadequate, the designer would have to modify the SSD table outside WWHM and re-import into WWHM and route the runoff through it again. The iteration will continue until a pond or vault that complies with the flow duration standard is correctly sized.

   Example for SSD table characteristics: A potential scenario is to initially set the pump discharge rate at just below one-half of the 2-year flow from the pre-developed condition. As runoff coming into the stormwater storage pond or tank increases and the available stormwater storage volume gets filled up, it may be necessary to increase the pump discharge rate above one-half of the 2-year flow. The increase(s) above one-half of the 2-year flow must be such that the amount of required storage is reduced but at the same time will not cause violations of the flow duration standard at the higher flows. The final design SSD table will identify the appropriate pumping rates and the corresponding stage and storages.

d. When building such a flow control system, the design must ensure that any automatic adjustments to pumping rates will be a result of changes to the available storage in accordance with the final design SSD table.

e. Note that the above procedures would be used to meet the flow control requirements. Filtration or chemical treatment systems must be able to meet the runoff treatment requirements as described in elsewhere in this volume. It is likely that the discharge flow rate of one-half of the 2-year flow or more may exceed the treatment capacity of the system. If that is the case, the untreated stormwater discharge rate(s) (i.e., influent to the treatment system) must be reduced to allow proper treatment. Any reduction in the flows would likely result in the need for a larger untreated stormwater storage volume.

If the discharge is to the storm drainage system, the allowable discharge rate may also be limited by the capacity of the public system. Refer to SPU Design Standards and Guidelines Appendix 18B Temporary Discharges for allowable discharge rates. It may be necessary to clean the municipal system prior to the start of the discharge to prevent scouring solids from the drainage system.

Maintenance

- Flow control measures must be monitored and promptly maintained to fully functioning condition as necessary to ensure continued performance of their intended function.
- Flow control facilities, including control structures, must be inspected at least once every calendar week and within 24 hours of any flow discharged from the site. After any 24-hour runoff-producing event, any control structures will be inspected for integrity.

- At no time will more than 1 foot of sediment be allowed to accumulate in a control structure. Sediment in the control structure must not be allowed to interfere with its operation.
- At no time will more than 6 inches of sediment be allowed to accumulate in a flow control pond, trap, or tank.
- Maintain and repair all temporary and permanent BMPs as needed to ensure continued performance of their intended function in accordance with BMP specifications.

4.4.2. BMP E4.20: Temporary Groundwater Dewatering

Description

The removal and appropriate discharge and release of groundwater, whether from a simple trench or a large excavation.

Purpose

Temporary dewatering is used when groundwater must be removed before certain operations can be performed or to keep work conditions safe. It is typical for contractors to use ditch pumps or well points to dewater, but it is very important to identify and use the appropriate locations for discharge. Dewatering may require a temporary BMP for settling and/or filtering sediment-laden water. A temporary sediment pond or other equivalent facility is used to settle and filter the water. Properly designed and implemented temporary dewatering will:

- prevent the discharged water from eroding soil on site.
- remove sediment from the collected water.
- choose the best location for discharge.
- preserve downstream natural resources and real property.

Projects that are required to comply with Minimum Requirements for Flow Control (SMC 22.805.080) must account for dewatering discharge in determining an allowable release rate.

Conditions Where Practice Applies

Public or private properties with the following:

- Foundation excavations
- Utilities and infrastructure construction projects, including installation, repair, and maintenance of:
  - Electrical conduits
  - Vaults and tanks
  - Sanitary sewer and public drainage systems
  - Phone and cable lines
  - Gas or other fuel lines
  - Other excavations or graded areas requiring dewatering

Clean, non-turbid dewatering water, such as well-point groundwater, may be discharged to the public combined sewer, systems tributary to receiving waters, or directly into receiving waters, provided the dewatering flow is discharged to a stabilized system and does not cause erosion or flooding of receiving waters or downstream systems. Clean dewatering water should not be routed through stormwater sediment ponds.

If dewatering must occur, a Side Sewer Permit for Temporary Dewatering (SSPTD) and a Discharge Authorization Letter from King County Industrial Waste may be required prior to

commencing dewatering at the site. The SSPTD permit may include a separate Temporary Dewatering Plan, water quality treatment, or flow control requirements as well as compliance monitoring requirements.

Planning Considerations

Prior to implementing temporary dewatering, reduce the amount of water that will be collected and the potential amount of sediment that may enter the water. Implement the following prior to temporary dewatering:

- For trench excavation, limit the trench length to 150 feet and place the excavated material on the up-gradient side of the trench.
- Install diversion ditches or berms to reduce the amount of clean stormwater runoff allowed into the excavated area.
- Dewatering in periods of intense, heavy rain when the infiltrative capacity of the soil is exceeded should be avoided.
- Never discharge to bare or newly vegetated areas.

Once the site has been prepared as described above, assess the site for the issues listed below to assist the City in determining which discharge option to approve:

- Water clarity. If the water is turbid (cloudy), dissolved and settable solids are present in the water that should be filtered or settled out prior to discharge. Determine if contaminants are present in impounded water. Check for odors, discoloration, or oily sheen. Check any soils or groundwater testing results.
    - If contamination may be or is present, the Director of SPU reserves the right to require sampling and analysis to prove that water quality is being protected. Highly turbid or contaminated dewatering water must be handled separately from stormwater. Contaminated groundwater is a prohibited discharge; however, it may be treated to become a permissible discharge if metals and other pollutants are mitigated to meet concentration thresholds in state water quality standards. If no such water quality standards exist for a pollutant, discharge limits must be based on the stricter standard of any other appropriate and relevant water quality criteria (i.e., Washington State water quality standards, U.S. EPA national recommended water quality criteria for aquatic life and human health, and the National Toxics Rule).Depending on the type of downstream infrastructure and the desired discharge volume, the dewatering discharge flow rate may be required to be limited to a daily (measured by gallons or cubic feet per day) or instantaneous (measured by gallons or cubic feet per second) maximum. Refer to additional requirements in Section 4.3.8. BMP E3.60 Construction Stormwater Filtration.

Design Criteria

One of several types of dewatering facilities may be constructed, depending on site conditions and the type of activities.

Water Removal

The removal of water from the excavated area can be accomplished by numerous methods. The most common of these are:

- Gravity drain through a daylight channel
- Mechanical pumping
- Siphoning
- Using the appropriate construction equipment to scoop and dump water from the excavation

Stabilize channels or any conveyance feature dug for discharging water from the excavated area. If flow velocities cause erosion within the channel, install a ditch lining, such as geotextile or heavy plastic sheeting.

Discharge Structure

Water conveyed by channels, ditches, pumps, hose, or equipment buckets should be discharged in a regulated manner to a stable structure. The structure must:

- Be appropriate to filter sediment.
- Be able to withstand the velocity of the discharged water to prevent erosion.
- Be sized and operated such that pumped water will flow through an energy dissipation device and be converted to gravity flow prior to discharge to a downstream system.
- Not overtop the structure.

Typical constructed areas are:

- Sediment traps (refer to BMP E3.40)
- Portable sediment tanks (refer to BMP E3.50)
- Enclosure of hay bales, filter fabric (refer to BMP E3.10), or both
- Sediment filter bag

Sediment Removal — General

Sediment must be settled prior to discharge. All settling systems should be engineered and adequately sized for site conditions. Sediment removal is required when establishing wells for well-point dewatering but may be removed once the well and filter pack are established and the discharge is found to be clean and non-turbid. General settling and filtering options include the following:

- Containment in a pond structure for a minimum of 4 hours or until water is clear (time will vary greatly depending on gradation of sediment). Place a pump in a gravel bed at the bottom of the pond.
- Discharge to a manufactured or pre-made structure specifically designed for sediment removal, such as a Silt Sak, Silt Bag, or other similar product. Pump to a settling tank with sampling ports.
- Transport off site in a vehicle, such as a vacuum flush truck, for legal disposal.
- Filter through a sieve or other filter media (e.g., swimming pool filter). Simple onsite filter systems can be constructed, including wrapping the ends of the suction and discharge pipes with filter fabric, discharging through a series of drums filled with

successively finer gravel and sand, and other filtering techniques like those described under inlet protection (BMP E3.25).

- If the groundwater is contaminated, an engineered filtration treatment system is required. Refer to Section 4.3.8. BMP E3.60 Construction Stormwater Filtration for the storage tank or pond and filtration system sizing criteria.
- Manufactured bags, polymers, or other systems. These systems do not always work on fine clay soils and will only be allowed for use where approved. Chemical treatments should have state approval before they are used (refer to Ecology BMP C250 Construction Stormwater Chemical Treatment).
- Line or protect the flow path in some way to prevent mobilization of additional sediment.
- Dry and reuse filtered material on site in a mixture with other site soils, or appropriately dispose of the material based on nature and levels of any contaminants present.

Vegetated Buffer

A well-stabilized, onsite, vegetated area may serve as a dewatering facility if the area is appropriate to filter sediment and at the same time withstand the velocity of the discharged water without erosion. The discharge of sediment-laden water onto a vegetated area must not pose a threat to the survival of the existing vegetative stand through smothering by sedimentation.

Direct discharge of lightly sediment-bearing water into well-buffered areas with a 2 percent slope may be possible as long as a method of spreading flow into sheet flow is available.

Straw Bale/Filter Fabric Pit

An excavated or bermed sedimentation pond or structure can also be created using straw bale and filter fabric (refer to BMP E3.10 Filter Fence) to create a pit. Flow to the structure may not exceed the sediment removal structure's capacity to settle and filter flow or the structure's volume capacity. Wherever possible, the structure should also discharge to a well-vegetated buffer through sheet flow, should maximize the distance to the nearest receiving water, and should reduce the slope of the buffer area. Also, the excavated portion may need to be lined with geotextile material to help reduce scour and to prevent the inclusion of soil from within the structure (refer to BMP E3.40 Sediment Trap).

Sediment Filter Bag

The filter bag should be constructed of non-woven geotextile material that will provide adequate filtering ability to capture larger soil particles from the pumped water. The bag should be constructed so there is an inlet neck that may be clamped around the dewatering pump discharge hose so that all of the pumped water passes through the bag.

The filter bag should be used in combination with a straw bale or filter fence pit when located within 50 feet of a receiving water. When the distance is greater than 50 feet, the bag may be placed on well-established vegetation or on an aggregate pad constructed of crushed rock at a minimum depth of 6 inches. The bag should never be placed on bare soil.

The capacity of the sediment filter bag should be adequate to handle the dewatering pump discharge and be based on the bag manufacturer's recommendation.

When used in conjunction with a straw bale or filter fence pit, a filter bag may be operated until the water in the pit reaches the crest of the emergency overflow. The pump must be shut off at this point. When placed on either a rock pad or well-established vegetation, the bag may be operated until the discharge from the bag reaches a receiving water. Unless the discharge is at least as clear as the receiving water, the pump must be shut off at this point.

When the bag has been completely filled with sediment, it should be cut open, re-graded in place, and immediately stabilized with either sod or erosion control mat.

Maintenance

- Check filtering devices frequently to make sure they are unclogged and operating correctly. Pay special attention to the buffer area for any sign of erosion and concentration of flow that may compromise the buffer area. Where possible, observe the visual quality of the effluent and determine if additional treatment can be provided.
- Make adjustments depending on the amount of sediment in the water being pumped.
- Repair or replace any equipment that does not function as designed.
- The accumulated sediment removed during maintenance must be spread on site and stabilized or disposed of at an approved disposal site.
- Systems should be filled in or otherwise removed when permanent dewatering controls are in place and connected to an approved treatment and receiving system.

CHAPTER 5 – Source Control & Monitoring Practices for Construction Pollutants Other than Sediment

5.1. Source Control Practices

The City of Seattle (City) is committed to protecting the public drainage system or public combined sewer, ponds, wetlands, lakes, streams, and coastal and estuarine water bodies from damage by sediment and other pollutants generated during construction activities. The focus of *Chapter 4* was erosion and sediment control; however, potential pollutants other than sediment are common at project sites and may also impact stormwater and groundwater quality when they come into direct contact with runoff.

Potential pollutants include non-hazardous materials such as wood, paper, demolition debris, concrete, and metal scraps. There are also potential pollutants from hazardous materials and their associated wastes such as pesticides (e.g., insecticides, fungicides, herbicides, rodenticides), petrochemicals (e.g., oils, gasoline, asphalt degreaser), and other construction chemicals such as concrete products, sealer, paints, and washwater associated with these products.

The most economical and effective controls for pollutants other than sediment are good "housekeeping" practices and an awareness by construction workers, planners, engineers, and developers of the need for and purpose of compliance with federal, state, and local regulations.

Please refer to the Stormwater Code and *Volume 4 — Source Control* for further information concerning controlling pollution at the source and preventing contamination of stormwater for all discharges. This volume should be reviewed to ensure that all Director's Rules requirements are being met for each construction project.

The standards for each individual best management practice (BMP) are divided into six sections:

1. Description
2. Purpose
3. Conditions Where Practice Applies
4. Planning Considerations
5. Design Criteria
6. Maintenance

Note that some BMPs were divided into different sections to reflect their individual needs. As with erosion and sediment control BMPs, source control BMPs include "Conditions Where Practice Applies," which always refers to site conditions. As site conditions change, BMPs must be changed to remain in compliance.

This chapter contains the standards and specifications for source control BMPs to properly manage construction pollutants other than sediment. They include:

- BMP C1.15: Material Delivery, Storage, and Containment (*Section 5.1.1*)
- BMP C1.20: Use of Chemicals During Construction (*Section 5.1.2*)
- BMP C1.25: Demolition of Buildings (*Section 5.1.3*)
- BMP C1.30: Building Repair, Remodeling, and Construction (*Section 5.1.4*)
- BMP C1.35: Sawcutting and Paving Pollution Prevention (*Section 5.1.5*)
- BMP C1.45: Solid Waste Handling and Disposal (*Section 5.1.6*)
- BMP C1.50: Disposal of Asbestos and Polychlorinated Biphenyls (PCBs) (*Section 5.1.7*)
- BMP C1.55: Airborne Debris Curtain (*Section 5.1.8*)
- BMP C1.56: Concrete Handling (*Section 5.1.9*)
- BMP C1.58: Concrete Washout Area (*Section 5.1.10*)
- BMP C1.59: High pH Neutralization Using CO_2 (*Section 5.1.11*)

5.1.1. BMP C1.15: Material Delivery, Storage, and Containment

Description

Best practices for all deliveries, storage, and containment of materials, liquid and solid, on a project site that may potentially pollute stormwater.

Purpose

The purpose of this BMP is to prevent, reduce, or eliminate the discharge of pollutants to the drainage system or receiving water from the delivery and storage of materials on site. This is achieved by reducing the storage of hazardous materials on site, storing materials in a designated area, and installing secondary containment.

Conditions Where Practice Applies

These procedures are recommended for use at all project sites with delivery and storage of the following materials:

- Petroleum products such as fuel, oil and grease
- Soil stabilizers and binders (e.g., Polyacrylamide)
- Fertilizers, pesticides, and herbicides
- Detergents
- Asphalt and concrete compounds
- Hazardous chemicals such as acids, lime, adhesives, paints, solvents, and curing compounds
- Any other material that may be detrimental if released to the environment

Planning Considerations

Dangerous solid wastes must be stored and handled according to special guidelines and may require a permit. Follow the regulations and requirements outlined by the Washington State Department of Ecology (Ecology) and, in some cases, King County.

Design Criteria

The following steps must be taken to minimize risk:

- Locate temporary storage area away from vehicular traffic, near the construction entrance(s), and away from drainage channels or storm drains.
- Keep Safety Data Sheets (SDS) on site for all materials stored. Keep chemicals in their original labeled containers.
- Reduce hazardous material storage on site.
- Handle hazardous materials as infrequently as possible.
- During the wet weather season (October 1 to April 30), consider storing materials in a covered area.
- Do not store chemicals, drums, or bagged materials directly on the ground. Place these items on a pallet and, when possible, in secondary containment.

- If drums must be kept uncovered, store them at a slight angle to reduce ponding of rainwater on the lids to reduce corrosion. Domed plastic covers are inexpensive and snap to the top of drums, preventing water from collecting.
- Store materials with secondary containment, such as a curbed paved area, pallets with built-in containment, or even a children's wading pool for non-reactive materials such as detergents, oil, grease, and paints. Small amounts of material may be secondarily contained in server trays or concrete mixing trays.
- Use spill prevention and control measures for maintenance, fueling, and repair of heavy equipment and vehicles. Clean contaminated surfaces immediately following any spill incident.
- Provide cover, containment, and protection from vandalism for all chemicals, liquid products, petroleum products, and other materials that have the potential to pose a threat to human health or the environment. Include secondary containment for onsite fueling tanks.

Secondary Containment Practices:

- Store all hazardous substances with a listed Reportable Quantity in approved containers and drums and in secondary containment. The list of Reportable Quantities is available on the U.S. Environmental Protection Agency's (U.S. EPA's) website (www.epa.gov/superfund).
- Provide temporary secondary containment facilities with a spill containment volume able to contain precipitation from a 25--year, 24--hour storm event plus 10 percent of the total enclosed container volume of all containers, or 110 percent of the capacity of the largest container within its boundary, whichever is greater.
- Provide sufficient separation between stored containers to allow for spill cleanup and emergency response access.
- During the wet weather season (October 1 to April 30), cover each secondary containment facility during non-working days prior to and during rain events.
- Provide secondary containment facilities that are impervious to the materials stored for a minimum contact time of 72 hours.

Maintenance

- Keep secondary containment facilities free of accumulated rainwater and spills. In the event of spills or leaks, collect accumulated rainwater and spills and place into drums. Treat these liquids as hazardous waste unless testing determines them to be non-hazardous.
- Keep material storage areas clean, organized, and equipped with an ample supply of appropriate spill cleanup material (spill kit). For spill prevention and cleanup requirements, including spill kit instructions, refer to *Volume 4 — Source Control*.

5.1.2. BMP C1.20: Use of Chemicals During Construction

Description

Best practices for control, storage, cleaning, and disposal of all chemicals used at a project site that may potentially pollute stormwater.

Purpose

A large percentage of potential pollutants from chemicals can be effectively controlled at project sites through implementation of source control and soil erosion and sedimentation control practices.

Conditions Where Practice Applies

This BMP applies to most project sites because many types of chemicals may be used during construction activities. These chemical pollutants include paints, acids, cleaning solvents, asphalt products, soil additives, concrete-curing compounds, and many others. These materials can be carried by sediment and water runoff from project sites.

Planning Considerations

Disposal of concrete products, additives, and curing compounds depends on the product. Some liquid wastes must be stored and handled according to special guidelines and may require a permit. Follow the regulations and requirements outlined by Ecology and, in some cases, King County.

Refer to *Volume 4 — Source Control* to see if additional source controls are required.

Design Criteria

- As in the case of other pollutants, good housekeeping is the most important means of controlling pollution.
- Use only the recommended amounts of chemical materials and apply them in a proper manner to further reduce pollution.
- Acid and alkaline solutions from exposed soil or rock units high in acid and alkaline-forming natural elements should be controlled using good site planning and preconstruction geological surveys. Refer to BMP C1.56 Concrete Handling. Neutralization of these pollutants often provides the best treatment.
- The City requires project site operators to adjust the pH of stormwater if necessary to prevent violations of water quality standards. Refer to BMP C1.59 High pH Neutralization Using CO_2.
- Chemicals used in batch treatment or flow-through treatment must be approved in writing by Ecology prior to use. Formal approval from the City is based on Ecology's protocols. For a list of treatment chemicals that have been evaluated and are currently approved for use by Ecology, refer to the Department's website (https://ecology.wa.gov/Regulations-Permits/Guidance-technical-assistance/Stormwater-permittee-guidance-resources/emerging-stormwater-treatment-technologies).

- For paint disposal, the correct method of waste clean-up varies with the material:
  - Wash-up waters from water-based paints may go into a sanitary sewer, which is regulated by the King County Industrial Waste Program 206-477-5300.
  - Wastes from oil-based paints, cleaning solvents, thinners, and mineral spirits must be disposed of through a licensed waste management firm or treatment, storage, and disposal (TSD) facility.

Maintenance

- Sealing fractures in the bedrock with grout and bentonite will reduce the amount of acid or alkaline seepage from excavations.
- Adequate treatment and disposal of concrete further reduces pollution.

5.1.3. BMP C1.25: Demolition of Buildings

Description

Methods used to protect stormwater from pollution associated with the removal of existing buildings (and clearing of the rubble) by means of controlled explosions, wrecking balls, or manual methods.

Purpose

The loose debris produced by building demolition activities can contain toxic organic compounds, metals, and suspended solids that may pollute stormwater.

Certain building materials, such as caulk and other sealants, joint materials, paint, siding, and roofing produced between about 1930 and 1980, may contain polychlorinated biphenyls (PCBs), particularly if installed between 1950 and 1980. PCB-containing building materials were more often used in commercial, industrial, and large multi-story residential buildings as well as institutional buildings such as schools, hospitals, universities, fire houses, police stations, government offices, and military sites. It is broadly recognized (e.g., by EPA, Ecology, and the California Water Resources Control Board) that PCB-containing materials are at greater risk of being dislodged during demolition and renovation activities. If not properly managed and contained during these activities, particles containing PCBs can be washed into stormwater, contaminating the conveyance system and downstream water bodies.

This BMP is designed to help prevent the migration of PCBs that may be present in buildings undergoing demolition to the stormwater drainage system and downstream waterbodies.

Projects, regardless of size, must implement practices to properly handle and dispose of materials that may contain PCBs, such as transformers, light ballasts, caulk, paint, sealants, siding, and some roofing materials, so that they do not come into contact with stormwater.

Conditions Where Practice Applies

Complete or partial building demolition, structure demolition, or other activity that requires controlled explosions, wrecking balls, or manual methods to demolish a structure, or clearing of demolition rubble.

Planning Considerations

This BMP is intended to provide basic information to protect stormwater from being polluted by demolition debris. However, demolition of buildings is regulated in Washington by Ecology and the Puget Sound Clean Air Agency (PSCAA). Refer to Ecology's Construction and Demolition web page for additional requirements (https://ecology.wa.gov/Regulations-Permits/Guidance-technical-assistance/Dangerous-waste-guidance/Common-dangerous-waste/Construction-and-demolition) and PSCAA's website for other information and requirements (www.pscleanair.gov/185/Asbestos).

PCB-specific Considerations:

Seattle's extensive PCB source tracing experience suggests that industrial, commercial, institutional, and large multi-family residential structures built or renovated between 1950 and 1980 that are not wood-framed should be suspected of containing some PCB-containing

materials on their exterior. During the project planning phase, follow Ecology's guidance document *How to Find and Address PCBs in Building Materials* (Ecology 2024) to assess the likelihood that a building which will undergo demolition contains PCBs. The outcomes of the assessment can help guide whether sampling should be conducted to confirm the presence of PCB-containing materials, and at what levels, as well as the types of pollution prevention BMPs to implement.

Parties planning demolition activities should also refer to federal and state waste disposal regulations applicable to PCBs. The suspected or confirmed presence of PCB-containing building materials must be disclosed to the City's inspector at the First Ground Disturbance inspection or any pre-construction meetings prior to beginning demolition.

Design Criteria

- Identify, remove, and properly dispose of hazardous substances from the building before beginning demolition activities that could expose them to stormwater. Such substances could include PCBs, asbestos, lead paint, mercury switches, and electronic waste.
- When PCB-containing building materials are suspected or confirmed, implement the following BMPs:
    - Installing catch basin filter inserts or covers.
    - Dry vacuuming or dry sweeping adjacent hard surfaces (a dry vacuum system is preferred).
    - Preventing washwater or irrigation water from coming into contact with the PCB-containing building materials.
    - Educating landscaping and maintenance staff about avoiding the use of leaf blowers around the building.
    - Routinely visually survey the areas where PCB-containing building materials are suspected or confirmed to exist to check they have remained intact. If weathering (e.g., flaking, peeling) becomes noticeably worse as demolition continues, install additional BMPs as needed to prevent PCB discharges to the drainage system or surface waters.
- Never re-use or recycle PCB-contaminated construction materials. Keep this waste segregated from other materials and dispose of PCB-contaminated materials including, but not limited to, concrete, masonry, roofing, and siding, in accordance with EPA's Toxic Substances Control Act (TSCA) regulations and state waste regulations.
- Protect the drainage system from sediment-laden runoff and loose particles. Use inlet protection, drain covers, straw wattles, or compost socks to protect drainage inlets. To the extent possible, use dikes, berms, or other methods to protect overland discharge paths from runoff. During the workday, provide drain covers to keep dust and debris out of the drainage system and remove them at the end of the workday.
- Provide filter fence or other measures along the boundaries of disturbance. If there is more than 10,000 square feet of land-disturbing activity associated with the demolition project, direct runoff to a sediment trap or portable sediment tank prior to discharge.
- If the existing concrete slab for a demolished building will remain in place, provide permanent or interim measures to direct the runoff to an existing or new drainage

inlet structure within the site unless the slab will sheet flow across a vegetated flow path that meets the requirements of Volume 3, Section 5.3.5. Sheet Flow Dispersion. Do not allow building slab drainage to sheet flow directly across public sidewalks. If a building plumbing system will be converted into a drainage system, it must be demonstrated to meet the Side Sewer Code (SMC 21.16) and all Director's Rules published under this code. Provide inlet protection until the site is completely stabilized.

- Sweep street gutters, sidewalks, driveways, and other paved surfaces in the immediate area of the demolition daily to collect and properly dispose of loose debris and garbage.
- Lightly spray water (e.g., from a hydrant or water truck) to help control windblown fine materials such as soil, concrete dust, and paint chips. Control the amount of water so that runoff from the site does not occur, yet dust control is achieved. Never use oils for dust control.
- If feasible, construct a screen to prevent stray building materials and dust from escaping the area during demolition. Size and orient the screen to capture wind-blown materials and contain them on site.
- Schedule demolition during a dry time of year.
- Follow the guidance document *How to Find and Address PCBs in Building Materials* (Ecology 2024) for PCB-containing building materials undergoing demolition.
- Educate employees about the need to control site activities to prevent stormwater pollution and also train them in spill cleanup procedures.
- After demolition, stabilize the site using temporary or permanent cover practices (refer to Section 4.1). If the soils are contaminated, the site must be stabilized in a way to prevent runoff from coming into contact with the contaminated soils and discharging from the site.
- If crushed, rubblized, or recycled concrete is used to stabilize the site or to shore up basement walls that remain, use measures to prevent stormwater and groundwater from coming into contact with the concrete or collect the stormwater and groundwater and treat it to maintain a pH between 6.5 and 8.5 prior to discharging from the site.
- If stormwater or groundwater will be allowed to pond on the site after demolition, the following will be required:
  - Provide an overflow from the ponded area to an approved point of discharge.
  - All setbacks, site considerations, fencing requirements, embankment and failure analyses, and dam safety measures that are required for Detention Ponds must be met. Refer to Volume 3, Section 5.7.1.
  - Refer to Volume 1, Section 2.4.7 for considerations if the site has known or potential for contaminated soils or groundwater.

Maintenance

- Clean up debris on a regular basis to prevent stormwater contamination.
- Place stormdrain covers (or devices) at the beginning of the workday, then collect and properly dispose of the materials accumulated before removing the covers (or devices) at the end of the workday.

5.1.4. BMP C1.30: Building Repair, Remodeling, and Construction

Description

Best practices for the control of pollutants associated with construction of buildings and other structures such as, but not limited to, remodeling of existing buildings and houses, and general repair work on building exteriors.

Purpose

Pollutants of concern may be generated during building repair, remodeling, and construction, including petroleum hydrocarbons, toxic organic compounds (such as polychlorinated biphenyls, or PCBs), suspended solids, metals, pH, and oils and greases.

Certain building materials, such as caulk and other sealants, joint materials, paint, siding, and roofing produced between about 1930 and 1980, may contain polychlorinated biphenyls (PCBs), particularly if installed between 1950 and1980. PCB-containing building materials were more often used in commercial, industrial, and large multi-story residential buildings as well as institutional buildings such as schools, hospitals, universities, fire houses, police stations, government offices, and military sites. It is broadly recognized (e.g., by EPA, Ecology, and the California Water Resources Control Board) that PCB-containing materials are at greater risk of being dislodged during repair and remodeling activities. If not properly managed and contained during these activities, particles containing PCBs can be washed into stormwater, contaminating the conveyance system and downstream water bodies. This BMP is designed to help prevent the migration of PCBs that may be present in buildings undergoing remodeling and repair to the stormwater drainage system and downstream waterbodies.

Conditions Where Practice Applies

When buildings and structures are repaired, remodeled, and constructed.

Planning Considerations

Educating employees about the need to control site activities is one of the most effective methods to prevent stormwater pollution. Employees may include maintenance and landscaping staff working around buildings with exterior PCB-containing materials.

The focus of planning and education is to prevent pollutant-containing dust and solids from entering stormwater and stormwater conveyances.

Seattle's extensive PCB source tracing experience suggests that industrial, commercial, institutional, and large multi-family residential structures built or renovated between 1950 and 1980 that are not wood-framed should be suspected of containing some PCB-containing materials on their exterior. During the project planning phase, follow Ecology's guidance document *How to Find and Address PCBs in Building Materials* (Ecology 2024) to assess the likelihood that a building which will undergo renovation contains PCBs. The outcomes of the assessment can help guide whether sampling should be conducted to confirm the presence of PCB-containing materials, and at what levels, as well as the types of pollution prevention BMPs to implement. Inform the City's permitting group of the suspected or confirmed presence of PCB-containing building materials prior to commencing remodeling or repair activities.

Design Criteria

- Identify, remove, and properly dispose of hazardous substances from the building before beginning renovation activities that could expose them to stormwater. Such substances could include PCBs, asbestos, lead paint, mercury switches, and electronic waste.
    - Never re-use or recycle PCB-contaminated construction materials. Keep this waste separated from other materials and dispose of PCB-contaminated materials including, but not limited to, concrete, masonry, roofing, and siding in accordance with EPA's Toxic Substances Control Act (TSCA) regulations and state waste regulations.
- Follow the guidance document *How to Find and Address PCBs in Building Materials* (Ecology 2024) for PCB-containing building materials undergoing renovation.
- Use ground cloths or drop cloths underneath activities.
- Use drain covers or similarly effective devices if dust, grit, washwater, or other pollutants may impact onsite or downstream offsite catch basins. If covers are used, place them on the storm drains at the beginning of the workday and remove them at the end of the workday. Collect and dispose of the accumulated sediment-laden runoff and solids before the cover is removed. If storm drain covers are not feasible, install and maintain filter inserts in all catch basins that may receive stormwater from the work site (i.e., on the work site property and adjacent street(s)).
- Clean all tools and brushes covered with water-based paints in an inside sink that drains to the sanitary sewer. If cleaning must be done outside, collect all wastewater and dispose of properly.
- Clean non-water-based finishes from tools in a manner that allows the collection of used solvents for recycling or proper disposal. Do not discharge non-water-based finishes or paints or used solvents into the sanitary sewer or any other drain.
- Water can be lightly sprayed to help control windblown fine materials such as soil, concrete dust, and paint chips. Control the amount of water so that runoff from the site does not occur, yet dust control is achieved. Never use oils for dust control.
- When removing suspected PCB-containing materials, avoid working in high wind conditions or take extra precautions when working in wind strong enough to move dust and debris. Precautions could include constructing a wind screen of plastic at the edge of the groundcover to keep dust and debris from spreading. To the extent practical, use tools and work methods that generate the least dust and heat. Consider using manual tools as they generate less fine dust and heat.
- In the Shoreline District, as defined by SMC Chapter 23.60A Seattle Shoreline Program Regulations, comply with the provisions of SMC 23.60A.152 and SMC 23.60A.155 or the current Shoreline Master Program code.
- Construction and repair work must use BMPs to prevent the entry of debris and other waste materials into any water body. Any cleaning, sanding, cutting of treated wood, or resurfacing operation occurring over water or in water must be performed with tarpaulins, decking, or similarly effective materials securely attached above the water line to prevent material from entering the water. Before the tarpaulins, decking, or similarly effective materials are removed, the accumulated contents must be removed by vacuuming or an equivalent method that prevents material from entering the

water. Use dry methods to sweep the area daily to collect loose litter, paint chips, grit, and dirt.

- Use a HEPA vacuum below painted walls, caulking seams, windows, doors, downspouts, and any specific exterior features known or suspected of containing PCBs.
- No over-water or in-water application of paint, preservative treatment, or other chemical compounds is permitted, except in accordance with BMPs to prevent the compounds from entering the water.
- In addition to the BMPs that prevent debris and chemical compounds from construction, remodeling, and repair work from entering water bodies, a secondary containment system (e.g., floating containment boom) is required for work over water or in water. Additional requirements may apply, as required by local, state, and federal regulations.
- At all times, have spill cleanup materials appropriate to the chemicals used on site available at the work site.
- Construction staging areas must be as far from the water bodies on the site as possible.

Maintenance

- Place storm drain covers (or devices) at the beginning of the workday, then collect and properly dispose of the materials accumulated before removing the covers (or devices) at the end of the workday.
- Clean up the work site at the end of each workday. Put away materials (such as solvents) indoors or cover and secure them, so that unauthorized individuals will not have access to them.
- Maintain drain covers regularly (weekly or as needed) to prevent plugging.
- Recycle materials whenever possible, except when materials are contaminated by pollutants. PCB-containing materials should never be reused or recycled for reintroduction to the construction industry.

5.1.5. BMP C1.35: Sawcutting and Paving Pollution Prevention

Description

Best practices to minimize and eliminate wastewater and slurry from sawcutting and paving operations including, but not limited to, the following:

- Sawing
- Surfacing
- Coring
- Grinding
- Roughening
- Hydro-demolition
- Bridge and road surfacing

Purpose

Sawcutting and paving operations generate slurry and wastewater that contain fine particles and high pH, both of which can violate the water quality standards in receiving waters.

Conditions Where Practice Applies

Any time sawcutting or paving operations take place.

Planning Considerations

This BMP is intended to minimize and eliminate wastewater and slurry from entering the public drainage control system and receiving waters. Wastewater may be permitted to be discharged to a sanitary sewer, which is regulated by Seattle Public Utilities and the King County Industrial Waste Program (206-477-5300).

Design Criteria

- Vacuum slurry and cuttings during the activity to prevent migration off site. Do not allow slurry and cuttings to remain on permanent concrete or asphalt paving overnight.
- Dispose of collected slurry and cuttings in a manner that does not violate groundwater or surface water quality standards.
- Do not drain wastewater generated during hydro-demolition, surface roughening, or similar operations to any natural or constructed drainage conveyance. Dispose of wastewater in a manner that does not violate groundwater or surface water quality standards.
- Clean and dispose of waste material and demolition debris in a manner that does not cause contamination of water. If the area is swept with a pick-up sweeper, haul out the material to an appropriate disposal site.

Maintenance

Continually monitor operations to determine whether slurry, cuttings, or wastewater could enter the public drainage system or the public sewer. If inspections show that a violation of water quality standards could occur, stop operations and immediately implement preventative measures such as berms, barriers, secondary containment, and vacuum trucks.

5.1.6. BMP C1.45: Solid Waste Handling and Disposal

Description

Methods used to protect stormwater from pollution associated with the management, handling, and disposal of all solid waste generated on a project site.

Purpose

Solid waste is one of the major pollutants caused by construction and can have direct impacts to stormwater as a potential pollutant if not managed and disposed of properly. Solid waste includes the following:

- Trees and shrubs removed during land clearing
- Wood and paper used in packaging and building materials
- Scrap metals and metal shavings
- Sanitary wastes
- Rubber, plastic, and glass pieces
- Masonry products
- Leftover food, food containers, beverage cans, coffee cups, lunch wrapping paper, aluminum foil, and plastic
- Cigarette packages and butts
- Unwanted or discarded construction and demolition products

Conditions Where Practice Applies

All project sites.

Refer to BMP C1.50 for PCB-containing waste and debris.

Planning Considerations

The major control mechanism for these pollutants is to provide adequate disposal facilities.

Design Criteria

- Collection containers: Project sites should have at least two collection containers: one for garbage or non-recyclable construction wastes and another for recycling. Multiple containers for source-separated recyclables, such as clean wood and metal, are encouraged. Source-separating recyclables on the site means more recycling, less waste, and generally lower tipping fees and disposal costs. All containers located on the job site should be clearly marked, labeled with a list of acceptable materials, and kept closed when not in use. Any container designated for recycling should have at least 90% of its contents be recyclable and no garbage or items not accepted by the receiving facility. Garbage should not be deposited in a container designated for construction waste or for recycling.
- Remove garbage frequently to maintain project sites in a clean and attractive manner. Remove and dispose of accumulated solid waste at authorized disposal areas.

- Label waste containers and locate them in a covered area. Keep lids closed at all times.
- The City requires the recycling of readily recyclable construction and demolition waste materials and submittal of a Waste Diversion Report per SMC 21.36.089 and subsequent SPU Director's Rules related to construction materials disposal bans. In addition, the Seattle Department of Construction and Inspection now requires that a Waste Diversion Plan be part of the permit application for a building permit if the project is 750 square feet or greater and that a Salvage Assessment be performed for any job involving demolition. At the end of each project, a Waste Diversion Report must be submitted to Seattle Public Utilities that documents through facility weight receipts where materials from the construction or demolition site went for reuse, recycling, and disposal.
- Reuse and Recycling: Reuse on and off site reduces waste and is the preferred method for handling materials. Several local firms provide salvage assessment and resale of building materials. Green building credits recognize reuse as well as recycling.
- Hauling: Reusables and recyclables may be hauled by any company you choose or you may "self-haul" yourself. Non-recyclable construction waste such as painted and treated wood or fiberglass insulation must be hauled only by the City's contracted hauler, Waste Management, or you may "self-haul" to the appropriate receiving facility.
- Recyclable Materials from Project Sites: Current and future targeted materials and their handling, hauling, and destination requirements are listed in Table 9.
- For more information about the City's construction and demolition waste recycling requirements, refer to the City's website (www.seattle.gov/utilities/businesses-and-key-accounts/construction/construction-waste).
- For assistance with finding recycling facilities, refer to the King County Green Tools web page (https://kingcounty.gov/depts/dnrp/solid-waste/programs/green-building.aspx).
- For assistance in determining where to take motor oil, pesticides, smoke alarms, fluorescent bulbs, and other hazardous materials, refer to the Local Hazardous Waste Management Program website (www.hazwastehelp.com).
- Selective (rather than wholesale) removal of trees is helpful in conservation of soil and reduction of wood wastes. Avoid indiscriminate removal of trees and other beneficial vegetation.

Table 9a. Handling, Hauling, and Destination Requirements for Targeted Materials.

Targeted Materials	Banned from Disposal	Collection Method and Hauling	Facilities[a]
Land Clearing (such as trees, shrubs, stumps)	Yes	• Self-haul or • Order drop box from a private recycler • Grind and use on site	• City transfer stations • Private drop sites for yard waste • Composting facilities • Wood waste recyclers
Asphalt Paving	Yes	• Self-haul or • Order drop box from a private hauler or recycler	• Concrete recyclers • Sand and gravel operations • Mixed waste recyclers
Bricks	Yes, if whole	• Reuse on or off site • Self-haul to a reuse store or private recycler	• Reuse stores • Sand and gravel operations
Concrete	Yes, if unpainted	• Reuse on or off site as fill only if appropriate for groundwater conditions • Self-haul	• Concrete recyclers, • Sand and gravel operations • Mixed waste recyclers
Cardboard and Paper	Yes	• Use City-provided curbside recycling containers or commercial recycling cart service if available for the building site • Self-haul	• City transfer stations • Many private recyclers
Metal (ferrous and non-ferrous)	Yes	• Use City-provided curbside recycling container if available for building site • Self-haul	• City transfer stations • Many private recyclers
New Construction Gypsum Scrap	Yes	• Self-haul • Drop box from a private recycler	• Drywall recyclers • Mixed waste recyclers
Carpet	Yes, starting in July 2022[b]	• Self-haul • Drop box from a private hauler or recycler	• Take back offered through flooring stores for installers • Some mixed waste recyclers if clean
Plastic Film Wrap	Yes, starting in July 2022[b]	• Self-haul • Drop box from a private hauler or recycler	• Mixed waste recyclers if clean
Wood	Yes, if unpainted and untreated wood over 6 inches in length	• Self-haul • Drop box from a private hauler or recycler	• City transfer stations • Private drop sites and recycling facilities
Tear-off Asphalt Roofing Shingles	Yes, starting in July 2022[b]	• Self-haul to a private recycler	• Private asphalt shingle recyclers • Some mixed waste recyclers

Table 9b. Handling, Hauling, and Destination Requirements for Targeted Materials.

Targeted Materials	Banned from Disposal	Collection Method and Hauling	Facilities*
Food Waste (such as from lunches)	Yes for food but not the wrappings or containers	• Use City-provided curbside organics container or commercial cart service if available for the building site	
Tin and Aluminum Cans, Glass and Plastic Bottles and Jars	Yes	• Use City-provided curbside recycling container or commercial recycling cart service if available for the building site • Self-haul	• City transfer stations • Private recyclers
Cups	Yes	• Use City-provided curbside recycling container or commercial recycling cart service if available for the building site	• City transfer stations • Private recyclers
Other Non-Recyclable Waste Materials		• Self-haul to City transfer stations for disposal • Order a container from Waste Management, the City's contractor for the hauling of non-recyclable construction wastes at 1--800--592-9995	• Self-haul to City transfer stations for disposal • Order a container from Waste Management, the City's contractor for the hauling of non-recyclable construction wastes at 1--800--592-9995

[a] For a list of construction waste recycling facilities, refer to the City's website (www.seattle.gov/utilities/businesses-and-key-accounts/construction/construction-waste/recycling-requirements/certified-facilities).

[b] Refer to Director's Rule SW-640 (formerly DR SW-405.3) for the effective date for bans on carpet, plastic film wrap, and tear-off asphalt roofing shingles.

Maintenance

Soil erosion and sediment control structures capture much of the solid waste from project sites. Frequently remove litter from these structures to reduce the amount of solid waste littering the landscape.

5.1.7. BMP C1.50: Disposal of Asbestos and Polychlorinated Biphenyls (PCBs)

Use and disposal of these potential pollutants are regulated by both state and federal agencies. For further information, contact:

- For asbestos:
  - Puget Sound Clean Air Agency (https://pscleanair.gov) (206) 343--8800 or toll-free (800) 552--3565
  - U.S. EPA (www.epa.gov/asbestos) (206) 553-1200 or toll-free (800) 424--4EPA
- For wastes containing PCBs:
  - Washington Department of Ecology - Hazardous Waste Toxics Reduction Program. Contact Ecology's Northwest Regional Office at 206-594-0000. PCBs are regulated under Chapter 173-303 WAC (Washington Administrative Code), Dangerous Waste Regulations. For background information about PCBs as a Dangerous Waste, refer to Ecology Publication 21-04-034.
  - U.S. EPA – Region 10 PCB Program (https://www.epa.gov/pcbs/region-10-pcb-program) . Region 10 PCB Coordinator: 206-553-2899. More information about EPA-regulated PCB disposal can be found here: https://www.epa.gov/pcbs/disposal-and-storage-polychlorinated-biphenyl-pcb-waste.

5.1.8. BMP C1.55: Airborne Debris Curtain

Description

Using plastic or other material to create a vertical barrier, or curtain, around a building or other structure undergoing exposed construction or cleaning activities to minimize the spread of airborne debris.

Purpose

Activities related to exposed building construction, repair, or cleaning include spraying, pressure washing, surface preparation, sand blasting, paint removal, sanding, and painting. If conducted outdoors, all of these activities are associated with high risk for contaminating water resources.

Potential pollutants include spent fire retardants, abrasive grits, solvents, oils, washwater, paint overspray, cleaners and detergents, paint chips, glass fibers, and dust. Pollutant constituents include suspended solids, oils and greases, organic compounds, copper, lead, tin, and zinc.

Conditions Where Practice Applies

This BMP should be implemented when spraying, blasting, sanding, or washing outdoors.

Planning Considerations

- Relocate maintenance and repair activities that can be moved indoors to reduce the potential for direct pollution of stormwater.
- Evaluate disposal methods for spent abrasives, cleaners, etc.
- Consider using no soaps or detergents. Brush the exterior surface with water only.

Despite what is on the label, the term biodegradable does not mean that the product is safe or environmentally friendly. Some cleaning products may degrade eventually but are still harmful to the environment.

Design Criteria

- Use fixed platforms with appropriate plastic or tarpaulin barriers as work surfaces and for containment when work is performed near a receiving water. This helps to prevent material or overspray from coming into contact with stormwater or the receiving water.
- Use sanders that have dust-containment bags and avoid sanding in windy conditions.
- Store materials such as paints, tools, and ground cloths indoors or in a covered area when not in use.
- Contain blasting and spraying activities by hanging tarpaulins to block the wind and prevent dust and overspray from escaping. Do not perform uncontained spray painting, blasting, or sanding activities over open water without proper protection (e.g., overspray collection, drop cloths, booms).
- Use plywood or plastic sheeting to cover open areas when sandblasting.

- During painting, finishing, or sand blasting, use ground cloths to collect drips, spills, paint chips, and used blasting sand.
- Avoid collecting debris in areas subject to foot or vehicular traffic to control tracking.

Maintenance

- Collect spent abrasives and other waste materials regularly. Contain and store them under cover until they can be disposed of properly.
- At least once each week or more often as needed, sweep and clean ground surface areas. Do not hose them down. Properly dispose of the collected materials.
- Use one of the following treatment BMPs when paint chips or blasting grit are present in the work area:
  - Cleaning Inlets and Catch Basins (BMP E3.65)
  - Street Sweeping and Vacuuming (BMP E3.70)
  - Inlet Protection (BMP E3.25). Use filtration with media designed for the pollutants present.

Catch basin filters only remove solids and do not provide treatment for other pollutants associated with some building cleaning activities.

5.1.9. BMP C1.56: Concrete Handling

Description

Concrete work includes storage, mixing, pouring, placement, finishing, removal, saw cutting, and cleanup of concrete materials, slurry, or process water associated with these activities.

Purpose

To prevent or reduce the discharge of fine particles and high pH process water and slurry from concrete materials. Concrete spillage or concrete discharge to waters of the state is prohibited.

Conditions Where Practice Applies

Any time concrete is used, removed, or disposed of, including, but not limited to, placement and maintenance of:

- Curbs
- Sidewalks
- Roads
- Bridges
- Foundations
- Floors
- Runways

Any time cured or uncured concrete is used, removed or disposed of, or water that has come in contact with uncured concrete is present, it must be disposed of properly. Activities that use, remove, or dispose of concrete include, but are not limited to, sawing slurry, coring, grinding, roughening, hydro-demolition, and bridge and road surfacing.

Planning Considerations

Washwater and stormwater that has contacted uncured cement will become high-pH waters, which must be collected and treated before release to the public drainage system or public combined sewer. Concrete should not be placed during heavy rain events.

Wash concrete truck drums and other concrete handling equipment at an approved offsite location or in designated concrete washout areas only. Do not wash out concrete trucks on the ground (including formed areas awaiting concrete) or into storm drains, open ditches, streets, or streams. Refer to BMP C1.58 for information on concrete washout areas.

Refer to BMP C1.59 for pH adjustment requirements. Refer to Section 5.1.11 and, if applicable, the Construction Stormwater General Permit for pH monitoring requirements if the project involves one of the following activities:

- Significant concrete work (greater than 1,000 cubic yards poured concrete or recycled concrete used over the life of a project).

- The use of engineered soils amended with, but not limited to, Portland cement-treated base, cement kiln dust, or fly ash.
- Discharge of stormwater to receiving waters on the 303(d)list (Category 5) for high pH.

Education:

- Discuss the concrete management techniques described in this BMP with the ready-mix concrete supplier before any deliveries are made.
- Educate employees and subcontractors on the concrete waste management techniques described in this BMP.
- Arrange for contractor's superintendent or CESCL to oversee and enforce concrete waste management procedures.
- Install a sign adjacent to each temporary concrete washout area (BMP C1.58) to inform concrete equipment operators about utilizing the proper facilities.

Contracts:

Incorporate requirements for concrete waste management into concrete supplier and subcontractor agreements.

Design Criteria

- Within 15 feet of receiving waters, always use forms or solid barriers for concrete pours, such as pilings.
- Return unused concrete remaining in the truck and pump to the originating batch plant for recycling.
- Prefabricated containers are most resistant to damage and protect against spills and leaks. Companies may offer delivery service and provide regular maintenance and disposal of solid and liquid waste.
- Use approximately 7 gallons of washwater or less to wash one truck chute.
- Use approximately 50 gallons of washwater or less to wash out the hopper of a concrete pump truck.
- Washout facilities (BMP C1.58) should be maintained to provide adequate holding capacity with a minimum freeboard of 12 inches.
- Washout facilities (BMP C1.58) must be cleaned or new facilities must be constructed and ready for use once the washout is 75 percent full.
- Do not allow process water generated during hydro-demolition, surface roughening, or similar operations to drain to any natural or constructed drainage conveyance, including stormwater systems. Dispose of process water in a manner that does not violate groundwater or surface water quality standards.
- Wash hand tools including, but not limited to, screeds, shovels, rakes, floats, and trowels into formed areas or into a designated concrete washout area (BMP C1.58) only.

- Handle and dispose of cleaning waste material and demolition debris in a manner that does not cause contamination of water. Dispose of sweeping material from a pick-up sweeper at an appropriate disposal site.
- Wash equipment that is difficult to move, such as concrete pavers, in areas that do not directly drain to natural or constructed stormwater conveyances.
- Do not allow washdown from areas, such as concrete aggregate driveways, to drain directly to natural or constructed stormwater conveyances.
- Never wash off concrete into the footprint of an area where an infiltration feature will be installed.
- Contain washwater and leftover product in a lined container when no formed areas are available. Dispose of contained concrete in a manner that does not violate groundwater or surface water quality standards.
- The following steps will help reduce stormwater pollution from concrete wastes:
    - Do not allow excess concrete to be dumped on site, except in designated concrete washout areas.
    - If self-installed concrete washout areas are used, below-grade structures are preferred over above-grade structures because they are less prone to spills and leaks. Self-installed above-grade structures should only be used if excavation is not practical.

5.1.10. BMP C1.58: Concrete Washout Area

Description

Methods for control, containment, removal, and disposal of concrete materials and waste products to prevent contamination of storm drains, open ditches, or critical areas such as water bodies and wetlands. Concrete work includes storage, mixing, pouring, placement, finishing, removal, sawcutting, or cleanup of concrete materials, slurry, or process water associated with these activities. It also includes the proper construction of a contained area on a project site where concrete and concrete wastewater and washout may be stored for later disposal.

Purpose

Prevent or reduce the discharge of pollutants from concrete waste to stormwater by conducting washout off site or performing onsite washout in a designated area.

Conditions Where Practice Applies

Concrete washout areas are implemented on construction projects where:

- Concrete is used as a construction material.
- It is not possible to dispose of all concrete wastewater and washout off site (ready mix plant, etc.).
- Concrete truck drums are washed on site.

  Note that auxiliary concrete truck components (e.g., chutes and hoses) and small concrete handling equipment (e.g., hand tools, screeds, shovels, rakes, floats, trowels, and wheelbarrows) may be washed off into formed areas awaiting a concrete pour.

At no time will concrete handling equipment be washed off into the footprint of a proposed area where an infiltration BMP will be installed.

Design Criteria

Location and Placement of Washout Areas:

- Locate washout area at least 50 feet from storm drains, open ditches, or critical areas such as water bodies and wetlands.
- Allow convenient access for concrete trucks, preferably near the area where the concrete is being poured.
- If trucks need to leave a paved area to access washout, prevent track-out with a pad of rock or quarry spalls (refer to BMP E2.10). These areas should be far enough away from other construction traffic to reduce the likelihood of accidental damage and spills.
- The number of washout facilities installed depends on the expected demand for storage capacity.
- On large sites with extensive concrete work, washout facilities should be placed in multiple locations for ease of use by concrete truck drivers.

- If the washout facility is nearing capacity, vacuum and dispose of the waste material in an approved manner.

  Note: If less than 10 concrete trucks or pumpers need to be washed out on site, the washwater may be disposed of in a formed area awaiting a concrete pour or an upland disposal site where it will not contaminate surface water or groundwater. The upland disposal site must be at least 50 feet from critical areas such as storm drains, open ditches, or water bodies, including wetlands.

- Concrete washout areas must be constructed and maintained in sufficient quantity and size to contain all liquid and concrete waste generated by washout operations.

Onsite Temporary Concrete Washout Facility and Transit Truck Washout Procedures:

- Locate temporary concrete washout facilities a minimum of 50 feet from critical areas, including storm drain inlets, open drainage BMPs, and receiving waters. Refer to Figures 20 and 21.
- Construct and maintain concrete washout facilities in sufficient quantity and size to contain all liquid and concrete waste generated by washout operations.
- Perform washout of concrete trucks in designated areas only.
- Concrete washout from concrete pumper bins can be washed into concrete pumper trucks and discharged into the designated washout area or properly disposed of off site.
- Once concrete wastes are washed into the designated area and allowed to harden, break up, remove, and dispose of the concrete per applicable solid waste regulations. Dispose of hardened concrete on a regular basis.

Temporary Above-grade Concrete Washout Facility:

- Construct temporary concrete washout facilities (type above grade) (refer to Figures 20 and 21), with a recommended minimum length and minimum width of 10 feet, but with sufficient quantity and volume to contain all liquid and concrete waste generated by washout operations.
- Use plastic lining material that is a minimum of 10 mil polyethylene sheeting and free of holes, tears, or other defects that compromise the impermeability of the material.

Temporary Below-grade Concrete Washout Facility:

- Construct temporary concrete washout facilities (refer to Figure 20, type below-grade) with a recommended minimum length and minimum width of 10 feet. The quantity and volume should be sufficient to contain all liquid and concrete waste generated by washout operations.
- Use commercial type lath and flagging.
- Use plastic lining material that is a minimum of 10 mil polyethylene sheeting and free of holes, tears, or other defects that compromise the impermeability of the material.
- Install liner seams in accordance with manufacturers' recommendations.
- Prepare soil base so it is free of rocks or other debris that may cause tears or holes in the plastic lining material.

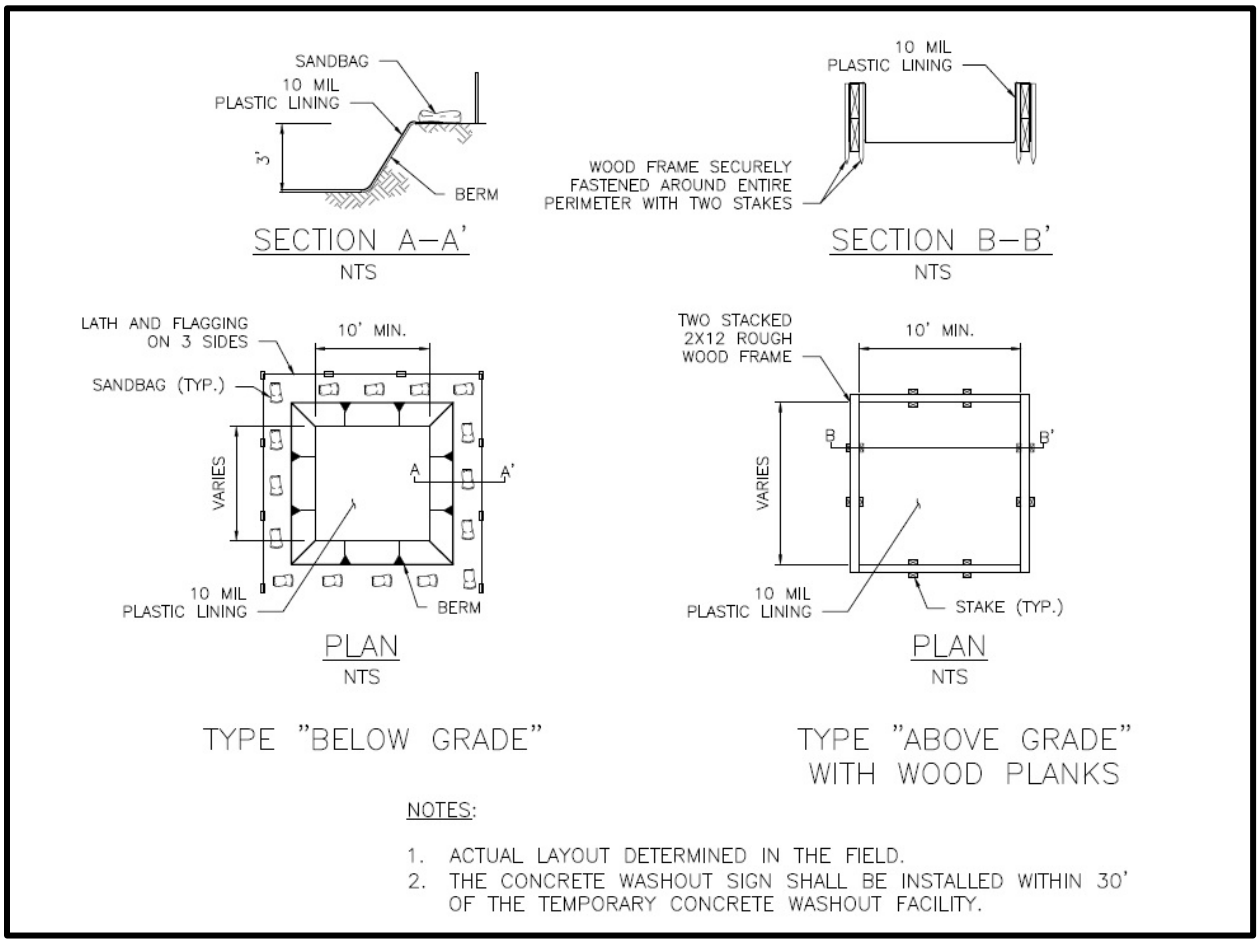


Figure 20. Concrete Washout Facility.

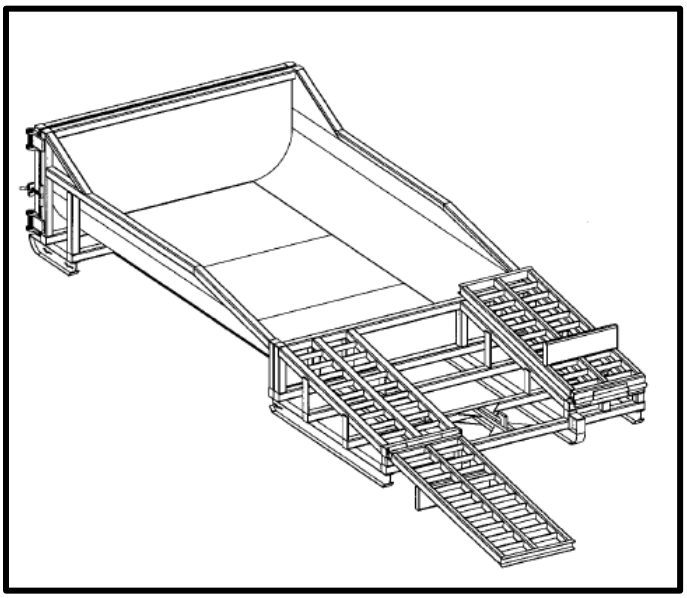


Figure 21. Prefabricated Concrete Washout Container with Ramp.

Maintenance

- Check containers daily for holes in the liner during concrete pours and repair the same day.
- Continually monitor operations to determine whether slurry, cuttings, or process water could enter receiving waters. If inspections show that a violation of water quality standards could occur, stop operations and immediately implement preventive measures such as berms, barriers, secondary containment, and vacuum trucks.
- Inspect and verify that concrete washout BMPs are in place prior to the commencement of concrete work.
- During periods of concrete work, inspect daily to verify continued performance.
- Check overall condition and performance.
- Check remaining capacity (percent full).
- If using self-installed washout facilities, verify plastic liners are intact and sidewalls are not damaged.
- If using prefabricated containers, check for leaks.
- Do not discharge liquid or slurry to receiving waters, drainage channels, storm drains, or directly onto ground.
- Do not use the public sanitary sewer without King County Industrial Waste Program approval.
- Place a secure, non-collapsing, non-water-collecting cover over the concrete washout facility prior to a predicted wet weather event to prevent accumulation and overflow of precipitation.
- Remove and dispose of hardened concrete and return the structure to a functional condition. Concrete may be reused on site or hauled away for disposal or recycling.
- When removing materials from the self-installed concrete washout, build a new structure. If the previous structure is still intact, inspect for signs of weakening or damage, and make any necessary repairs. Re-line the structure with new plastic after each cleaning.

Removal of Temporary Concrete Washout Facilities:

- When temporary concrete washout facilities are no longer required for the work, remove and properly dispose of the hardened concrete, slurries, and liquids.
- Remove and dispose of or recycle materials used to construct temporary concrete washout facilities.
- Backfill, repair, and stabilize holes, depressions, or other ground disturbance caused by the removal of the temporary concrete washout facilities to prevent erosion.

5.1.11. BMP C1.59: High pH Neutralization Using CO_2

Description

Methods for neutralization of high pH water prior to discharge into the drainage system or receiving waters.

Purpose

When pH levels in stormwater rise above 8.5 it is necessary to lower the pH levels to the acceptable range of 6.5 to 8.5, this process is called pH neutralization. pH neutralization involves the use of solid or compressed carbon dioxide gas in water requiring neutralization (CO_2 Sparging). Neutralized stormwater may be discharged to receiving waters under the Ecology Construction Stormwater General permit.

Neutralized process water, such as concrete truck washout, hydro-demolition, or sawcutting slurry, must be managed to prevent discharge to receiving waters. Any stormwater contaminated during concrete work is considered process wastewater and must not be discharged to receiving waters.

Reasons for pH Neutralization:

- A pH range of 6.5 to 8.5 is typical for most natural watercourses, and this neutral pH is required for the survival of aquatic organisms. Should the pH rise or drop out of this range, fish and other aquatic organisms may become stressed and may die.
- Calcium hardness can contribute to high pH values and cause toxicity that is associated with high pH conditions. A high level of calcium hardness in receiving waters is not allowed.
- The water quality standard for pH in Washington State is in the range of 6.5 to 8.5. The groundwater standard for calcium and other dissolved solids in Washington State is less than 500 mg/l.

Conditions Where Practice Applies

Causes of High pH:

High pH at project sites is most commonly caused by the contact of stormwater with poured or recycled concrete, cement, mortars, and other construction materials containing Portland cement or lime. (Refer to BMP C1.56 for more information on concrete handling procedures.) The principal caustic agent in cement is calcium hydroxide (free lime).

Advantages of CO_2 Sparging:

- Rapidly neutralizes high pH water.
- Cost effective and safer to handle than acid compounds.
- CO_2 is self-buffering. It is difficult to overdose and create harmfully low pH levels.
- Material is readily available.

The Chemical Process:

When carbon dioxide (CO2) is added to water (H2O), carbonic acid (H2CO3) is formed, which can further dissociate into a proton (H+) and a bicarbonate anion (HCO3-) as shown below:

$$CO_2 + H_2O \leftrightarrow H2CO_3 \leftrightarrow H+ + HCO_{3-}$$

The free proton is a weak acid that can lower the pH. Water temperature has an effect on the reaction as well. The colder the water temperature the slower the reaction occurs and the warmer the water temperature the quicker the reaction occurs. Most construction applications in Washington State have water temperatures in the 50°F or higher range so the reaction is almost instantaneous.

Design Criteria

Treatment Process:

High pH water may be treated using continuous treatment, continuous discharge systems. These manufactured systems continuously monitor influent and effluent pH to ensure that pH values are within an acceptable range before being discharged. All systems must have fail safe automatic shut off switches in the event that pH is not within the acceptable discharge range. Only trained operators may operate manufactured systems. System manufacturers often provide trained operators or training on their devices.

The following procedure may be used when not using a continuous discharge system:

1. Make every effort to isolate the potential high pH water in order to treat it separately from other stormwater on site.
2. Store water in an acceptable storage facility, detention pond, or containment cell prior to treatment.
3. Transfer water to be treated to the treatment structure. Ensure that treatment structure size is sufficient to hold the amount of water that is to be treated. Do not fill tank completely, allow at least 2 feet of freeboard.
4. Sample the water for pH and note the clarity of the water. Generally, less CO_2 is necessary for clearer water. Record this information in the stormwater treatment logbook.
5. In the pH adjustment structure, add CO_2 until the pH falls in the range of 6.9 to 7.1. Remember that pH water quality standards apply so adjusting pH to within 0.2 pH units of receiving water (background pH) is recommended. It is unlikely that pH can be adjusted to within 0.2 pH units using dry ice. Compressed carbon dioxide gas should be introduced to the water using a carbon dioxide diffuser located near the bottom of the tank, which will allow carbon dioxide to bubble up through the water and diffuse more evenly.
6. Slowly discharge the water, making sure water does not get stirred up in the process. Release about 80 percent of the water from the structure leaving any sludge behind.
7. Discharge treated water through a pond or drainage system.

8. Excess sludge must be disposed of properly as concrete waste. If several batches of water are undergoing pH treatment, sludge can be left in the treatment structure for the next batch treatment. Dispose of sludge when it fills 50 percent of tank volume.

Sites that must implement flow control for the developed site must also control stormwater release rates during construction. All treated stormwater must go through a flow control facility before being released to receiving waters or systems that require flow control.

Maintenance Standards:

Safety and Materials Handling

- Handle all equipment in accordance with Occupational Safety and Health Administration (OSHA) rules and regulations.
- Follow manufacturer guidelines for materials handling.

Operator Records

Each operator should provide:

- A diagram of the monitoring and treatment equipment.
- A description of the pumping rates and treatment equipment capacity .

Each operator should keep a written record of the following:

- Client name and phone number
- Date of treatment
- Weather conditions
- Project name and location
- Volume of water treated
- pH of untreated water
- Amount of CO_2 needed to adjust water to a pH range of 6.9 to 7.1
- pH of treated water
- Discharge point location and description

A copy of this record should be given to the project proponent/owner/contractor who must retain the record for 3 years.

5.2. Monitoring Practices

5.2.1. Turbidity Monitoring

All Large Projects that have concentrated discharges, such as sediment tank or sediment trap discharges, to public or private storm drainage systems or surface waters are required to monitor the turbidity prior to discharge and provide additional treatment if required to meet turbidity benchmarks. Small Projects may also require turbidity monitoring if the site is suspected of causing a surface water quality standards violation. If the discharge is to a combined sewer system, then refer to the requirements of the King County Construction Dewatering Authorization.

For construction turbidity monitoring, turbidity benchmarks of 25 and 250 NTU (nephelometric turbidity unit) are used. It is presumed that turbidity of 25 NTU or less is not likely to cause an exceedance of State of Washington water quality standards under most conditions, and BMPs are presumed to be functioning properly. If a turbidity reading exceeds 25 NTU, it is presumed that necessary BMPs have not been implemented or are not functioning properly and corrective action must be taken, such as employing additional BMPs around the site, providing additional time for settling out particles, or using filtration or chemical treatment (such as chitosan, etc.) to reduce the turbidity to below 25 NTU. If the turbidity benchmark of 250 NTU is exceeded, there is a much higher risk of exceeding state water quality standards.

During construction, sampling for turbidity must be performed (i) during or after each rainfall event of at least 0.25 inches within a calendar day that results in concentrated discharge from the site, (ii) prior to any batch discharge, and (iii) at least once every calendar week when there is a discharge. Sampling is not required outside of operational hours or during unsafe conditions. No more than one sample is required in a day, and no more than two samples are required per week if the test indicates that turbidity is 25 NTU or less. If the sample indicates that turbidity is in excess of 25 NTU after the initial sample is taken or visibly turbid water is observed coming from the site, then the site must immediately begin the process to fully implement and maintain appropriate source control and/or treatment BMPs and evaluate if additional BMPs are necessary to meet the 25 NTU benchmark. If the sample test indicates that turbidity is more than 250 NTU, additional samples at least daily are required until the turbidity is 25 NTU or less. In this event, (i) immediate corrective actions must be taken to reduce turbidity levels, and (ii) the City inspector *and* Ecology (206-594-0000) must both be notified within 24 hours of becoming aware of the elevated turbidity result.

Additional monitoring requirements may apply if the project is subject to the Ecology Construction Stormwater General Permit or other Ecology-issued permits or authorizations.

5.2.2. pH Monitoring

pH monitoring is required for any Large Project that includes any of the following activities:

- Significant concrete work (greater than 1,000 cubic yards poured concrete or recycled concrete used over the life of a project).

- The use of engineered soils amended with (but not limited to) Portland cement-treated base, cement kiln dust, or fly ash.
- Discharge of stormwater to receiving waters on the 303(d)list (Category 5) for high pH.

Small Projects may also require pH monitoring if the site is suspected of causing a surface water quality violation.

When there are discharges from the site, sampling for pH is required at least once weekly during the following activities:

- Starting when concrete is first placed or poured and exposed to precipitation and continuing through the curing period until the stormwater pH is in the range of 6.5 to 8.5.
- For sites with recycled concrete or Portland cement-treated soils, starting when the recycled concrete or engineered soils are first exposed to precipitation until the recycled concrete or soils are fully stabilized with the stormwater pH in the range of 6.5 to 8.5.

The benchmark value for pH is 8.5. Any time sampling indicates that pH is greater than 8.5, the high pH water must be prevented from entering the storm drainage system, surface waters, or groundwater, and, if necessary, the high pH water must be adjusted or neutralized. Refer to Section 5.1.12. BMP C1.59 High pH Neutralization Using CO_2. Also, refer to Sections 5.1.10 and 5.1.11 for additional concrete handling and washout area requirements.

Additional monitoring requirements may apply if the project is subject to the Ecology Construction Stormwater General Permit or other Ecology permits or authorizations. If the discharge is to a combined system, then the monitoring requirements must reflect the King County Construction Dewatering Authorization.

ATTACHMENT 1

Checklist to Select Small and Large Project Construction BMPs

ATTACHMENT 1 – CHECKLIST TO SELECT SMALL AND LARGE PROJECT CONSTRUCTION BMPS

Table 1a-1. Checklist to Select Small Project Construction BMPs.

Project Name:

Element Number	Required Element	Small Project[a] (check selection)	If not applicable, describe why in the space below.
1	Mark Clearing Limits and Environmentally Critical Areas	Recommended[b] BMPs: ☐ E1.30 Preserving Natural Vegetation (refer to *Section 4.1.2.1)* ☐ E1.35 Buffer Zones (refer to *Section 4.1.2.2*) ☐ E1.50 High-Visibility Fencing (refer to *Section 4.1.2.5)*	
2	Retain Top Layer	Required BMP: Within the boundaries of the project site, retain the duff layer, topsoil, and native vegetation, if there is any, in an undisturbed state to the maximum extent possible. If it is not possible to retain the top layer in place, stockpile on site, cover to prevent erosion, and replace immediately upon completion of ground-disturbing activities to the maximum extent possible.	
3	Establish Construction Access	Required BMP: ☐ E2.10 Stabilization Construction Access (refer to *Section 4.2.1.1*) Recommended BMPs: ☐ E2.15 Tire Wash (refer to *Section 4.2.1.2*) ☐ E2.20 Construction Road Stabilization (refer to *Section 4.2.1.3*)	
4	Protect Downstream Properties and Receiving Waters	Recommended BMP: ☐ Ecology BMP C241 Temporary Sediment Pond (or Basin)	

Table 1a-2. Checklist to Select Small Project Construction BMPs.

Project Name:

Element Number	Required Element	Small Project[a] (check selection)	If not applicable, describe why in the space below.
5	Prevent Erosion and Sediment Transport from the Site	Required BMPs – one or more of the following: ☐ E3.10 Filter Fence (refer to *Section 4.3.1*) ☐ E3.20 Gravel Filter Berm (refer to *Section 4.3.2*) ☐ E3.30 Vegetated Strip (refer to *Section 4.3.4*) ☐ E3.35 Straw Wattles, Compost Socks, and Compost Berms (refer to *Section 4.3.5*) ☐ E3.40 Sediment Trap (refer to *Section 4.3.6*) ☐ E3.50 Portable Sediment Tank (refer to *Section 4.3.7*) ☐ E3.60 Construction Stormwater Filtration (refer to *Section 4.3.8*) ☐ Ecology BMP C231 Brush Barrier ☐ Ecology BMP C241 Temporary Sediment Pond (or Basin) ☐ Ecology BMP C250 Construction Stormwater Chemical Treatment	
6	Prevent Erosion and Sediment Transport from the Site by Vehicles	Required BMPs – one or more of the following: ☐ E3.65 Cleaning Inlets and Catch Basins (refer to *Section 4.3.9*) ☐ E3.70 Street Sweeping and Vacuuming (refer to *Section 4.3.10*)	
7	Stabilize Soils	Required BMPs for all exposed soils and stockpiles – one or more of the following: ☐ E1.10 Temporary Seeding (refer to *Section 4.1.1.1*) ☐ E1.15 Mulching, Matting, and Compost Blankets (refer to *Section 4.1.1.2*) ☐ E1.20 Clear Plastic Covering (refer to *Section 4.1.1.3*) ☐ E1.40 Permanent Seeding and Planting (refer to *Section 4.1.2.3*) ☐ E1.45 Sodding (refer to *Section 4.1.2.4*) ☐ E2.45 Dust Control (refer to *Section 4.2.1.6*) ☐ Ecology BMP C126 Polyacrylamide for Soil Erosion Protection ☐ Ecology BMP C130 Surface Roughening ☐ Ecology BMP C131 Gradient Terracing	

Table 1a-3. Checklist to Select Small Project Construction BMPs.

Project Name:

Element Number	Required Element	Small Project[a] (check selection)	If not applicable, describe why in the space below.
8	Protect Slopes (refer to the Environmentally Critical Area ordinance [SMC 25.09.180] for additional requirements and development standards for steep slopes)	Required BMPs – one or more of the following: ☐ Level Spreader (refer to *Appendix E*) ☐ E2.35 Check Dams (refer to *Section 4.2.1.4*) ☐ E2.40 Triangular Silt Dike (Geotextile-encased Check Dam) (refer to *Section 4.2.1.5*) ☐ Pipe Slope Drains (refer to *Appendix E*) ☐ E2.70 Subsurface Drains (refer to *Section 4.2.3.1*) ☐ E2.80 Earth Dike and Drainage Swale (refer to *Section 4.2.3.2*) ☐ Ecology BMP C201 Grass-lined Channels ☐ Ecology BMP C130 Surface Roughening ☐ Ecology BMP C131 Gradient Terracing	
9	Protect Storm Drains	Required BMPs: ☐ E3.25 Inlet Protection (refer to *Section 4.3.3*) ☐ E3.65 Cleaning Inlets and Catch Basins (refer to *Section 4.3.9*) ☐ E3.70 Street Sweeping and Vacuuming (refer to *Section 4.3.10*)	
10	Stabilize Channels and Outlets	Recommended BMPs: ☐ Level Spreader (refer to *Appendix E*) ☐ E2.35 Check Dams (refer to *Section 4.2.1.4*) ☐ E2.80 Earth Dike and Swale (refer to *Section 4.2.3.2*) ☐ Outlet Protection (refer to *Appendix E*) ☐ Ecology BMP C201 Grass-lined Channels ☐ Ecology BMP C202 Channel Lining ☐ Ecology BMP C203 Water Bars	

Table 1a-4. Checklist to Select Small Project Construction BMPs.

Project Name:

Element Number	Required Element	Small Project[a] (check selection)	If not applicable, describe why in the space below.
11	Control Pollutants (also refer to *Volume 4 — Source Control*)	Required BMPs: ☐ C1.15 Material Delivery, Storage, and Containment (refer to *Section 5.1.1*) ☐ C1.20 Use of Chemicals During Construction (refer to *Section 5.1.2*) ☐ C1.25 Demolition of Buildings (refer to *Section 5.1.3*) ☐ C1.30 Building Repair, Remodeling, and Construction (refer to *Section 5.1.4*) ☐ C1.35 Sawcutting and Surfacing Pollution Prevention (refer to *Section 5.1.5*) ☐ C1.45 Solid Waste Handling and Disposal (refer to *Section 5.1.6*) ☐ C1.50 Disposal of Asbestos and Polychlorinated Biphenyls (PCBs) (refer to *Section 5.1.7*) ☐ C1.55 Airborne Debris Curtain (refer to *Section 5.1.8*) ☐ C1.56 Concrete Handling (refer to *Section 5.1.9*) ☐ C1.58 Concrete Washout Area (refer to *Section 5.1.10*)	
12	Control Dewatering	Recommended BMP: ☐ E4.20 Temporary Dewatering (refer to *Section 4.4.2*)	
13	Maintain BMPs	Required BMP: ☐ Maintain and repair all temporary and permanent erosion and sediment control BMPs as needed to ensure continued performance of their intended function.	
14	Inspect BMPs	Required BMP: ☐ Inspect, maintain, and repair all BMPs as needed to ensure continued performance of their intended function.	

Table 1a-5. Checklist to Select Small Project Construction BMPs.

Project Name:

Element Number	Required Element	Small Project[a] (check selection)	If not applicable, describe why in the space below.
15	Execute Construction Stormwater Control and Soil Management Plan	Required BMPs: Implement and maintain an updated Construction Stormwater Control and Soil Management Plan, beginning with initial land disturbance. ☐ Retain the Small Project Construction Stormwater Control and Soil Management Plan on site or within reasonable access to the site. Modify the plan as needed. Coordination with Utilities, Contractors, and Others ☐ When preparing the Small Project Construction Stormwater Control and Soil Management Plan, the primary project proponent should evaluate, with input from utilities and other contractors, the stormwater management requirements for the entire project, including the utilities. Project Closeout: ☐ Remove all temporary erosion and sediment control BMPs within 5 business days after final site stabilization is achieved or after they are no longer needed—whichever is later.	
16	Minimize Open Trenches	Required BMP: In the construction of underground utility lines, where possible, no more than one hundred fifty (150) feet of trench should be opened at one time, unless soil is replaced within the same working day. Where consistent with safety and space considerations, place excavated material on the uphill side of trenches. Trench dewatering devices should discharge into a sediment trap or sediment pond.	
17	Phase the Project	Required BMPs: Construction Phasing ☐ Phase development projects where possible to prevent soil erosion and, to the maximum extent practical, the transport of sediment from the site during construction. Seasonal Work Limitations ☐ From October 31 through April 1, clearing, grading, and other soil-disturbing activities will be subject to additional limitations.	

Table 1a-6. Checklist to Select Small Project Construction BMPs.

Project Name:

Element Number	Required Element	Small Project[a] (check selection)	If not applicable, describe why in the space below.
18	Install Permanent Flow Control and Water Quality Facilities	• Refer to *Volume 1* for applicable minimum requirements and *Volume 3* for BMP design.	
19	Protect Stormwater BMPs	General: Protect all stormwater BMPs from sedimentation through installation and maintenance of erosion and sediment control BMPs. Restore the BMPs to their fully functioning condition if they accumulate sediment during construction. Restoring the stormwater BMP must include removal of sediment and any sediment-laden soils and replacing the removed soils with soils meeting the design specification. ☐ The approved plan sheets provide construction sequencing that protects the infiltration facility during construction. Sediment Control: Protect infiltration BMPs from sedimentation that can clog the facility and reduce infiltration capacity. ☐ Minimize site disturbance at the location of the infiltration BMPs and in up-gradient areas. ☐ Do not use infiltration BMPs as sediment control facilities. ☐ Direct all drainage away from the facility location after initial rough grading. ☐ Flow can be directed away from the facility with temporary diversion swales or other approved protection. ☐ Do not construct infiltration BMPs until all contributing drainage areas are stabilized with appropriate erosion and sediment control BMPs and to the satisfaction of the engineer.	

Table 1a-7. Checklist to Select Small Project Construction BMPs.

Project Name:

Element Number	Required Element	Small Project[a] (check selection)	If not applicable, describe why in the space below.
19	Protect Stormwater BMPs (continued)	☐ Do not construct infiltration BMPs until all contributing drainage areas are stabilized with appropriate erosion and sediment control BMPs and to the satisfaction of the engineer. ☐ Inspect and maintain erosion and sediment control practices on a regular basis. If deposition of sediment occurs in the infiltration area, remove material and scarify the surface to a minimum depth of 3 inches. ☐ Control erosion and avoid introducing sediment from surrounding land uses onto permeable pavements. Do not allow muddy construction equipment on the base material or pavement. Do not allow sediment-laden runoff onto permeable pavements or base materials. ☐ Permeable pavement fouled with sediments or no longer passing an initial infiltration test must be cleaned until infiltrating per design or replaced. Compaction Prevention: Soil compaction can lead to a reduction of infiltration rates and facility failure; accordingly, minimizing compaction of the base and sidewalls of the infiltration area is critical. ☐ Before the development site is graded, rope or fence the area of the infiltration BMP to restrict access and flag to prevent soil compaction by heavy equipment and foot traffic. ☐ Perform excavation with machinery operating adjacent to the infiltration BMP and do not allow heavy equipment with narrow tracks, narrow tires, or large lugged, high-pressure tires on the bottom of the infiltration BMP footprint. ☐ Protect established completed lawn and landscaped areas from compaction due to construction equipment. ☐ Do not excavate during wet or saturated conditions.	

[a] A small project is defined as one with less than 5,000 square feet of new plus replaced hard surface and less than 10,000 square feet of land-disturbing activity.

[b] Recommended BMPs provide further guidance for minimizing potential stormwater pollution resulting from activities.

Construction Stormwater Pollution Prevention Plan Checklist

Project Number:
Review Date:
Onsite Inspection Review Date:
Construction SWPPP Reviewer:

Table 1b-1. Checklist to Select Large Project Construction BMPs.

Project Name:

Element Number	Required Element	Large Project[a] (check selection)	If not applicable, describe why in the space below.
1	Mark Clearing Limits and Environmentally Critical Areas	Required BMPs: ☐ E1.30 Preserving Natural Vegetation (refer to *Section 4.1.2.1*) ☐ E1.35 Buffer Zones (refer to *Section 4.1.2.2*) ☐ E1.50 High-Visibility Fencing (required at the edges of non-disturbance areas of environmentally critical areas (ECAs) and their buffers; refer to *Section 4.1.2.5*)	
2	Retain Top Layer	Required BMP: Within the boundaries of the project site, retain the duff layer, topsoil, and native vegetation, if there is any, in an undisturbed state to the maximum extent feasible. If it is not feasible to retain the top layer in place, stockpile on site, cover to prevent erosion, and replace immediately upon completion of the ground-disturbing activities to the maximum extent possible.	
3	Establish Construction Access	Required BMPs: ☐ E2.10 Stabilized Construction Access (refer to *Section 4.2.1.1*) ☐ E2.15 Tire Wash (refer to *Section 4.2.1.2*) ☐ E2.20 Construction Road Stabilization (refer to *Section 4.2.1.3*)	
4	Protect Downstream Properties and Receiving Waters	Required BMP for contributing area of 3 acres or greater: ☐ Ecology BMP C241 Sediment Pond (Temporary)	

Table 1b-2. Checklist to Select Large Project Construction BMPs.

Project Name:

Element Number	Required Element	Large Project[a] (check selection)	If not applicable, describe why in the space below.
5	Prevent Erosion and Sediment Transport from the Site	Required BMPs: ☐ E3.10 Filter Fence (refer to *Section 4.3.1*) ☐ Ecology BMP C231 Brush Barrier ☐ E3.20 Gravel Filter Berm (refer to *Section 4.3.2*) AND ☐ E3.40 Sediment Trap (refer to *Section 4.3.6*) OR ☐ Ecology BMP C241 Sediment Pond (Temporary) OR ☐ E3.50 Portable Sediment Tank (refer to *Section 4.3.7*) Additional recommended BMPs: ☐ E3.30 Vegetated Strip (refer to *Section 4.3.4*) ☐ E3.35 Straw Wattles, Compost Socks, and Compost Berms (refer to *Section 4.3.5*) ☐ E3.60 Construction Stormwater Filtration (refer to *Section 4.3.8*) ☐ Ecology BMP C250 Construction Stormwater Chemical Treatment	
6	Prevent Erosion and Sediment Transport from the Site by Vehicles	Required BMPs: ☐ E3.65 Cleaning Inlets and Catch Basins (refer to *Section 4.3.9*) ☐ E3.70 Street Sweeping and Vacuuming (refer to *Section 4.3.10*)	

Table 1b-3. Checklist to Select Large Project Construction BMPs.

Project Name:

Element Number	Required Element	Large Project[a] (check selection)	If not applicable, describe why in the space below.
7	Stabilize Soils	Required BMPs for all exposed soils and stockpiles – one or more of the following: ☐ E1.10 Temporary Seeding (refer to *Section 4.1.1.1*) ☐ E1.15 Mulching, Matting, and Compost Blankets (refer to *Section 4.1.1.2*) ☐ E1.20 Clear Plastic Covering (refer to *Section 4.1.1.3*) ☐ E1.40 Permanent Seeding and Planting (refer to *Section 4.1.2.3*) ☐ E1.45 Sodding (refer to *Section 4.1.2.4*) ☐ E2.45 Dust Control (refer to *Section 4.2.1.6*) ☐ Ecology BMP C130 Surface Roughening ☐ Ecology BMP C131 Gradient Terracing ☐ Ecology BMP C126 Polyacrylamide for Soil Erosion Protection	
8	Protect Slopes (refer to the Environmentally Critical Areas ordinance [SMC 25.09.180] for additional requirements and development standards for steep slopes)	Required BMPs – one or more of the following: ☐ Level Spreader (refer to *Appendix E*) ☐ E2.35 Check Dams (refer to *Section 4.2.1.4*) ☐ E2.40 Triangular Silt Dike (Geotextile-encased Check Dam) (refer to *Section 4.2.1.5*) ☐ Pipe Slope Drains (refer to *Appendix E*) ☐ E2.70 Subsurface Drains (refer to *Section 4.2.2.2*) ☐ E2.80 Earth Dike and Drainage Swale (refer to *Section 4.2.3.2*) ☐ Ecology BMP C130 Surface Roughening ☐ Ecology BMP C131 Gradient Terracing ☐ Ecology BMP C201 Grass-lined Channels	

Table 1b-4. Checklist to Select Large Project Construction BMPs.

Project Name:

Element Number	Required Element	Large Project[a] (check selection)	If not applicable, describe why in the space below.
9	Protect Storm Drains	Required BMPs: ☐ E3.25 Inlet Protection (refer to *Section 4.3.3*) ☐ E3.65 Cleaning Inlets and Catch Basins (refer to *Section 4.3.9*) ☐ E3.70 Street Sweeping and Vacuuming (refer to *Section 4.3.10*)	
10	Stabilize Channels and Outlets	Required BMPs – one or more of the following: ☐ Level Spreader (refer to *Appendix E*) ☐ E2.35 Check Dams (refer to *Section 4.2.1.4*) ☐ E2.80 Earth Dike and Drainage Swale (refer to *Section 4.2.3.2*) ☐ Outlet Protection (refer to *Appendix E*) ☐ Ecology BMP C201 Grass-lined Channels ☐ Ecology BMP C202 Riprap Channel Lining ☐ Ecology BMP C203 Water Bars	
11	Control Pollutants (also refer to *Volume 4 — Source Control*)	Required BMPs: ☐ C1.15 Material Delivery, Storage, and Containment (refer to *Section 5.1.1*) ☐ C1.20 Use of Chemicals During Construction (refer to *Section 5.1.2*) ☐ C1.25 Demolition of Buildings (refer to *Section 5.1.3*) ☐ C1.30 Building Repair, Remodeling, and Construction (refer to *Section 5.1.4*) ☐ C1.35 Sawcutting and Surfacing Pollution Prevention (refer to *Section 5.1.5*) ☐ C1.45 Solid Waste Handling and Disposal (refer to *Section 5.1.6*) ☐ C1.50 Disposal of Asbestos and Polychlorinated Biphenyls (PCBs) (refer to *Section 5.1.7*) ☐ C1.55 Airborne Debris Curtain (refer to *Section 5.1.8*) ☐ C1.56 Concrete Handling (refer to *Section 5.1.9*) ☐ C1.58 Concrete Washout Area (refer to *Section 5.1.10*) ☐ C1.59 High pH Neutralization Using CO_2 (refer to *Section 5.1.11*)	

Table 1b-5. Checklist to Select Large Project Construction BMPs.

Project Name:

Element Number	Required Element	Large Project[a] (check selection)	If not applicable, describe why in the space below.
12	Control Dewatering	Required BMP: ☐ E4.20 Temporary Dewatering (refer to *Section 4.4.2*)	
13	Maintain BMPs	Required BMP: ☐ Maintain and repair all temporary and permanent erosion and sediment control BMPs as needed to ensure continued performance of their intended function.	
14	Inspect BMPs	Required BMP: ☐ Inspect, maintain, and repair all BMPs as needed to ensure continued performance of their intended function. ☐ Certified Erosion and Sediment Control Lead (refer to *Section 2.3*): For projects over 1 acre; inspections should be conducted by the Certified Erosion and Sediment Control Lead identified in the Large Project Construction Stormwater Control and Soil Management Plan.	
15	Execute Construction Stormwater Control and Soil Management Plan	Required BMPs: Implement and maintain an updated Construction Stormwater Control and Soil Management Plan beginning with initial land disturbance. ☐ Retain the Large Project Construction Stormwater Control and Soil Management Plan on site or within reasonable access to the site. Modify the plan as needed. Coordination with Utilities, Contractors, and Others ☐ The primary project proponent should evaluate, with input from utilities and other contractors, the stormwater management requirements for the entire project, including the utilities, when preparing the Small Project Construction Stormwater Control and Soil Management Plan. Project Closeout ☐ Remove all temporary erosion and sediment control BMPs within 5 business days after final site stabilization is achieved or after they are no longer needed, whichever is later.	

Table 1b-6. Checklist to Select Large Project Construction BMPs.

Project Name:

Element Number	Required Element	Large Project[a] (check selection)	If not applicable, describe why in the space below.
16	Minimize Open Trenches	Required BMP: In the construction of underground utility lines, where possible, no more than one hundred and fifty (150) feet of trench should be opened at one time unless soil is replaced within the same working day. Where consistent with safety and space considerations, place excavated material on the uphill side of trenches. Trench dewatering devices should discharge into a sediment trap or sediment pond.	
17	Phase the Project	Required BMPs: Construction Phasing ☐ Phase development projects where possible to prevent soil erosion and, to the maximum extent practical, the transport of sediment from the site during construction. Seasonal Work Limitations ☐ From October 31 through April 1, clearing, grading, and other soil-disturbing activities will be subject to additional limitations.	
18	Install Permanent Flow Control and Water Quality Facilities	Refer to *Volume 1* for applicable minimum requirements and *Volume 3* for BMP design.	
19	Protect Stormwater BMPs	General: Protect all stormwater BMPs from sedimentation through installation and maintenance of erosion and sediment control BMPs. Restore the BMPs to their fully functioning condition if they accumulate sediment during construction. Restoring the stormwater BMP must include removal of sediment and any sediment-laden soils and replacing the removed soils with soils meeting the design specification. ☐ The approved plan sheets provide construction sequencing that protects the infiltration facility during construction. Sediment Control: Protect infiltration BMPs from sedimentation that can clog the facility and reduce infiltration capacity. ☐ Minimize site disturbance at the location of the infiltration BMPs and in up-gradient areas. ☐ Do not use infiltration BMPs as sediment control facilities. ☐ Direct all drainage away from the facility location after initial rough grading.	

Table 1b-7. Checklist to Select Large Project Construction BMPs.

Project Name:

Element Number	Required Element	Large Project[a] (check selection)	If not applicable, describe why in the space below.
19	Protect Stormwater BMPs (continued)	☐ Flow can be directed away from the facility with temporary diversion swales or other approved protection. ☐ Do not construct infiltration BMPs until all contributing drainage areas are stabilized with appropriate erosion and sediment control BMPs and to the satisfaction of the engineer. ☐ Inspect and maintain erosion and sediment control practices on a regular basis. If deposition of sediment occurs in the infiltration area, remove material and scarify the surface to a minimum depth of 3 inches. ☐ Control erosion and avoid introducing sediment from surrounding land uses onto permeable pavements. Do not allow muddy construction equipment on the base material or pavement. Do not allow sediment-laden runoff onto permeable pavements or base materials. ☐ Permeable pavement clogged with sediments or no longer passing an initial infiltration test must be cleaned until infiltrating per design or replaced. Compaction Prevention: Soil compaction can lead to a reduction of infiltration rates and facility failure; accordingly, minimizing compaction of the base and sidewalls of the infiltration area is critical. ☐ Before the development site is graded, rope or fence the area of the infiltration BMP to restrict access and flag to prevent soil compaction by heavy equipment and foot traffic. ☐ Perform excavation with machinery operating adjacent to the infiltration BMP and do not allow heavy equipment with narrow tracks, narrow tires, or large lugged, high-pressure tires on the bottom of the infiltration BMP footprint. ☐ Protect established completed lawn and landscaped areas from compaction due to construction equipment. ☐ Do not excavate during wet or saturated conditions.	

[a] A large project is one with greater than or equal to 5,000 square feet of new plus replaced hard surface or greater than or equal to 10,000 square feet of land-disturbing activity.

[b] Recommended BMPs provide further guidance foaar minimizing potential stormwater pollution resulting from activities.

Construction Stormwater Pollution Prevention Plan Checklist

Project Number:
Review Date:
Onsite Inspection Review Date:
Construction SWPPP Reviewer:

VOLUME 3

PROJECT STORMWATER CONTROL

City of Seattle | Stormwater Manual

July 2026

City of Seattle

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CHAPTER 1 – Introduction

1.1. Purpose of this Volume

Volume 3 (*Project Stormwater Control*) of the City of Seattle Stormwater Manual presents approved methods, requirements, criteria, details, and general guidance for analysis and design of on-site stormwater management, flow control, and water quality treatment pursuant to the Seattle Municipal Code (SMC), Chapter 22.800 through 22.808, the Stormwater Code.

This volume describes and provides technical requirements for selecting, designing, constructing, and maintaining best management practices (BMPs) required by the Stormwater Code. These BMPs are designed to reduce the flow rates or volumes of stormwater runoff, reduce the level of pollutants contained in that runoff, and convey stormwater runoff. In accordance with provisions of the Stormwater Code, additional BMPs beyond those specified in this volume may be required.

1.2. How to Use this Volume

- *Chapter 1* (this chapter) outlines the purpose and content of this volume.
- *Chapter 2* describes the BMP categories.
- *Chapter 3* describes the steps required to select appropriate BMPs after the minimum requirements for on-site stormwater management, flow control, and/or water quality treatment have been determined using *Volume 1*.
- *Chapter 4* provides general design requirements for the following:
  - On-site List Approach, Pre-sized Approach, and Modeling Approach
  - Information pertinent to bypass and conveyance design
  - Presettling and pretreatment requirements
  - Infiltration BMP sizing requirements
- *Chapter 5* provides detailed descriptions and design criteria for BMPs outlined in *Chapter 2*.
- Several appendices also support the information contained in this volume. These appendices include:
  - *Appendix A* — Definitions
  - *Appendix C* — On-site List Infeasibility Criteria
  - *Appendix D* — Subsurface Investigation and Infiltration Testing for Infiltration BMPs
  - *Appendix E* — Additional BMP Design Requirements
  - *Appendix F* — Hydrologic Analysis and Design
  - *Appendix G* — Stormwater Control Operations and Maintenance Requirements
  - *Appendix H* — Financial Feasibility Documentation for Vegetated Roofs and Rainwater Harvesting
  - *Appendix I* — Landscape Management Plans and Integrated Pest Management Plans
  - *Appendix J* — Plant and Tree Lists for Stormwater BMPs

CHAPTER 2 – BMP Categories

2.1. Introduction

BMPs are designed to reduce the flow rates or volumes of stormwater runoff, reduce the level of pollutants contained in that runoff, and convey stormwater runoff. BMPs include structural stormwater facilities that provide long-term management of stormwater at developed sites. This volume covers four primary functional categories of stormwater BMPs:

- **On-site stormwater management** includes BMPs designed to reduce runoff volume and pollutants from development using infiltration, dispersion, and retention of stormwater runoff on site.
- **Flow control BMPs** typically detain, retain, or infiltrate stormwater runoff to control the flow rate, frequency, duration, and sometimes the volume of stormwater runoff leaving the site.
- **Water quality treatment BMPs** remove pollutants through one or more of the following processes: gravity settling of particulate pollutants, filtration, biological processes, and/or adsorption. Target pollutants include:
    - Sand, silt, and other suspended solids
    - Metals such as copper, lead, and zinc
    - Nutrients (e.g., nitrogen and phosphorus)
    - Certain bacteria and viruses
    - Organic contaminants such as petroleum hydrocarbons and pesticides

    Water quality treatment in this volume is divided into the following four categories based on the type of pollutant removal provided: basic treatment, metals treatment, oil treatment, or phosphorus treatment. Additional details on these treatment categories are provided in *Section 3.5*.
- **Conveyance BMPs** are designed to transport stormwater and can incorporate additional functions such as flow control or water quality treatment.

Note that some BMPs fall under more than one functional category. Determining which BMPs to use for a given application will depend on the applicable Stormwater Code requirements (refer to *Volume 1*), as well as site-specific factors such as available land surface and infiltration capacity of the soils. Distributed BMPs using infiltration, filtration, storage, evapotranspiration, or stormwater reuse are preferred when feasible. Additional requirements for conveyance are described in the Side Sewer Code (SMC, Chapter 21.16) and associated rules.

To help further differentiate among the many functions, applications, and design requirements presented in this volume, the following sections describe eight subcategories of BMPs. BMPs are placed in one of the following subcategories based on their primary function:

1. Soil amendment BMP
2. Tree planting and retention
3. Dispersion BMPs

4. Infiltration BMPs
5. Rainwater harvesting BMPs
6. Alternative surface BMPs
7. Detention BMPs
8. Non-infiltrating BMPs

Each section contains a chart identifying the functional categories to which the BMP can be applied (to meet a requirement) and a reference to the section within this volume containing additional information.

2.2. Soil Amendment

Site soils must meet the minimum quality and depth requirement at project completion (*Section 5.1*). Requirements may be achieved by either retaining and protecting undisturbed soil or restoring the soil (e.g., amending with compost) in disturbed areas.

2.3. Tree Planting and Retention

Tree planting and retention provides interception and evapotranspiration of stormwater.

BMP	On-site	Flow Control	Water Quality	Conveyance	Reference
Tree planting and retention	x[a]	x[a]			*Section 5.2*

[a] On-site Performance and Flow Control Standards may be partially achieved.

2.4. Dispersion BMPs

Dispersion is a simple method of stormwater management that uses surface grading to avoid concentrating flows or to disperse flows over vegetation.

The dispersion BMPs described in this volume include:

BMP	On-site	Flow Control	Water Quality	Conveyance	Reference
Full dispersion	x[a]	x[a]			*Section 5.3.2*
Splashblock downspout dispersion	x[a]	x[a]	x[b]		*Section 5.3.3*
Trench downspout dispersion	x[a]	x[a]	x[b]		*Section 5.3.4*
Sheet flow dispersion	x[a]	x[a]	x[b]		*Section 5.3.5*
Concentrated flow dispersion	x[a]	x[a]	x[b]		*Section 5.3.6*
Sidewalk/trail compost-amended strip	x[a]	x[a]			*Section 5.3.7*

[a] On-site Performance and Flow Control Standards may be partially or completely achieved depending upon underlying soil type.

[b] Meets Basic Treatment when additional design requirements for vegetated filter strips are met (refer to *Section 5.8.4*).

2.5. Infiltration BMPs

Infiltration BMPs are designed to facilitate infiltration of stormwater into the ground. Infiltration is feasible only where sufficiently porous soils are available and where other site constraints are not limiting (e.g., steep slopes, high groundwater), as detailed under *Section 3.2*.

The infiltration BMPs described in this volume include:

BMP	On-site	Flow Control	Water Quality	Conveyance	Reference
Infiltration trenches[a]	x	x	x[b, c]		*Section 5.4.2*
Drywells[a]	x	x			*Section 5.4.3*
Infiltrating bioretention	x[d]	x[d]	x[c]	x[e]	*Section 5.4.4*
Rain gardens	x[f]			x[e]	*Section 5.4.5*
Permeable pavement facilities	x	x	x[c, g]		*Section 5.4.6*
Perforated stub-out connections	x[f]				*Section 5.4.7*
Infiltration ponds	x[h]	x	x[b]		*Section 5.4.8*
Infiltration chambers/vaults	x[h]	x	x[b]		*Section 5.4.9*
Infiltrating soil cell bioretention	x[d]	x[d]	x[c]	x[e]	*Section 5.4.10*

[a] Only applicable where the site measured infiltration rate is at least 5 inches per hour. PGHS or PGPS may only be directed to infiltration trenches and drywells if the soil suitability criteria for the subgrade soils are met (*Section 4.5.2*).

[b] Soil suitability criteria for subgrade soils (refer to *Section 4.5.2*) and applicable drawdown requirements (*Section 4.5.1*) also apply.

[c] Refer to Phosphorus treatment train options for infiltration BMPs included in *Section 4.4.3.2*.

[d] For infiltrating bioretention with underdrain and infiltrating soil cell bioretention with underdrain, On-site Performance and Flow Control standards may be partially or fully achieved depending on ponding depth, degree of underdrain elevation, infiltration rate, contributing area, and use of orifice control.

[e] Infiltrating bioretention, infiltrating soil cell bioretention, and rain gardens may be connected in series, with the overflows of upstream cells directed to downstream cells to provide conveyance.

[f] Included in the On-site List but cannot be used to meet the On-site Performance Standard.

[g] Underlying soil must meet the treatment soil requirements outlined in *Section 4.5.2* or a water quality treatment course must be included per *Section 5.4.6.5*.

[h] Not included in the On-site List but can be used to meet the On-site Performance Standard.

2.6. Rainwater Harvesting BMPs

Rainwater harvesting BMPs capture and store rainwater for beneficial use. Roof runoff may be routed to cisterns for storage and non-potable uses such as irrigation, toilet flushing, mechanical equipment, and cold water supply to laundry with basic filtration. Additional filtration and disinfection are required for use of collected roof runoff for potable use. Using collected roof runoff for potable use is only allowed for residential projects. Design plans for use of harvested rainwater must be prepared per *Rainwater Harvesting and Connection to Plumbing Fixtures* (Public Health — Seattle & King County 2011).

The rainwater harvesting BMPs described in this volume include:

BMP	On-site	Flow Control	Water Quality	Conveyance	Reference
Rainwater harvesting[a]	x	x			*Section 5.5.1*
Residential cisterns	x				*Section 5.5.2*

[a] Rainwater harvesting is not approved for pollution-generating surfaces, so the water quality treatment standard is not applicable.

2.7. Alternative Surface BMPs

Alternative surface BMPs convert a conventional impervious surface to a surface that reduces the amount of stormwater runoff and also provides flow control.

The alternative surface BMPs described in this volume include:

BMP	On-site	Flow Control	Water Quality	Conveyance	Reference
Vegetated roof systems	x[a]	x[a]			*Section 5.6.1*
Permeable pavement surfaces[b]	x	x[c, d]	x[c, d, e]		*Section 5.6.2*

[a] On-site Performance and Flow Control Standard may be partially achieved.

[b] While similar to permeable pavement "facilities" (refer to *Section 2.5*), permeable pavement "surfaces" are designed to function as a permeable land surface and not intended to receive runoff from other surfaces. Therefore, they are not considered infiltration facilities and have less onerous siting and design requirements.

[c] Infiltration testing is required to meet flow control and water quality treatment standards (refer to *Appendix D*).

[d] Standard may be partially or completely achieved depending upon subgrade slope, infiltration rate of subgrade soil, and whether aggregate subbase is laid above or below surrounding grade.

[e] Underlying soil must meet the treatment soil requirements outlined in *Section 4.5.2* or a water quality treatment course must be included per *Section 5.4.6.5*.

2.8. Detention BMPs

Detention BMPs are designed to collect and temporarily store runoff and then release it over a period of time at a reduced rate. Detention BMPs have an outlet control structure designed to release flows at an attenuated rate to meet flow control standards. Detention BMPs can also be combined with non-infiltrating BMPs to provide water quality treatment as well as flow control benefits. For a summary of combined detention and wet pool BMPs refer to *Section 2.9*.

The detention BMPs described in this volume include:

BMP	On-site	Flow Control	Water Quality	Conveyance	Reference
Detention ponds	x[a]	x		x	*Section 5.7.1*
Detention pipes	x[a]	x[b]		x	*Section 5.7.2*
Detention vaults/ chambers	x[a]	x[b]		x	*Section 5.7.3*
Detention cisterns	x	x[b]		x	*Section 5.7.4*
Other detention options		x		x	*Section 5.7.5*

[a] Not included in the On-site List but can be used to partially achieve the On-site Performance Standard for smaller contributing areas.

[b] Standard may be partially or completely achieved depending on contributing area and minimum orifice size.

2.9. Non-infiltrating BMPs

Non-infiltrating BMPs are designed to remove pollutants contained in stormwater runoff. Some non-infiltrating BMPs may provide low levels of flow control as a secondary benefit or be combined with detention BMPs to meet flow control requirements.

Subcategories of non-infiltrating BMPs are presented below:

- **Non-infiltrating Bioretention** is similar to infiltrating bioretention (*Section 5.4.4*) except that facilities are designed with a low-permeability or impervious bottom and sidewalls preventing infiltration to underlying soil. Non-infiltrating bioretention can also be used without a liner if the existing site soil infiltration rate is less than required for an infiltrating BMP and certain criteria described in *Section 5.8.2* are met. After infiltrating through the bioretention soil, the water is discharged via an underdrain. Non-infiltrating bioretention provides the following functions:

BMP	On-site	Flow Control	Water Quality	Conveyance	Reference
Non-infiltrating Bioretention	x[a]	x[a]	x	x[b]	*Section 5.8.2*

[a] On-site Performance and Flow Control Standards may be partially or completely achieved depending upon ponding depth, contributing area, and use of orifice control.

[b] Non-infiltrating bioretention may be connected in series, with the overflows of upstream cells directed to downstream cells to provide conveyance.

- **Biofiltration Swales** use vegetation in conjunction with slow and shallow-depth flow for water quality treatment. Biofiltration swales may also result in some incidental infiltration to underlying soils. Biofiltration swales described in this volume include:

BMP	On-site	Flow Control	Water Quality[a]	Conveyance	Reference
Basic biofiltration swale			x	x	*Section 5.8.3*
Wet biofiltration swale			x	x	*Section 5.8.3*
Continuous inflow biofiltration swale			x	x	*Section 5.8.3*
Compost-amended biofiltration swale			x	x	*Section 5.8.3*

[a] Refer to *Section 3.5.2.2* for more information on Two-BMP Treatment Trains.

- **Filter Strips/Drains** are grassy slopes that receive unconcentrated runoff from adjacent hard surfaces such as a parking lots, driveways, or roadways. Filter strips are graded to maintain sheet flow over their entire width. Compost and other amendments can be incorporated into filter strip designs to provide metals treatment. Filter strip/drain BMPs described in this volume include:

BMP	On-site	Flow Control	Water Quality	Conveyance	Reference
Vegetated filter strips			x[a]	x	*Section 5.8.4*
Compost-amended vegetated filter strips (CAVFS)			x	x	*Section 5.8.4*
Media filter drains (MFD)			x	x	*Section 5.8.4*

[a] Refer to *Section 3.5.2.2* for more information on Two-BMP Treatment Trains.

- **Sand Filters** pass stormwater through a constructed sand bed. Sand filters can be sized as either basic or large BMPs to meet different water quality objectives. The sand filter BMPs described in this volume include:

BMP	On-site	Flow Control	Water Quality[a]	Conveyance	Reference
Basic and large sand filter basins			x		*Section 5.8.5*
Sand filter vaults			x		*Section 5.8.5*
Linear sand filters			x		*Section 5.8.5*

[a] Refer to *Section 3.5.2.2* for more information on Two-BMP Treatment Trains.

- **Wet Ponds** are constructed stormwater ponds that retain a permanent pool of water (i.e., a wet pool or dead storage) at least during the wet season. The wet pond BMPs described in this volume include:

BMP	On-site	Flow Control	Water Quality[a]	Conveyance	Reference
Wet ponds – basic and large			x	x	*Section 5.8.6*

[a] Refer to *Section 3.5.2.2* for more information on Two-BMP Treatment Trains.

- **Wet Vaults** are drainage facilities that contain permanent pools of water that are filled during the initial runoff from a storm event. They are similar to wet ponds, except the facility is constructed below grade in a concrete (or similar) vault. The wet vault BMPs described in this volume include:

BMP	On-site	Flow Control	Water Quality[a]	Conveyance	Reference
Wet vaults			x	x	*Section 5.8.7*

[a] Refer to *Section 3.5.2.2* for more information on Two-BMP Treatment Trains.

- **Stormwater Treatment Wetlands** are similar to wet ponds, except they also provide a shallow marsh area to allow the establishment of emergent wetland aquatic plants, which improves pollutant removal. In land development situations, wetlands are usually constructed for two main reasons: to replace or mitigate impacts when natural wetlands are filled or impacted by development (mitigation wetlands) or to treat stormwater runoff (stormwater treatment wetlands). Mitigation wetlands may not be used as stormwater treatment facilities because stormwater treatment functions are not compatible with normal wetland function. The stormwater treatment wetland BMPs described in this volume include:

BMP	On-site	Flow Control	Water Quality[a]	Conveyance	Reference
Stormwater treatment wetlands			x	x	*Section 5.8.8*

[a] Refer to *Section 3.5.2.2* for more information on Two-BMP Treatment Trains.

- **Combined Detention and Wet Pool BMPs** provide a combination of water quality treatment and flow control. If combined, the wet pool portion of the facility can often be incorporated below the detention facility to minimize further loss of development area. Combined detention and wet pool facilities described in this volume include:

BMP	On-site	Flow Control	Water Quality[a]	Conveyance	Reference
Combined detention and wet pond		x	x	x	*Section 5.8.9*
Combined detention and wet vault		x[b]	x	x	*Section 5.8.9*
Combined detention and stormwater wetland		x	x	x	*Section 5.8.9*

[a] Refer to *Section 3.5.2.2* for more information on Two-BMP Treatment Trains.

[b] Standard may be partially or completely achieved depending on contributing area and minimum orifice size.

- **Oil/Water Separators** remove floating and dispersed oil using gravity. Oil/water separators described in this volume include:

BMP	On-site	Flow Control	Water Quality	Conveyance	Reference
American Petroleum Institute (API baffle type) oil/water separator			x		*Section 5.8.10*
Coalescing plate (CP) oil/water separator			x		*Section 5.8.10*

- **Proprietary and Emerging Water Quality Treatment Technologies** consist of technologies that are monitored in the State of Washington through the Technology Assessment Protocol — Ecology (TAPE) process. Upon completion of a monitoring

program, the monitoring data is evaluated by Ecology and the technology may be approved for use for pretreatment, basic treatment, metals treatment, oil treatment, and/or phosphorus treatment. Refer to Ecology's website for a list of General Use Level Designations (GULD) approved stormwater technologies, including uses and limitations and technologies currently under review (https://ecology.wa.gov/Regulations-Permits/Guidance-technical-assistance/Stormwater-permittee-guidance-resources/Emerging-stormwater-treatment-technologies). Refer to *Section 3.5 BMP Selection for Water Quality Treatment* and *Section 5.8.11 Proprietary and Emerging Water Quality Treatment Technologies* for additional Seattle requirements for sizing proprietary technologies for annual maintenance.

- **Non-infiltrating Soil Cell Bioretention** is similar to infiltrating soil cell bioretention (*Section 5.4.10*) except that facilities are designed with a low-permeability or impervious bottom and sidewalls preventing infiltration to underlying soil. Non-infiltrating soil cell bioretention can also be used without a liner if existing site soil infiltration rate is less than required for an infiltrating BMP and certain criteria described in *Section 5.8.2* are met. After infiltrating through the bioretention soil, the water is discharged via an underdrain. Non-infiltrating soil cell bioretention provides the following functions:

BMP	On-site	Flow Control	Water Quality	Conveyance	Reference
Non-infiltrating Soil Cell Bioretention	x[a]	x[a]	x		*Section 5.8.12*

[a] On-site Performance and Flow Control Standards may be partially or completely achieved depending on ponding depth and contributing area.

CHAPTER 3 – BMP Selection and Sizing Approach

This chapter describes the steps for selecting appropriate stormwater BMPs and is organized into the following five sections:

- *Section 3.1* — Determine Dispersion Feasibility
- *Section 3.2* — Determine Infiltration Feasibility
- *Section 3.3* — BMP Selection for On-site Stormwater Management
- *Section 3.4* — BMP Selection for Flow Control
- *Section 3.5* — BMP Selection for Water Quality Treatment

Because dispersion and infiltration BMPs can serve multiple functions (on-site stormwater management, flow control, or water quality treatment), the process for evaluating feasibility for those types of BMPs is described first. Following the dispersion and infiltration feasibility determination are specific steps related to the minimum requirements (on-site stormwater management, flow control, and/or water quality treatment) that apply to a specific project. To determine which of these three minimum requirements apply to a project, refer to the 8-step approach in *Volume 1*, *Chapter 2*. Note that more than one, two, or all three of these minimum requirements may apply.

3.1. Determine Dispersion Feasibility

This section provides a two-step procedure for evaluating the feasibility of dispersion for a site (refer to *Section 2.4* for a list of dispersion BMPs).

Each of the following steps is outlined in more detail in the subsequent sections.

- *Step 1* — Evaluate horizontal setbacks and site constraints
- *Step 2* — Evaluate use of dispersion to meet minimum requirements

Step 1: Evaluate horizontal setbacks and site constraints

Assess the following to determine dispersion feasibility for the site:

Horizontal Setbacks

Horizontal setbacks vary depending on the type of dispersion BMP selected. Refer to the following sections for horizontal setback requirements:

- *Section 5.3.3* — Splashblock downspout dispersion
- *Section 5.3.4* — Trench downspout dispersion
- *Section 5.3.5* — Sheet flow dispersion
- *Section 5.3.6* — Concentrated flow dispersion
- *Section 5.3.7* — Sidewalk/trail compost-amended strip

Site Constraints

- Steep Slope or Landslide-prone Areas — the dispersion flow path is not typically permitted within landslide-prone areas or within a setback of 10 times the height of the steep slope to a maximum of 500 feet above a steep slope area. Dispersion within this area may be feasible provided a slope stability analysis is completed by a licensed geotechnical engineer or engineering geologist. The analysis must determine the effects that dispersion would have on the landslide-prone or steep slope area and adjacent properties.
- Septic Systems and Drain Fields — the dispersion flow path is not permitted within 30feet of proposed or existing septic system drainfield areas and reserve areas or within 10 feet of proposed or existing septic sewage tanks and distribution boxes.
- Contaminated Sites and Landfills — the dispersion flow path is not permitted within 100 feet of a contaminated site or landfill (active or closed).

Flow Path Requirements

Dispersion BMPs have minimum requirements for a vegetated flow path that can be difficult to achieve in an urban environment. Assess the following:

- Full dispersion — the flow path must be directed over a minimum of 100 feet of vegetation.
- Sheet flow dispersion — the flow path must be directed over a minimum of 10 feet of vegetation.

- Concentrated flow dispersion, trench downspout dispersion and splashblock downspout dispersion — the flow path must be directed over a minimum of 25 feet of vegetation.

Step 2: Evaluate use of dispersion to meet minimum requirements

If dispersion is considered feasible for the site, evaluate the feasibility of individual dispersion BMPs (*Section 5.3*) when selecting BMPs in *Section 3.3* — On-site Stormwater Management, *Section 3.4* (Flow Control), and *Section 3.5* (Water Quality Treatment).

3.2. Determine Infiltration Feasibility

This section provides step-by-step procedures for evaluating the feasibility of infiltration for a site and determining design infiltration rates for facility design. Refer to *Section 2.5* for a list of infiltration BMPs.

Each of the following steps is outlined in more detail in the subsequent sections.

- *Step 1* — Evaluate Infiltration Investigation Map
- *Step 2* — Evaluate horizontal setbacks and site constraints
- *Step 3* — Conduct subsurface investigation and evaluate vertical separation requirements
- *Step 4* — Conduct infiltration testing
- *Step 5* — Determine design infiltration rate
- *Step 6* — Conduct groundwater monitoring, receptor characterization, and mounding analysis, if applicable
- *Step 7* — Evaluate use of infiltration to meet minimum requirements

Step 1: Evaluate Infiltration Investigation Map

- Determine if Seattle has mapped the site as "infiltration investigation not required to meet the on-site stormwater management, flow control, or water quality treatment requirements." Based on some of the required setbacks and known infiltration restrictions, the City has mapped areas where infiltration is expected to be limited due to proximity to environmentally critical area (ECA), steep slopes, and known landfills (www.seattle.gov/sdci/codes/codes-we-enforce-(a-z)/stormwater-code).
- The map is advisory and does not include all site constraints. If the site is fully within an area that is mapped, further infiltration investigation to meet the on-site stormwater management, flow control, or water quality treatment requirements is not required. Select other non-infiltrating BMPs in *Section 3.3* (on-site stormwater management), *Section 3.4* (flow control), and *Section 3.5* (water quality treatment) to meet these requirements. If the site is partially within a mapped area or not at all within the mapped area, the following steps must be used to determine if infiltration is feasible on any portion of the site.

Step 2: Evaluate Horizontal Setbacks and Site Constraints

Evaluate the following criteria related to limitations, horizontal setbacks, and contaminated soil or groundwater. For any portion of the site that falls within an area that limits or restricts infiltration BMPs, further infiltration investigation to meet the on-site stormwater management, flow control, or water quality treatment requirements is not required. An infiltration feasibility flow chart is presented in Figure 3.1.

Assess the following to determine infiltration feasibility for the site:

Horizontal Setbacks

For infiltrating bioretention and rain gardens, horizontal setbacks are measured from the vertical extent of the cell or basin (e.g., top of the bioretention soil). For infiltration chambers/vaults, horizontal setbacks are measured from the outside bottom of the structure. For all other infiltration BMPs, horizontal setbacks are measured from edge of the aggregate.

Infiltration is not permitted in the following areas:

- Within 5 feet from property lines. As an exception, no setback is required from the property line abutting the public right-of-way.
- Within 10 feet of another infiltration facility.
- Within the following setbacks from on-site and off-site structures:
    - When runoff from less than 5,000 square feet of impervious surface area is infiltrated on the site, the infiltration BMP must not be within 5 feet from a building without a basement and/or 10 feet from a building with a basement.
    - When runoff from 5,000 square feet or more of impervious surface area is infiltrated on the site, a building must not intersect with a 1H:1V slope from the bottom edge of an infiltration BMP. The resulting setback must be no less than 5 feet from a building without a basement and/or 10 feet from a building with a basement. For setbacks from buildings or structures on adjacent lots, potential buildings or structures should be considered for future build-out conditions.

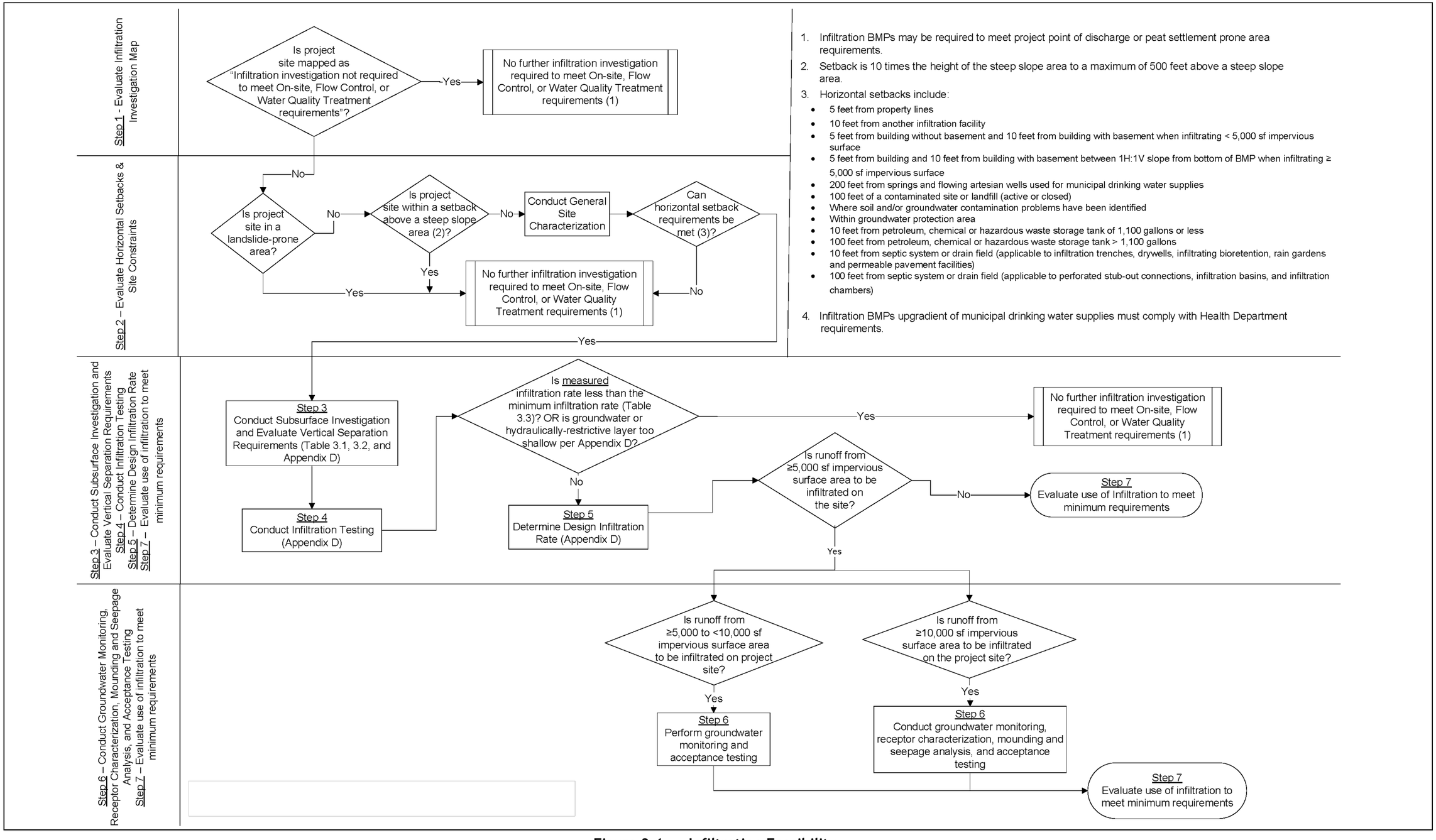
Note:

- If the development site is located within a peat settlement prone area, infiltration is required in order to achieve no net reduction in surface runoff volume that is infiltrated in the existing condition. Refer to SMC, Section 25.09.110.G. Guidance and sizing for infiltration facilities provided in SDCI Director's Rule 12-2008 — Infiltration Facilities in Peat Settlement-prone Areas.
- If development is located in an area with no off-site point of discharge (*Section 4.3.2*) infiltration may be feasible, but the drainage control plan must be prepared by a civil engineer.
- Deviations from these site constraints and setbacks must be approved by the Director and require a report stamped and signed by a licensed professional stating that the siting of an infiltration BMP within a setback will not cause an adverse impact to the public or the environment.

The thresholds above are based on impervious surface area rather than hard surface area to exclude permeable pavement surfaces (non-infiltrating BMPs) from the threshold.

Vertical Setbacks

Refer to Step 3 and Appendix D for vertical setbacks from groundwater and hydraulically restrictive layers.



1. Infiltration BMPs may be required to meet project point of discharge or peat settlement prone area requirements.
2. Setback is 10 times the height of the steep slope area to a maximum of 500 feet above a steep slope area.
3. Horizontal setbacks include:
   - 5 feet from property lines
   - 10 feet from another infiltration facility
   - 5 feet from building without basement and 10 feet from building with basement when infiltrating < 5,000 sf impervious surface
   - 5 feet from building and 10 feet from building with basement between 1H:1V slope from bottom of BMP when infiltrating ≥ 5,000 sf impervious surface
   - 200 feet from springs and flowing artesian wells used for municipal drinking water supplies
   - 100 feet of a contaminated site or landfill (active or closed)
   - Where soil and/or groundwater contamination problems have been identified
   - Within groundwater protection area
   - 10 feet from petroleum, chemical or hazardous waste storage tank of 1,100 gallons or less
   - 100 feet from petroleum, chemical or hazardous waste storage tank > 1,100 gallons
   - 10 feet from septic system or drain field (applicable to infiltration trenches, drywells, infiltrating bioretention, rain gardens and permeable pavement facilities)
   - 100 feet from septic system or drain field (applicable to perforated stub-out connections, infiltration basins, and infiltration chambers)
4. Infiltration BMPs upgradient of municipal drinking water supplies must comply with Health Department requirements.

Figure 3.1. Infiltration Feasibility.

Site Constraints

- Steep Slope or Landslide-prone Areas — infiltration is limited within landslide-prone areas or within a setback of 10 times the height of the steep slope to a maximum of 500 feet above a steep slope area (as defined by the regulations for ECAs [SMC, Section 25.09.030]). Infiltration within this area may be feasible provided a slope stability analysis is completed by a licensed geotechnical engineer or engineering geologist. The analysis must determine the effects that infiltration would have on the landslide-prone or steep slope area and adjacent properties.
- Septic Systems and Drain Fields — Within30 feet of proposed or existing septic system drain fields and reserve areas or within 10 feet of proposed or existing septic sewage tanks and distribution boxes (applicable to infiltration trenches, drywells, infiltrating bioretention, rain gardens, and permeable pavement facilities). Other infiltration BMPs (perforated stub-out connections, infiltration ponds, and infiltration chambers/vaults) are not permitted within 100 feet of proposed or existing septic systems or drain fields.
- Drinking Water Supply Wells or Springs — Within 100 feet of drinking water supply wells or springs used for drinking water.
- Groundwater Protection Area — Within a groundwater protection area unless approved by the King County Department of Health and the Director. If approved, water quality treatment per *Section 4.5.2.2* (*Imported Soil Requirements for Bioretention Systems*) may be required.
- Contaminated Sites and Landfills:
    - Within 100 feet of a contaminated site or landfill (active or closed). For projects where runoff from 5,000 square feet or more of impervious surface area will be infiltrated on the site, infiltration within 500 feet up-gradient or 100 feet down-gradient of a contaminated site or landfill (active or closed) requires analysis and approval by a licensed hydrogeologist.
    - Where soil and/or groundwater contamination problems have been identified, including, but not limited to, the following:
        - EPA Superfund Program National Priorities List and Map (https://www.epa.gov/superfund/search-superfund-sites-where-you-live)
        - EPA mapping tool that plots the locations of Superfund and Resource Conservation and Recovery Act (RCRA) regulated sites (www.epa.gov/cleanups/cleanups-my-community)
        - Ecology-regulated contaminated sites (https://ecology.wa.gov/Regulations-Permits/Guidance-technical-assistance/Site-Register-lists-and-data)
        - Ecology Toxics Cleanup Program website (https://ecology.wa.gov/Spills-Cleanup/Contamination-cleanup/Cleanup-sites/Toxic-cleanup-sites)
- Petroleum, Chemical, or Liquid Hazardous Waste Storage Tanks:
    - Within 10 feet of an underground or above ground storage tank or connecting underground pipes when the capacity of the tank and pipe system is 1,100 gallons or less.

- Within 100 feet of an underground or above ground storage tank or connecting underground pipes when the capacity of the tank and pipe system is greater than 1,100 gallons.

Step 3: Conduct Subsurface Investigation and Evaluate Vertical Separation Requirements

Note that the applicant may choose to perform Step 3 and Step 4 in either order (i.e., Step 4 — Conduct Infiltration Testing can be done before Step 3 — Conduct Subsurface Investigation and Evaluate Vertical Separation Requirements).

Subsurface Investigations

Subsurface investigations are required to identify subsurface and groundwater conditions that may affect performance of the infiltration facility. Investigations must be performed at the location of the proposed facility or as close as possible, but no more than 50 feet away. The number and type of subsurface investigations required are provided in Table 3.1 and Table 3.2. Seasonal timing for infiltration testing and groundwater monitoring requirements for infiltration facilities can impact project schedules. Subsurface investigations are preferred to be scheduled during the wet season, between November and March. Larger projects may want to consult with a licensed professional early in project development. Seasonal timing, depth of subsurface investigations, and investigation procedures are provided in *Appendix D*.

This manual includes four types of subsurface investigations:

- Simple subsurface investigation
- Standard subsurface investigation
- Comprehensive subsurface investigation
- Deep infiltration subsurface investigation

Subsurface investigation is required for the entire site or portion(s) of the site that have not been excluded based on information reviewed in Steps 1 and 2.

The type of subsurface investigation required for a project is provided in Table 3.1 and Table 3.2 and varies by the impervious surface area infiltrated on site. Subsurface investigation procedures are provided in *Appendix D*. The minimum required vertical separation from groundwater and hydraulically restrictive layers is provided in the tables in Appendix D, Section D-2, and varies depending on the type of subsurface investigation required, the time of year the investigation is done, and the type of infiltration facility that is used.

Projects must document the results of the required subsurface investigation and evaluation of vertical separation requirements. The information to be contained in this report is provided in *Appendix D*. If the infiltration testing report is required to be prepared by a licensed professional, then the subsurface investigation must also be prepared by a licensed professional.

Table 3.2 provides information for deep infiltration BMPs. Deep infiltration BMPs are typically used to direct stormwater past surface soil layers that have lower infiltration rates and into well-draining soil. The depth of the soil layers with lower infiltration rates can vary significantly, so the technique required to reach the well-draining soils will also vary.

Table 3.1. Minimum Investigation and Testing Requirements for Shallow Infiltration BMPs.

Impervious Area Infiltrated on the Site[a,h] excluding PPS[j]	Step 3– Subsurface Investigation: Minimum Number	Step 3– Subsurface Investigation: Type	Step 4– Infiltration Testing: Minimum Number	Step 4– Infiltration Testing: Type	Step 6– Groundwater Monitoring: Minimum Number of Wells	Step 6– Groundwater Monitoring: Duration and Frequency	Step 6– Characteriza-tion of Infiltration Receptor	Step 6– Groundwater Mounding and Seepage Analysis	Step 6– Acceptance Testing
<2,000 ft^2	1 per facility AND at least 1 per 150 linear feet of a facility[c,d]	Simple subsurface investigation	1 per facility AND at least 1 per 150 linear feet of a facility[c,d]	Simple Infiltration Test[i]	0	NA	No	No	No
≥2,000 to <5,000 ft^2	1 per facility AND at least 1 per 150 linear feet of a facility[c,d]	Standard subsurface investigation	1 per facility AND at least 1 per 150 linear feet of a facility[c,d]	Simple Infiltration Test[i] or Small PIT; if ≥2,000 ft^2 of the site infiltration will occur within a single facility,[e] the Small PIT[f] method is required	0	NA	No	No	No
≥5,000 to <10,000 ft^2	1 per facility AND at least 1 per 150 linear feet of a facility[c,d]	Comprehensive subsurface investigation[h]	1 per facility AND at least 1 per 150 linear feet of a facility[c,d]	Small PIT[f]	1	Monthly for at least 1 wet season[b]; monthly for at least 1 year if within 200 feet of a designated receiving water[b]	No	No	Yes
≥10,000 ft^2 to <1 acre	1 per facility AND at least 1 per 150 linear feet of a facility[c,d]	Comprehensive subsurface investigation[h]	1 per facility AND at least 1 per 150 linear feet of a facility[c,d]	Small PIT[f]	3	Monthly for at least 1 year[b]	Yes, for infiltration ponds	Yes[g]	Yes

Table 3.1 (continued). Minimum Investigation and Testing Requirements for Shallow Infiltration BMPs.

Impervious Area Infiltrated on the Site[a,h] excluding PPS[j]	Step 3– Subsurface Investigation: Minimum Number	Step 3– Subsurface Investigation: Type	Step 4– Infiltration Testing: Minimum Number	Step 4– Infiltration Testing: Type	Step 6– Groundwater Monitoring: Minimum Number of Wells	Step 6– Groundwater Monitoring: Duration and Frequency	Step 6– Characterization of Infiltration Receptor	Step 6– Groundwater Mounding and Seepage Analysis	Step 6– Acceptance Testing
≥1 acre	1 per facility AND at least 1 per 150 linear feet of a facility[c,d]	Comprehensive subsurface investigation[h]	1 per facility AND at least 1 per 150 linear feet of a facility[c,d]	Large PIT[f,k]	3	Monthly for at least 1 year[b]	Yes, for infiltration ponds	Yes[g]	Yes

Note: Deviations from the minimum requirements in this table, when recommended and documented by the licensed professional, may be approved by the Director. If the licensed professional determines continuity of subsurface materials based on site investigations or if acceptance testing will be done during construction then fewer tests may be approved. Designer must be prepared to make allowances to the design during construction if site conditions differ from those assumed for the design or if the acceptance test during construction determines the infiltration rate is lower than assumed for the design.

[a] Site is defined for Parcel projects as the project area; for Trail, Sidewalk, or Roadway projects, it is defined by one intersection to the other and blocks may vary in length.

[b] If the project site is within 200 feet of tidal waters, groundwater data capturing low/high tide fluctuation for one calendar year must be collected to determine if groundwater at the project is influenced by tidal fluctuations. Groundwater monitoring is not required if available groundwater elevation data within 50 feet of the proposed facility shows the highest measured groundwater level to be at least 10 feet below the bottom of the proposed infiltration facility or if the initial groundwater measurement is more than 15 feet below the bottom of the proposed infiltration facility.

[c] For bioretention or rain gardens, a facility refers to either a single cell, or a series of cells connected in series, with the overflows of upstream cells directed to downstream cells to provide additional flow control and/or treatment and conveyance.

[d] Preferably, the investigation is conducted at the location of the proposed infiltration facility, but it must be within 50 feet of the facility location.

[e] A single facility is defined as a facility that has at least a 10-foot separation distance from another infiltration facility, measured from the closest vertical extent of maximum ponding before overflow, or for bioretention and rain gardens, the maximum vertical extent of the top of the bioretention soil or compost amended soil.

[f] The investigation and infiltration testing report must be prepared by a licensed professional.

[g] Groundwater mounding and seepage analysis is required where the depth to the seasonal high groundwater elevation or hydraulically restrictive material is less than 15 feet below the bottom of the proposed infiltration facility.

[h] For projects with infiltration facilities within 500 feet up-gradient or 100 feet down-gradient of a contaminated site or landfill (active or closed), analysis and approval by a licensed hydrogeologist is required if runoff from 5,000 square feet or more of impervious surface area will be infiltrated on the site.

[i] The Simple Infiltration Test is not allowed for projects with no off-site point of discharge (*Section 4.3.2*). These projects must use a Small PIT.

[j] Permeable pavement surfaces (PPS) are not included in the impervious area total.

[k] A small scale PIT may be substituted if the site has a high infiltration rate (>4 in/hr), making a large-scale PIT difficult, and the site geotechnical investigations suggest uniform subsurface characteristics.

Table 3.2. Minimum Investigation and Testing Requirements for Deep Infiltration BMPs.

Impervious Area Infiltrated on the Sitea, excluding PPS[e]	Step 3– Subsurface Investigations: Minimum Number and Location	Step 3– Subsurface Investigations: Type	Step 4– Infiltration Tests: Minimum Number and Location	Step 4– Infiltration Tests: Type	Step 6– Groundwater Monitoring: Minimum Number of Wells	Step 6– Groundwater Monitoring: Duration and Frequency	Step 6– Characteriza-tion of Infiltration Receptor	Step 6– Groundwater Mounding and Seepage Analysis	Step 6– Acceptance Testing
<10,000 ft^2	One at every deep infiltration location	Deep infiltration subsurface investigation[d]	One at every deep infiltration location	Deep Infiltration Test	3	Monthly for at least 1 wet season; monthly for at least 1 year if within 200 feet of a designated receiving water[b]	No	No	Yes
≥10,000 ft^2	One at every deep infiltration location	Deep infiltration subsurface investigation[d]	One at every deep infiltration location	Deep Infiltration Test	3	Monthly for at least 1 year[b]	Yes	Yes[c]	Yes

Note: Deviations from the minimum requirements in this table, when recommended and documented by the licensed professional, may be approved by the Director. If the licensed professional determines continuity of subsurface materials based on site investigations or if acceptance testing will be done during construction, then fewer tests may be approved. Designer must be prepared to make allowances to the design during construction if site conditions differ from those assumed for the design or if the acceptance test during construction determines that the infiltration rate is lower than assumed for the design.

[a] Site is defined for Residential and Parcel projects as the project area; for Trail, Sidewalk, or Roadway projects, it is defined by one intersection to the other and blocks may vary in length.

[b] If the project site is within 200 feet of tidal waters, groundwater data capturing low/high tide fluctuation for one calendar year must be collected to determine if groundwater at the project is influenced by tidal fluctuations. Groundwater monitoring is not required if available groundwater elevation data within 50 feet of the proposed facility shows the highest measured groundwater level to be at least 10 feet below the bottom of the proposed facility.

[c] Groundwater mounding and seepage analysis is required where the depth to the seasonal high groundwater elevation or hydraulically restrictive material is less than 15 feet below the bottom of the proposed infiltration facility.

[d] For projects where runoff from 5,000 square feet or more of impervious surface area will be infiltrated on the site, infiltration within 500 feet up-gradient or 100 feet down-gradient of a contaminated site or landfill (active or closed) requires analysis and approval by a licensed hydrogeologist.

[e] Permeable pavement surfaces (PPS) are not included in the impervious area total.

Vertical Separation Requirements

Vertical separation requirements must be evaluated when performing a subsurface investigation. Infiltration BMPs require a minimum vertical separation from the lowest elevation of the facility to the underlying groundwater table or hydraulically restrictive material (*Appendix D*, *Section D-2.2.4*). The vertical separation requirements for shallow infiltration BMPs depend on the type of subsurface investigation required and the seasonal timing of the geotechnical exploration conducted to evaluate clearances.

Step 4: Conduct Infiltration Testing

This manual includes four methods of field infiltration testing to determine the measured infiltration rate:

- Simple Test (Small-scale infiltration test)
- Small Pilot Infiltration Test (PIT)
- Large PIT
- Deep Infiltration Test

The type of infiltration test required for a project is provided in Table 3.1 and Table 3.2 and varies by the impervious surface area routed to infiltration BMPs on a site. Infiltration testing procedures are provided in *Appendix D*. The Small PIT, Large PIT, and Deep Infiltration Test reports must be prepared by a licensed professional.

The minimum allowed infiltration rates are provided in Table 3.3.

Table 3.3. Minimum Measured Infiltration Rates.

Infiltration BMP	Minimum Measured Infiltration Rate for On-site List Approach [e] (in/hr)	Minimum Allowed Measured Infiltration Rate for Meeting Flow Control, Water Quality Treatment, and On-site Performance Standards [e] (in/hr)
Infiltration Trenches	2 [c]	2 [c]
Drywells	5 [d]	5 [d]
Infiltrating Bioretention without underdrain	0.6	0.6
Infiltrating Bioretention with underdrain	0.3	No minimum
Rain Gardens	0.3	Not applicable (only for On-site List Approach)
Permeable Pavement Facility	0.3	0.3
Permeable Pavement Surface	0.3 [a]	0.3[b]
Sidewalk/Trail Compost-amended Strip	0.3 [a]	No minimum
Perforated Stub-out Connections	0.3	Not applicable (only for On-site List Approach)
Infiltration Ponds	Not applicable	0.6
Infiltration Chambers/Vaults	Not applicable	0.6

Table 3.3 (continued). Minimum Measured Infiltration Rates.

Infiltration BMP	Minimum Measured Infiltration Rate for On-site List Approach [e] (in/hr)	Minimum Allowed Measured Infiltration Rate for Meeting Flow Control, Water Quality Treatment, and On-site Performance Standards [e] (in/hr)
Infiltrating Soil Cell Bioretention without underdrain	0.6	0.6
Infiltrating Soil Cell Bioretention with underdrain	0.3	No minimum

[a] Infiltration testing not required, only necessary to prove infeasibility. As an option, this BMP may be used for the OSM List Approach if measured infiltration rate is less than 0.3 in/hr, but it is not required.

[b] No minimum infiltration rate if the BMP is modeled using an approved continuous runoff model and the minimum 48-hr drawdown time is demonstrated. If using pre-sized factors, the minimum infiltration rate indicated in this table must be met.

[c] Minimum infiltration rates based on Ecology requirements for T5.10A Infiltration Trenches in Volume V of the SWMMWW (trench length as a function of soil type). Soil types were converted to initial infiltration rates based on Ecology's Table 3.7 – Recommended Infiltration Rates based on USDA Soil Textural Classification from Ecology's 2005 SWMMWW Volume III.

[d] Minimum infiltration rates based on Ecology requirements for T5.10A Drywells in Volume V of the SWMMWW (drywell aggregate volume as a function of soil type). Soil types were converted to initial infiltration rates based on Ecology's Table 3.7 – Recommended Infiltration Rates based on USDA Soil Textural Classification from Ecology's 2005 SWMMWW Volume III.

[e] The minimum infiltration rates in this table are not applicable to small projects determined by the Director to have no accessible off-site point of discharge per Section 4.3.2. However, in order to use the pre-sized drywell tables in Appendix E, Section E-10, the minimum measured infiltration rate is 0.25 in/hr.

Step 5: Determine Design Infiltration Rate

- The measured infiltration rate determined in Step 4 must be reduced using correction factors to account for site variability and number of tests conducted, uncertainty of the test method, and potential for long-term clogging due to siltation and bio-buildup. The corrected infiltration rate is considered the long-term or design infiltration rate and is used for all BMP sizing calculations. Correction factors and methodology is provided in *Appendix D, Section D-4.*

Step 6: Conduct Groundwater Monitoring, Receptor Characterization, Mounding and Seepage Analysis, and Acceptance Testing (as applicable)

Groundwater Monitoring

Groundwater monitoring is required when runoff from more than 5,000 square feet of impervious surface area is infiltrated on the site (refer to Table 3.1). If the results of this groundwater monitoring indicate that adverse conditions could occur, as determined by a licensed professional, the infiltration facility must not be built. Groundwater elevation data must be used to evaluate the bottom of the facility against the vertical separation requirements in *Appendix D, Section D-2.2.4* to determine infiltration feasibility.

Characterization of the Infiltration Receptor

For projects proposing an infiltration pond or deep infiltration BMPs to infiltrate runoff from more than 10,000 square feet of impervious surface area, the infiltration receptor (unsaturated and saturated soil receiving the stormwater) must be characterized (refer to Table 3.1 and *Appendix D*). If the results of this characterization indicate that adverse

conditions could occur, as determined by a licensed professional, the infiltration facility must not be built. Refer to *Appendix D, Section D-6.*

Groundwater Mounding and Seepage Analysis

A mounding analysis will be required for projects that will be infiltrating 10,000 square feet or more of impervious surface area on the site and where the depth to the seasonal high groundwater elevation or hydraulically restrictive material is less than 15 feet below the bottom of the proposed BMP. If the results of the mounding analysis indicate that adverse conditions could occur, as determined by a licensed professional, the infiltration facility must not be built. Refer to *Appendix D, Section D-7.*

Acceptance Testing

Thresholds for acceptance testing are summarized in Table 3.1 and Table 3.2. Acceptance testing requirements are provided in *Appendix D, Section D-8.* In general, acceptance testing will be performed for infiltration BMPs receiving runoff from greater than 5,000 square feet of impervious surface area; however, acceptance testing may also be required for infiltration BMPs receiving runoff from a smaller contributing area. As an exception, all permeable pavement facilities and surfaces are required to perform acceptance testing per *Section 5.4.6.5.*

At a minimum, the acceptance testing must demonstrate that the infiltration facility performs at the design infiltration rate.

Acceptance testing of deep infiltration BMPs must consist of the infiltration testing procedures for deep infiltration wells described in *Appendix D, Section D-4.*

Step 7: Evaluate Use of Infiltration to Meet Minimum Requirements

- If infiltration is considered feasible, evaluate the feasibility of infiltration BMPs when selecting BMPs in *Section 3.3* (on-site stormwater management), *Section 3.4* (flow control), and *Section 3.5* (water quality treatment).

3.3. BMP Selection for On-site Stormwater Management

If the on-site stormwater management requirement is triggered, it can be met by using the On-site List Approach or the On-site Performance Standard. The procedures for selecting BMPs under these options are provided in the following sections. Selection of BMPs must build upon site assessment and planning information described in *Volume 1*, *Section 2.4* and *Volume 3*, *Sections 3.1 and 3.2*. Flow control and water quality treatment requirements may also apply (refer to *Sections 3.4 and 3.5*).

3.3.1. On-site List Approach

If the on-site stormwater management requirement is triggered (per *Volume 1*, *Chapter 4*) and the On-site List Approach is selected as the method for compliance, follow the steps presented below to select the appropriate BMP(s) for a given project. The City has also prepared a spreadsheet tool (On-site Stormwater Management — List Approach Calculator) to help users document and implement the On-site List Approach. Refer to SDCI's Stormwater Code web page to download the latest version of the spreadsheet tool: www.seattle.gov/sdci/codes/codes-we-enforce-(a-z)/stormwater-code.

Step 1: Determine if Dispersion and Infiltration are Feasible

Refer to *Section 3.1* and *Section 3.2*.

Step 2: Calculate Areas by Surface Type

For each project type, divide the project area into hard surface areas with distinct drainage pathways (e.g., downspouts, collection points, and grading toward leaving a project site) and conduct a BMP evaluation for each surface sub-area.

Step 3: Refer to Applicable On-site List(s)

Identify the On-site List(s) in SMC, Section 22.805.070 or *Volume 1*, *Section 5.2* for the project type(s) that apply to the project. The On-site Lists provide On-site BMPs prioritized by category, with Category 1 comprising the first priority BMPs.

Step 4: Evaluate BMPs by Category

For each hard surface area type (i.e., roof or non-roof [ground-related surface]), evaluate the On-site BMP(s) as described in Steps 5 through 7 below. Evaluate the feasibility of all On-site BMPs in the first category before moving on to the next category. Note that the On-site List Approach assumes each hard surface area may be evaluated separately. Proposals to use BMPs in series (i.e., multiple bioretention cells) may require modeling using the On-site Performance Standard. Refer to the *General Design Requirements* in *Chapter 4* for additional requirements that may affect the design and placement of BMPs on the site.

Step 5: Evaluate Feasibility of Category 1 BMPs

Determine feasibility of the BMP(s) in Category 1. The BMP is considered infeasible if one of the following applies:

- The BMP is considered infeasible per the "Infeasibility Criteria" provided for the BMP in *Appendix C*, which includes applicable Design Criteria and Site Considerations provided for the BMP in *Chapter 5*.
- Competing needs (e.g., historic preservation laws, health and safety standards) as provided in SMC, Section 22.805.070 conflict with the BMP.
- The BMP size as detailed in the sizing for the On-site List Approach in *Chapter 5* cannot be met.

Note: Some BMPs that are not sized can meet the requirements for a sub-area. Refer to *Credit for On-site List Approach* in *Chapter 5*.

Step 6: Select Category 1 BMP(s)

If any of the Category 1 BMPs are feasible for a surface (or surface sub-area), then a Category 1 BMP must be used to manage runoff for a given hard surface area (or surface sub-area). Any of the feasible BMPs within the category can be used. Size the BMPs for the contributing area per the On-site List Approach sizing requirements in *Chapter 5*.

Step 7: Document Infeasibility of Category 1 BMPs (if applicable)

If all the Category 1 BMPs are deemed infeasible, infeasibility must be documented. The applicant must provide a completed On-site List Requirement Infeasibility Criteria Checklist (refer to the tables provided in *Appendix C*) or a narrative description and rationale with substantial evidence sufficient to explain and justify the applicant's conclusion that the On-site BMPs are infeasible.

If there are remaining unmanaged hard surfaces, proceed to Step 8. If all hard surfaces are managed, the BMP selection process for the On-site List Approach is complete.

Step 8: Evaluate/Select Category 2 BMPs

If there are remaining unmanaged hard surfaces, evaluate the On-site BMPs in Category 2 using the same approach described in Steps 5 through 7.

If all hard surfaces are managed, the BMP selection process for the On-site List Approach is complete.

Step 9: Evaluate/Select Category 3 BMPs

If there are remaining unmanaged hard surfaces, evaluate the On-site BMPs in Category 3 using the same approach described in Steps 5 through 7.

If all hard surfaces are managed, the BMP selection process for the On-site List Approach is complete.

Step 10: Evaluate/Select Category 4 BMPs (Residential and Parcel-based projects only)

If there are remaining unmanaged hard surfaces, evaluate the On-site BMPs in Category 4 using the same approach described in Steps 5 through 7.

If all hard surfaces are managed, the BMP selection process for the On-site List Approach is complete.

Step 11: Evaluate/Select Category 5 BMPs (Residential and Parcel-based projects only)

If there are remaining unmanaged hard surfaces, evaluate the On-site BMPs in Category 5 using the same approach described in Steps 5 through 7.

If all hard surfaces are managed, the BMP selection process for the On-site List Approach is complete. If none of the BMPs in the appropriate categories on the On-site List are feasible, then no further evaluation is required for that surface and the BMP selection process for the On-site List Approach is considered complete (refer to SMC, Section 22.805.070).

3.3.2. On-site Performance Standard

If the on-site stormwater management requirement is triggered and the On-site Performance Standard is selected as the method for compliance, follow the steps presented below to select the appropriate BMP(s) for a given project.

Step 1: Determine if Dispersion and Infiltration are Feasible

Refer to *Section 3.1* and *Section 3.2*.

Step 2: Select BMP(s)

Select a BMP, or multiple BMPs, to meet the On-site Performance Standard. Refer to the *General Design Requirements* in *Chapter 4* for additional requirements that may affect the design and placement of BMPs on the site. Refer to *Chapter 5* of this volume for BMP applicability, site suitability, and design criteria. Note that in order to meet the On-site Performance Standard, the selected BMP(s) will most likely need to include infiltration.

Step 3: Use Modeling Approach for BMP design

The Modeling Approach for each BMP design must be applied. Refer to *Section 4.1.3* and *Appendix F, Section F-4* for detailed information on modeling requirements/guidelines.

3.4. BMP Selection for Flow Control

If the flow control minimum requirement is triggered, follow the steps presented below to select the appropriate flow control BMPs for a given project. All projects must use On-site BMPs (refer to *Volume 1, Section 5.2.2*) or other infiltration BMPs (refer to *Volume 3, Section 5.4*) to the maximum extent feasible to meet Flow Control Minimum Requirements per SMC 22.805.080.B. In addition, On-site Stormwater Management and Water Quality Treatment Requirements may apply (refer to *Sections 3.3* and *3.5*). The City has also prepared a spreadsheet tool (Pre-sized Flow Control Calculator) to help users document and implement the flow control BMP selection process for small sites (<10,000 square feet of new and replaced hard surface area). Refer to SDCI's Stormwater Code web page to download the latest version of the spreadsheet tool: www.seattle.gov/sdci/codes/codes-we-enforce-(a-z)/stormwater-code.

Step 1: Determine if Dispersion and Infiltration are Feasible

Refer to *Section 3.1* and *Section 3.2*.

Step 2: Determine if Water Quality Treatment requirements also apply

If the minimum requirements for water quality treatment also apply to a project, look for opportunities to use flow control BMPs that can also meet water quality treatment requirements (refer to *Chapter 2* and *Chapter 5* in this volume).

Step 3: Select Flow Control BMP(s)

Select a flow control BMP, or multiple BMPs (*refer to Chapter 2*). First evaluate the On-site BMPs from the On-site Lists in Volume 1, Section 5.2.2 and other infiltration BMPs per Section 5.4 before selecting traditional flow control BMPs. Note: In some cases, projects may manage a smaller portion of the project's new and replaced hard surface area to meet flow control requirements if only On-site BMPs are used to the maximum extent feasible. Refer to Volume 1, Section 5.3.

Refer to the *General Design Requirements* in *Chapter 4* for additional requirements that may affect the design and placement of BMPs on the site. Refer to *Chapter 5* of this volume for applicability, site suitability, and design criteria. Select flow control BMPs that best integrate with on-site stormwater management to the maximum extent feasible.

Step 4: Use Pre-sized or Modeling Approach for BMP Design

For projects with 10,000 square feet or more of new and replaced hard surface area, use the Modeling Approach for BMP design (Step 4b). For sites with less than 10,000 square feet of new and replaced hard surface area, either the Pre-sized Approach or Modeling Approach for BMP design may be used (Steps 4a or 4b).

Step 4a: Use Pre-sized Approach for BMP design

Apply the Pre-sized Approach for BMP design (refer to *Section 4.1.2*). The designer may also choose to use the Modeling Approach (refer to Step 4b).

Step 4b: Use Modeling Approach for BMP design

Apply the Modeling Approach for BMP design. Refer to *Section 4.1.3* and *Appendix F* for modeling guidelines.

Table 3.4 summarizes flow control BMPs that can be used to meet Pre-developed Forested, Pre-developed Pasture, and/or Peak Control Standards. Refer to each BMP section in *Chapter 5* for more specific information on modeling to meet flow control standards.

Table 3.4. Flow Control BMPs and Applicable Standards.

Flow Control BMP	Applicable Flow Control Standards– Forested	Applicable Flow Control Standards– Pasture	Applicable Flow Control Standards– Peak	Section Reference
Tree Planting and Retention	A	A	A	*Section 5.2*
Full Dispersion	B	B	x	*Section 5.3.2*
Splashblock Downspout Dispersion	B	B	x	*Section 5.3.3*
Trench Downspout Dispersion	B	B	B	*Section 5.3.4*
Sheet Flow Dispersion	B	B	B	*Section 5.3.5*
Concentrated Flow Dispersion	B	B	B	*Section 5.3.6*
Infiltration Trenches	B	B	B	*Section 5.4.2*
Drywells	B	B	B	*Section 5.4.3*
Infiltrating Bioretention without underdrain	x	x	x	*Section 5.4.4*
Infiltrating Bioretention with underdrain	C	C	C	*Section 5.4.4*
Permeable Pavement Facilities	x	x	x	*Section 5.4.6*
Infiltration Ponds	x	x	x	*Section 5.4.8*
Infiltration Chambers/Vaults	x	x	x	*Section 5.4.9*
Infiltrating Soil Cell Bioretention without underdrain	x	x	x	*Section 5.4.10*
Infiltrating Soil Cell Bioretention with underdrain	C	C	C	*Section 5.4.10*
Rainwater Harvesting	x	x	x	*Section 5.5.1*
Vegetated Roof Systems	A	A	A	*Section 5.6.1*
Permeable Pavement Surfaces	D	D	D	*Section 5.6.2*
Detention Ponds	x	x	x	*Section 5.7.1*
Detention Pipes	E	E	E	*Section 5.7.2*
Detention Vaults/Chambers	E	E	E	*Section 5.7.3*
Detention Cisterns	E	E	x	*Section 5.7.4*
Non-infiltrating Bioretention	C	C	C	*Section 5.8.2*
Combined Detention and Wet Pond	x	x	x	*Section 5.8.9*
Combined Detention and Wet Vault	E	E	E	*Section 5.8.9*
Combined Detention and Stormwater Wetland	x	x	x	*Section 5.8.9*
Non-infiltrating Soil Cell Bioretention	C	C	C	*Section 5.8.12*

x – Standard achieved.

A – Standard may be partially achieved.

B – Standard may be partially or completely achieved depending on underlying soil type.

C – Standard may be partially or completely achieved depending on ponding depth, degree of underdrain elevation (if applicable), infiltration rate (if applicable), contributing area, and use of orifice control.

D – Standard may be partially or completely achieved depending on subgrade slope, infiltration rate of subgrade soil, and whether aggregate subbase is laid above or below surrounding grade.

E – Standard may be partially or completely achieved depending on contributing area and minimum orifice size.

3.5. BMP Selection for Water Quality Treatment

If the Water Quality Treatment Minimum Requirement is triggered (refer to *Volume 1*, *Section 5.4.2*), this section describes the step-by-step process for selecting the type of treatment BMPs that apply to individual projects as well as the physical site features that can impact water quality treatment BMP selection. All projects must use On-site BMPs to the maximum extent feasible to meet Water Quality Treatment Minimum Requirements per SMC 22.805.090.B. Refer to *Section 3.5.2* for additional detail on BMP selection for the following water quality treatment performance goals — oil control, phosphorus, metals, and basic.

3.5.1. Selection Steps

If one or more Water Quality Treatment Minimum Requirements are triggered, designers should follow the steps presented below and in Figure 3.2 to select the appropriate water quality treatment BMPs for a given project. In addition, On-site Stormwater Management and Flow Control Requirements may apply (refer to *Sections 3.3 and 3.4*).

Step 1: Determine the Associated Pollutants of Concern

- Determine the pollutants of concern and potential loads through an analysis of the proposed use(s) of the project site. Identify areas of the project site associated with the production of metals, organic compounds, and other toxic wastes that can be entrained in precipitation and runoff (through air pollution or deposition on the ground surface).
- Determine the potential for high sediment input. Particularly, sites with a large amount of fine-grained particles, such as silt and sand, can clog infiltration and filtration BMPs. Pretreatment may be required to remove total suspended solids (TSS) for infiltration and filtration BMPs (refer to *Section 4.4*). High TSS loads can also hinder the function of oil/water separators, especially coalescing plate (CP) separator systems, if sediment clogs the coalescing plates.
- Either mean or upper confidence limit TSS loadings from Table 3.5 may be assumed when there is an absence of more site-specific information.

Table 3.5. Zoning Categorization and TSS Characteristics.

Zoning Categorization	Total Suspended Solids Concentration (mg/L)[a]: LCL	Total Suspended Solids Concentration (mg/L)[a]: UCL	Total Suspended Solids Concentration (mg/L)[a]: Mean
Parcels zoned as NR, RSL, LR, or MFR Non-arterial streets adjacent to properties zoned as NR, RSL, LR, or MFR	44	93	69
Parcels zoned as neighborhood/commercial, downtown, major institutions, master planned community, or residential/commercial Arterial streets with adjacent property zoned as neighborhood/commercial, downtown, major institutions, master planned community, or residential/commercial	58	106	82
Parcels zoned as manufacturing/industrial Non-arterial or arterial streets with adjacent property zoned as manufacturing/industrial	58	177	118

[a] Reference: SPU 2015.

LCL = lower confidence limit

UCL = upper confidence limit

NR = Neighborhood Residential

RSL = Residential Small Lot

LR = Low-rise Multifamily

MFR = Multifamily Residential

Step 2: Select an Oil Control BMP if Oil Control is Required

If oil control is required (refer to *Volume 1*, *Section 5.4.2.1*), select an Oil Control BMP using the list in Figure 3.2 and the information in *Section 3.5.2.1.* Refer to the *General Design Requirements* in *Chapter 4* for additional requirements that may affect the design and placement of BMPs on the site (e.g., bypass). Refer to *Section 5.8.9* of this volume for design information.

Step 3: Select a Phosphorus Treatment BMP if Phosphorus Treatment is Required

At the time this manual was developed, Green Lake was the only nutrient-critical receiving water determined to be impaired due to phosphorus contributed by stormwater When phosphorus treatment is required (refer to *Volume 1*, *Section 5.4.2.2*), select a Phosphorus Treatment BMP using the list in Figure 3.2 and the information in *Section 3.5.2.2* of this volume. If a project site is also subject to the metals treatment requirement, select a BMP or treatment train that is listed as providing both Metals Treatment and Phosphorus Treatment. Refer to the *General Design Requirements* in *Chapter 4* for additional requirements that may affect the design and placement of BMPs on the site (e.g., bypass). Refer to *Chapter 5* of this volume for BMP applicability, site considerations, and design criteria. Select water quality treatment BMPs that best integrate with the on-site stormwater management to the maximum extent feasible.

Step 4: Select a Metals Treatment BMP if Metals Treatment is Required

If metals treatment is required (refer to *Volume 1*, *Section 5.4.2.3*), select a Metals Treatment BMP using the list in Figure 3.2 and the information in *Section 3.5.2.3* of this volume. Determine whether infiltration is feasible (refer to *Section 3.2*). If infiltration is feasible, select an infiltration BMP (refer to Figure 3.2). Determine whether presettling or pretreatment is required (refer to *Section 4.4*). Select water quality treatment BMPs that best integrate with the on-site stormwater management to the maximum extent feasible.

If a project site is also subject to the phosphorus treatment requirement, select a BMP or treatment train that is listed as providing both Metals Treatment and Phosphorus Treatment. Refer to the General Design Requirements in *Chapter 4* for additional requirements that may affect the design and placement of BMPs on the site. Refer to *Chapter 5* of this volume for BMP applicability, site considerations, and design criteria.

Step 5: Select a Basic Treatment BMP

If the Water Quality Treatment Minimum Requirement is triggered (refer to *Volume 1*, *Chapters 2* and *5*) and the criteria for Phosphorus Treatment and Metals Treatment do not apply (refer to *Volume 1*, *Section 5.4.2.2* and *5.4.2.3*), then only basic treatment is required. Determine whether infiltration is feasible (refer to *Section 3.2*). If infiltration is feasible, select an infiltration BMP (refer to Figure 3.2). Determine whether presettling or pretreatment is required (refer to *Section 4.4*). Select treatment BMPs that best integrate with the on-site stormwater management to the maximum extent feasible.

Select a Basic Treatment BMP using the list in Figure 3.2 and the information in *Section 3.5.2.4*. Refer to the General Design Requirements in *Chapter 4* for additional requirements that may affect the design and placement of BMPs on the site. Refer to *Chapter 5* of this volume for BMP applicability, site considerations, and design criteria.

Step 6: Use Pre-sized or Modeling Sizing Approach for BMP Design

For projects with 10,000 square feet or more of new and replaced hard surface area, use the Modeling Approach for BMP design (Step 6b). For sites with less than 10,000 square feet new and replaced hard surface area, use either the Pre-sized Approach or Modeling Approach for BMP design (Steps 6a or 6b).

Step 6a: Use Pre-sized Approach for BMP design

Apply the Pre-sized Approach for BMP design (refer to *Section 4.1.2*). The designer may also choose to use the Modeling Approach (refer to Step 6b).

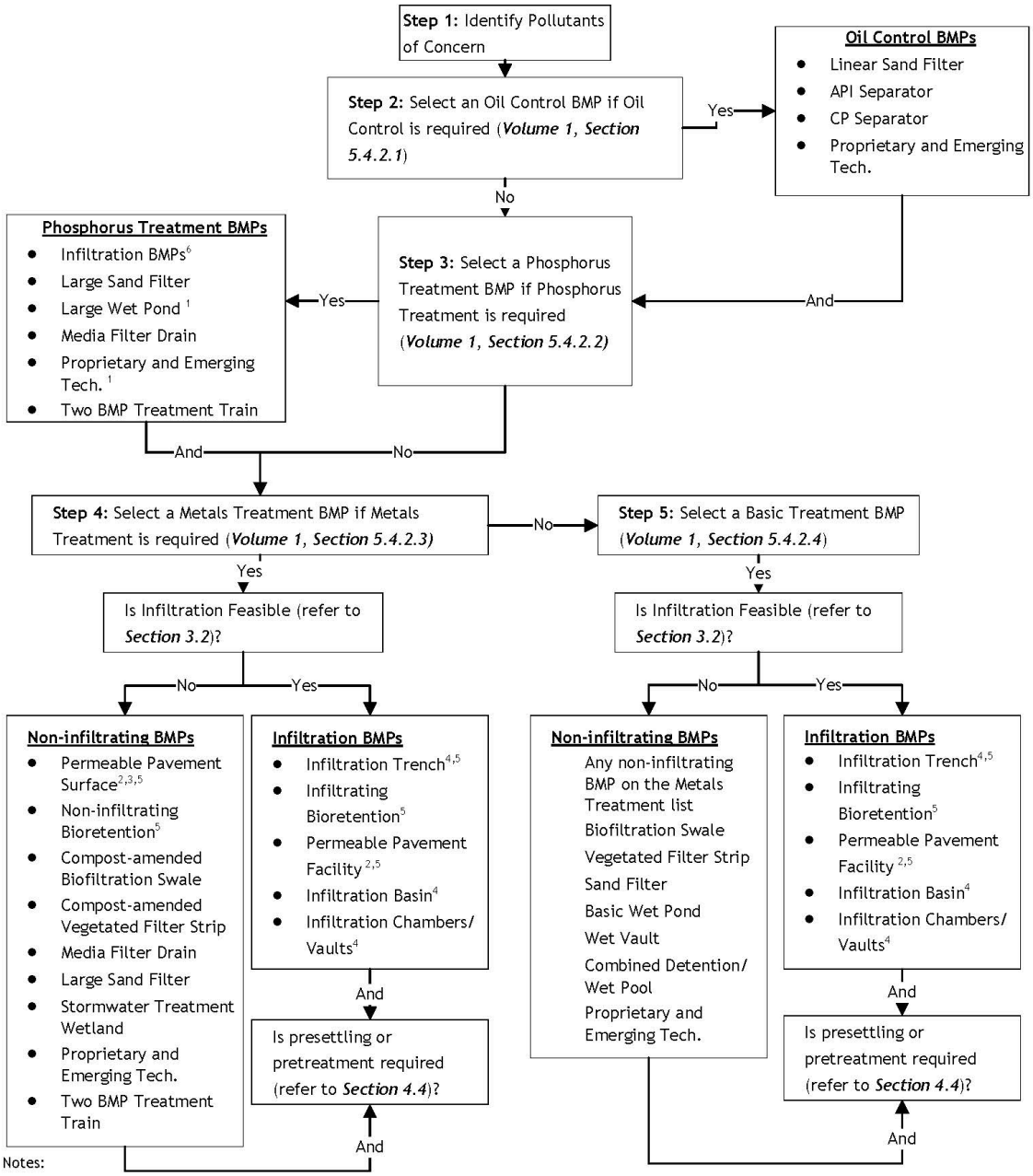
Step 6b: Use Modeling Approach for BMP design

Apply the Modeling Approach for BMP design. Refer to *Section 4.1.3* and *Appendix F* for modeling guidelines.

BMPs should be sized using either the water quality design storm volume or flow rate on an annual average basis. The performance goal applies on an average annual basis to the entire

annual discharge volume (treated plus bypassed). The incremental portion of runoff in excess of the water quality design flow rate or volume can be routed around the BMP (offline treatment facilities) or can be passed through the BMP (on-line treatment BMPs) provided a net pollutant reduction is maintained (refer to *Section 4.2*). Other contributing areas must bypass the facility, or the facility must be sized to accommodate the additional contributing area. Where feasible, offline facilities are required to prevent resuspension and washout of accumulated sediment (and associated metals and phosphorus) during large storm events.

Oil/water separators must be located offline and bypass the incremental portion of flows that exceed the offline water quality design flow rate (refer to *Section 4.2.1*). If it is not possible to locate the separator offline (e.g., roadway intersections), use the on-line water quality design flow rate (refer to *Section 4.2.1*).



Notes:

1 - When Phosphorous Control and Metals Treatment are required, the Large Wet Pond and certain types of emerging technologies will not meet both types of treatment requirements. A different or an additional treatment BMP will be required to meet Metals Treatment.

2 - Underlying soil must meet the treatment soil requirements outlined in *Section 4.5.2* or a water quality treatment course must be included per *Section 5.4.6.5*.

3 - Standard may be partially or completely achieved depending upon subgrade slope, infiltration rate of subgrade soil, and whether aggregate subbase is laid above or below surrounding grade.

4 - Soil suitability criteria (*Section 4.5.2*) and applicable drawdown requirements (*Section 4.5.1*) must be met.

5- BMP is on the On-site List (*Volume 1, Section 5.2*).

6. If the infiltration BMP is within ¼ mile of a phosphorus sensitive water (or tributary to that water), native soil must meet soil suitability criteria (Section 4.5.2) to be used to meet Phosphorus Treatment. If the infiltration BMP is a minimum of ¼ mile away, native soil does not have to meet the soil suitability criteria to be used to meet Phosphorus Treatment requirements if infiltration into the native soil is preceded by a Basic Treatment BMP.

Figure 3.2. Water Quality Treatment BMP Selection Flow Chart.

Mass-based Sizing for Proprietary BMPs

The City requires proprietary technologies to be sized to account for solids loading targeting annual maintenance. To achieve this target, the City requires adjustment of the water quality design flow rate based on mass loading ratios. Refer to *Section 5.8.11.6* to determine how to size proprietary BMPs using the mass-based sizing approach. When *Section 5.8.11.6* does not provide sizing guidance for a BMP of interest, refer to Table 3.5 and provide documentation from the manufacturer that the annual maintenance target has been met.

3.5.2. Treatment Performance Goals and BMP Options

This section identifies choices that meet the treatment BMP categories referred to in *Section 3.5.1*. The treatment BMP categories in this section are discussed in the order of the decision process outlined in Figure 3.2 and include the following:

- Oil Control Treatment, *Section 3.5.2.1*
- Phosphorus Treatment, *Section 3.5.2.2*
- Metals Treatment, *Section 3.5.2.3*
- Basic Treatment, *Section 3.5.2.4*

3.5.2.1. Oil Control Treatment

Performance Goal — Oil Control Treatment BMPs are designed to achieve the following:

- No ongoing or recurring visible sheen
- A 24-hour average Total Petroleum Hydrocarbon (TPH) concentration no greater than 10 mg/l
- A maximum of 15 mg/l for a discrete sample (grab sample)

Note: For the analysis of grab samples for most petroleum products, use the NWTPH-Dx method. If the concentration of gasoline is of interest, use the NWTPH-Gx method to analyze grab samples.

BMP Options — Any one of the following options may be selected to satisfy the oil control requirement:

- Linear Sand Filter (refer to *Section 5.8.5*)
- API-Type Oil/Water Separator (refer to *Section 5.8.10*)
- Coalescing Plate Oil/Water Separator (refer to *Section 5.8.10*)
- Proprietary and Emerging Water Quality Treatment Technologies (refer to *Section 5.8.11*)

Note: The linear sand filter is also used for basic, metals, and phosphorus treatment. If used to satisfy one of those treatment requirements, do not use the same BMP to satisfy the oil control requirement. This increase in maintenance is to prevent clogging of the filter by oil so that it will function for suspended solids, metals, and phosphorus removal as well.

3.5.2.2. Phosphorus Treatment

Performance Goal — Phosphorus Treatment BMPs are designed to achieve 50 percent total phosphorus (TP) removal for a range of influent concentrations of 0.1 to 0.5 mg/l. In addition, the Phosphorus Treatment BMPs are designed to achieve Basic Treatment.

BMP Options — Any one of the following options may be selected to satisfy the Phosphorus Treatment requirement:

- Infiltration Trench — refer to *Section 5.4.2*
- Infiltrating Bioretention (without underdrain). May use the default Bioretention Soil Media (BSM) if more than ¼ mile from phosphorus-limited water bodies. Otherwise, this BMP requires High Performance Bioretention Soil Media (HPBSM) and a polishing layer (refer to *Section 5.4.4*).
- Permeable Pavement Facility — refer to *Section 5.4.6*
- Infiltration Pond — refer to *Section 5.4.8*
- Infiltration Chamber/Vault — refer to *Section 5.4.9*
- Media Filter Drain — refer to *Section 5.8.4*
- Large Sand Filter — refer to *Section 5.8.5*
- Large Wet Pond — refer to *Section 5.8.6*
- Proprietary and Emerging Water Quality Treatment Technologies targeted for phosphorus removal — refer to *Section 5.8.11*
- Two-BMP Treatment Trains — refer to Table 3.6

Table 3.6. Treatment Trains for Phosphorus Treatment.

First BMP	Second BMP
Biofiltration Swale (*Section 5.8.3*)	Basic Sand Filter or Sand Filter Vault (*Section 5.8.5*)
Vegetated Filter Strip (*Section 5.8.4*)	Linear Sand Filter (*Section 5.8.5*), no presettling needed
Linear Sand Filter (*Section 5.8.5*)	Vegetated Filter Strip (*Section 5.8.4*)
Basic Wet Pond (*Section 5.8.6*)	Basic Sand Filter or Sand Filter Vault (*Section 5.8.5*)
Wet Vault (*Section 5.8.7*)	Basic Sand Filter or Sand Filter Vault (*Section 5.8.5*)
Stormwater Treatment Wetland (*Section 5.8.8*)	Basic Sand Filter or Sand Filter Vault (*Section 5.8.5*)
Basic Combined Detention and Wet Pool (*Section 5.8.9*)	Basic Sand Filter or Sand Filter Vault (*Section 5.8.5*)
Basic Treatment BMP (*Section 3.5.2.4*)	BMP that infiltrates into native soil[a]

[a] Either a) native soil must meet Soil Suitability Criteria (*Section 4.5.2*) or b) infiltration must be a minimum of 1/4 mile from phosphorus-sensitive water (or tributary to that water) and be preceded by a Basic Treatment BMP.

3.5.2.3. Metals Treatment

Performance Goal — Metals Treatment BMPs without compost are designed to remove greater than 30 percent dissolved copper and greater than 60 percent dissolved zinc. The performance goal assumes that the Metals Treatment BMP is treating stormwater with dissolved copper typically ranging from 5 to 20 µg/l, and dissolved zinc ranging from 20 to 300 µg/l. In addition, the Metals Treatment BMPs are designed to achieve Basic Treatment.

BMP Options — Any one of the following options may be selected to satisfy the Metals Treatment requirement:

- Infiltration Trench — refer to *Section 5.4.2*
- Infiltrating Bioretention — refer to *Section 5.4.4*
- Permeable Pavement Facilities — refer to *Section 5.4.6*
- Infiltration Pond — refer to *Section 5.4.8*
- Infiltration Chamber/Vault — refer to *Section 5.4.9*
- Infiltrating Soil Cell Bioretention — refer to *Section 5.4.10*
- Permeable Pavement Surfaces — refer to *Section 5.6.2*
- Non-infiltrating Bioretention — refer to *Section 5.8.2*
- Compost-amended Biofiltration Swale — refer to *Section 5.8.3*
- Compost-amended Vegetated Filter Strip (CAVFS) — refer to *Section 5.8.4*
- Media Filter Drain — refer to *Section 5.8.4*
- Large Sand Filter — refer to *Section 5.8.5*
- Stormwater Treatment Wetland — refer to *Section 5.8.8*
- Proprietary and Emerging Water Quality Treatment Technologies — refer to *Section 5.8.11*
- Non-infiltrating Soil Cell Bioretention — refer to *Section 5.8.12*
- Two-BMP Treatment Trains — refer to Table 3.7

Table 3.7. Treatment Trains for Metals Treatment.

First BMP	Second BMP
Biofiltration Swale (*Section 5.8.3*)	Basic Sand Filter, Sand Filter Vault, or an approved Proprietary and Emerging Water Quality Treatment Technology[a] (*Section 5.8.5* or *Section 5.8.11*)
Vegetated Filter Strip (*Section 5.8.4*)	Linear Sand Filter with no presettling cell needed (*Section 5.8.5*)
Linear Sand Filter (*Section 5.8.5*)	Vegetated Filter Strip (*Section 5.8.4*)
Basic Wet Pond (*Section 5.8.6*)	Basic Sand Filter, Sand Filter Vault, or an approved Proprietary and Emerging Water Quality Treatment Technology[a] (*Section 5.8.5* or *Section 5.8.11*)
Wet Vault (*Section 5.8.7*)	Basic Sand Filter, Sand Filter Vault, or an approved Proprietary and Emerging Water Quality Treatment Technology[a] (*Section 5.8.5* or *Section 5.8.11*)
Basic Combined Detention/Wet Pool (*Section 5.8.9*)	Basic Sand Filter, Sand Filter Vault, or an approved Proprietary and Emerging Water Quality Treatment Technology[a] (*Section 5.8.5* or *Section 5.8.11*)
Basic Sand Filter or Sand Filter Vault with a presettling cell if the filter is not preceded by a detention BMP (*Section 5.8.5*)	An approved Proprietary and Emerging Water Quality Treatment Technology[a] (*Section 5.8.5* or *Section 5.8.11*)

[a] The media must be of a type approved by Ecology for basic or metals treatment use and accepted by the Director.

3.5.2.4. Basic Treatment

Performance Goal — Basic Treatment BMPs are designed to achieve 80 percent removal of TSS for influent concentrations greater than 100 mg/l, but less than 200 mg/l. For influent concentrations greater than 200 mg/l, a higher treatment goal may be appropriate. For influent concentrations less than 100 mg/l, the BMPs are designed to achieve an effluent goal of 20 mg/l TSS.

BMP Options — Any one of the following options may be selected to satisfy the basic treatment requirement:

- Infiltration Trench — refer to *Section 5.4.2*
- Infiltrating Bioretention — refer to *Section 5.4.4*
- Permeable Pavement Facility — refer to *Section 5.4.6*
- Infiltration Pond — refer to *Section 5.4.8*
- Infiltration Chamber/Vault — refer to *Section 5.4.9*
- Infiltrating Soil Cell Bioretention — refer to *Section 5.4.10*
- Permeable Pavement Surfaces — refer to *Section 5.6.2*
- Non-infiltrating Bioretention — refer to *Section 5.8.2*
- Biofiltration Swales — refer to *Section 5.8.3*
- Vegetated Filter Strip — refer to *Section 5.8.4*
- Compost-amended Vegetated Filter Strip (CAVFS) — refer to *Section 5.8.4*
- Media Filter Drain — refer to *Section 5.8.4*
- Sand Filters — refer to *Section 5.8.5*
- Basic Wet Pond — refer to *Section 5.8.6*
- Wet Vault — refer to *Section 5.8.7*
- Stormwater Treatment Wetland — refer to *Section 5.8.8*
- Combined Detention and Wet Pool — refer to *Section 5.8.9*
- Proprietary and Emerging Water Quality Treatment Technologies — refer to *Section 5.8.11*
- Non-infiltrating Soil Cell Bioretention — refer to *Section 5.8.12*

CHAPTER 4 – General Design Requirements

This chapter describes general design requirements for the following:

- Sizing approach
- Bypass, flow-through, and off-site flow
- Conveyance
- Presettling and pretreatment
- Infiltration BMPs

4.1. Sizing Approach

This section describes the sizing approach for the following:

- **On-site List Approach**: to meet the On-site Stormwater Management requirement.
- **Pre-sized Approach**: flow control credits, BMP sizing factors, and BMP sizing equations to meet flow control or water quality treatment performance standards.
- **Modeling Approach**: continuous modeling approach to meet the On-site Performance Standard, a specific flow control standard, or a water quality treatment requirement.

The minimum requirements based on project type are provided in *Volume 1*, *Chapter 4*.

4.1.1. On-site List Approach

Under the On-site List Approach, the On-site Stormwater Management Requirement may be met by selecting from a prioritized list of On-site BMPs as explained in *Section 3.3.1*. On-site List BMPs must be sized as prescribed under the Sizing for On-site List Approach in each On-site BMP section in *Chapter 5*. The City has prepared a spreadsheet tool (On-site Stormwater Management — List Approach Calculator) to help users select and size BMPs using the On-site List Approach. Refer to SDCI's Stormwater Code web page to download the latest version of the spreadsheet tool: www.seattle.gov/sdci/codes/codes-we-enforce-(a-z)/stormwater-code.

4.1.2. Pre-sized Approach

The Pre-sized Approach may be used to select and size a BMP to meet flow control and water quality treatment performance standards without performing continuous modeling when the following conditions have been met:

- The new and replaced hard surface area associated with a project does not exceed 10,000 square feet, and
- The project is subject to the Pre-developed Pasture Standard, the Peak Control Standard, and/or Water Quality Treatment Standard (Basic, Oil, Phosphorus, and Metals Treatment).

4.1.2.1. Pre-sized Facilities

The BMPs included in the Pre-sized Approach include the following:

BMP Type	BMP Category and Name	Type of Credit/Factor	Applicable Standards
Trees	Tree Planting and Retention	Flow Control Credit	Flow Control
Dispersion BMPs	Downspout Dispersion	Flow Control Credit	Flow Control
	Sheet Flow Dispersion	Flow Control Credit	Flow Control
	Concentrated Flow Dispersion	Flow Control Credit	Flow Control
Infiltration BMPs	Infiltration Trenches	BMP Sizing Factor	Flow Control, Water Quality
	Dry Wells	BMP Sizing Factor	Flow Control
	Infiltrating Bioretention	BMP Sizing Factor	Flow Control, Water Quality
	Permeable Pavement Facilities	BMP Sizing Factor	Flow Control, Water Quality
	Infiltration Chambers	BMP Sizing Factor	Flow Control, Water Quality
	Infiltrating Soil Cell Bioretention	BMP Sizing Factor	Flow Control, Water Quality
Alternative Surface BMPs	Vegetated Roof Systems	Flow Control Credit	Flow Control
	Permeable Pavement Surfaces	Flow Control Credit	Flow Control
Detention BMPs	Detention Pipes	BMP Sizing Equation	Flow Control
	Detention Vaults	BMP Sizing Equation	Flow Control
	Detention Cisterns (aboveground)	BMP Sizing Equation	Flow Control
Non-infiltrating BMPs	Non-infiltrating Bioretention	BMP Sizing Factor	Flow Control, Water Quality
	Non-infiltrating Soil Cell Bioretention	BMP Sizing Factor	Flow Control, Water Quality

Specific design requirements for the pre-sized BMPs (e.g., side slopes, freeboard, aggregate thickness, soil depth) are provided in the *BMP Credit* or *BMP Sizing* sections in *Chapter 5*.

4.1.2.2. Pre-sized Credits, Sizing Factors, and Equations

The pre-sized BMPs are provided as either a flow control credit, BMP sizing factor, or BMP sizing equation. These are described below.

- **Flow Control Credits:** Flow control credits are awarded for BMPs that reduce hard surface areas. These credits can be applied to reduce the hard surface area requiring flow control. Note: This applies to flow control calculations only. If a site is also subject to water quality treatment requirements, calculations for water quality must also be performed. In addition, some projects may manage a smaller portion of the project's new and replaced hard surface area to meet flow control requirements if only On-site BMPs are used to the maximum extent feasible. Refer to *Volume 1, Section 5.3*.
- **BMP Sizing Factors:** BMPs may be sized using the sizing factors provided in *Chapter 5*. The sizing factors can be used to calculate the BMP size as a function of the contributing area (this includes undisturbed areas and off-site areas draining to the BMP). These sizing factors were developed using a continuous runoff hydrologic model to achieve applicable flow control and water quality treatment standards. For BMPs with variable allowable depths, sizing factors are provided for at least two typical depths. Designers may linearly interpolate BMP size for intermediate design depths but may not extrapolate.
- **BMP Sizing Equations:** BMPs may be sized using the sizing equations provided in *Chapter 5*. Sizing equations were developed using a continuous runoff hydrologic model to achieve applicable flow control and water quality treatment standards.

For each BMP, flow control credits, sizing factors, or sizing equations were developed for typical design variations (e.g., ponding depths, aggregate thickness, slopes, etc.). To use these BMPs with a different design configuration or BMPs not listed above, the designer must use the Modeling Approach (refer to *Section 4.1.3*).

When using the pre-sized sizing factors or sizing equations for water quality treatment, stormwater flows from other areas (beyond the area for which the BMP is sized) must be bypassed around the BMP or BMPs must be sized to treat runoff from the entire area draining to the BMP, even if some of those areas are not pollutant generating.

When using the pre-sized sizing factors or sizing equations for flow control, it is preferred that flow control BMPs be sized for the entire area draining to the BMP. Additional flows may pass through a BMP pre-sized to meet a flow control standard with the following limitations:

- The maximum additional area (i.e., area beyond the area for which the BMP is pre-sized) that passes through a pre-sized BMP must not exceed twice the area for which it is pre-sized.
- No flow control credit is given for runoff from any area in excess of the area for which the BMP was pre-sized.
- If additional area is routed to a BMP, it must be clearly noted on submitted plans.
- The overflow infrastructure must be sized for the full contributing area (refer to *Section 4.3.3*).
- Projects must still meet the flow control standards at the point of compliance.

BMP sizing factors and equations were developed for Pre-developed Pasture and Peak Control Standards. If both standards apply to a project (such as a site in a non-listed creek basin with a capacity constrained drainage system), the larger BMP size or conservative flow control credit must be used. A Pre-sized Approach was not developed for the Pre-developed Forested Standard because it is not triggered as often as the other flow control standards.

Generalized assumptions were used to design the pre-sized BMPs that may result in conservative sizing or may underestimate flow control or treatment credits for some sites. Refer to the *BMP Credit* or *BMP Sizing* sections each BMP section in *Chapter 5* for modeling assumptions used in the Pre-sized Approach. Designers have the option to use the pre-sized BMPs provided in this section, or to follow the Modeling Approach (refer to *Section 4.1.3*) and submit an alternative BMP size with supporting engineering calculations for review and consideration.

4.1.2.3. Pre-sized Calculator

The City has also prepared a spreadsheet tool (Pre-sized Flow Control Calculator) to help users document and implement the flow control BMP selection process for smaller sites (<10,000 square feet of new and replaced hard surface area). Refer to SDCI's Stormwater Code web page to download the latest version of the spreadsheet tool: www.seattle.gov/sdci/codes/codes-we-enforce-(a-z)/stormwater-code. This spreadsheet tool automates sizing calculations (i.e., the flow control credits, BMP sizing factors, and BMP sizing equations described above) and guides the applicant through the process of selecting BMPs. This calculator may be provided as part of a plan submittal to document compliance with flow control standards.

4.1.3. Modeling Approach

Unless otherwise adopted by the Director, all continuous modeling must be performed using the City of Seattle Extended Precipitation Time Series (SEPTS-99). This time series consists of a 158-year precipitation and evaporation time series that is representative of the climatic conditions in the City of Seattle) and a 5-minute computational time step (refer to Table F.12 in Appendix F, Section F-4 for correct time step). Refer to the Additional Resources section within Ecology's interactive online Stormwater Management Manual for Western Washington (SWMMWW) for a list of currently approved models and limitations.

Drainage basins for both disturbed and undisturbed areas must be clearly noted on submitted plans. Any off-site areas that are topographically tributary or have piped connections must be shown on drainage basin maps. Modeling must extend to the approved point of discharge or to the limits of a downstream capacity analysis.

Note that soils that are amended using options 2, 3, or 4 as described in *Section 5.1.6* may be modeled as pasture land use.

Simulation methods and a list of approved continuous runoff hydrologic models are provided in *Appendix F*.

4.1.3.1. On-site Performance Standard

As an alternative to the On-site List Approach (*Section 4.1.1*), the On-site Requirement can be met by demonstrating that the On-site Performance Standard (*Volume 1, Section 5.2*) is achieved. Under the Modeling Approach, BMPs are designed to achieve the On-site Performance Standard using a continuous runoff hydrologic model. Specific modeling requirements are presented in the *BMP Credit* or *BMP Sizing* section for each BMP in *Chapter 5*. For compliance with the On-site Performance Standard, it must be demonstrated that the suite of BMPs used on the site results in the standard being met at the discharge point (also known as the point of discharge).

4.1.3.2. Flow Control

The Modeling Approach may be used for any project to design flow control BMPs and is required for the following scenarios:

- Projects with new and replaced hard surface area equal to or exceeding 10,000 square feet that trigger a flow control standard.
- Projects with new and replaced hard surface area less than 10,000 square feet that are proposing to use different BMPs and/or assumptions than those used in the Pre-sized Approach.

Under the Modeling Approach, flow control BMPs are designed to achieve flow control standards using a continuous runoff hydrologic model (refer to *Volume 1, Section 5.3*). Specific modeling requirements are presented in the *BMP Sizing* or *BMP Credits* section for each BMP in *Chapter 5*. Note: some projects may manage a smaller portion of the project's new and replaced hard surface area to meet flow control requirements if only On-site BMPs are used to the maximum extent feasible. Refer to Volume 1, Section 5.3.

The BMPs used to meet the On-site List or the On-site Performance Standard may be included in the model and may contribute toward meeting the flow control standard(s), if applicable. When using the Modeling Approach, it must be demonstrated that the suite of BMPs used on the site results in the standard(s) being met at the point of discharge. Note: infiltrating BMPs are very helpful to meet the flow control standards, especially the Pre-developed Pasture and Pre-developed Forested Standards. Also, it is a requirement that the On-site BMPs from the On-site Lists in Volume 1, Section 5.2.2 and other infiltration BMPs per Section 5.4 be evaluated before selecting traditional flow control BMPs.

Minimum Orifice Diameter Alternative Sizing

See Appendix E, Section E-1 for the minimum orifice and weir dimensions. For detention BMPs, the minimum bottom orifice diameter will be too large to meet standard release rates in some scenarios, even with minimal head. Typically, flow control standards can be achieved using a 0.5-inch-diameter bottom orifice with a 3-foot live storage depth in the following scenarios:

- Pre-developed Forested Standard can be achieved when the contributing impervious area is greater than approximately 45,000 square feet.
- Pre-developed Pasture Standard can be achieved when the contributing impervious area is greater than approximately 19,000 square feet.
- Peak Control Standard can be achieved when the contributing impervious area is greater than approximately 2,000 square feet.

For smaller contributing impervious areas, the following design/modeling approach is required:

- *Step 1* — Before sizing a traditional detention BMP, first use infiltration or dispersion (or both) BMPs and any other feasible On-site BMP from the On-site Lists in Volume 1, Section 5.2.2. to the maximum extent feasible for the site. If it is not feasible to meet the required flow control standard with infiltration, dispersion, or other On-site BMPs, or a combination of these BMPs and a traditional detention facility with a 0.5-inch minimum orifice, then proceed to step 2.
- Step 2 - Size the detention facility either manually or, if applicable, using an auto sizing feature with no more than 3 feet of head to meet the flow control standard with an optimized orifice size (allow the orifice diameter to be smaller than the minimum allowed for construction in this step).
- *Step 3* — Depending on the flow control standard required, follow the instructions below:
    - For the Pre-developed Forested and Pre-developed Pasture standards, follow the sizing/iteration guidance and example in the Appendix V-B.
    - For the Peak Standard, go to step 4.
- Step 4 -Use the facility size (e.g., depth and storage volume) obtained in Step 2 and increase the orifice diameter to the minimum size (0.5 inch) on the construction plans if the modeling results in an orifice size less than 0.5 inch. Note: this is only applicable to the bottom orifice. Any other orifice must be modeled and constructed with a diameter that is 0.5 inch or greater.

4.1.3.3. Water Quality Treatment

The Modeling Approach may be used for any project to design water quality treatment BMPs, and is required for the following scenarios:

- Projects with new and replaced hard surface area equal to or exceeding 10,000 square feet that trigger Basic or Metals Treatment.
- Projects that trigger Phosphorus or Oil Treatment.
- Projects with new and replaced hard surface area less than 10,000 square feet that are proposing to use different BMPs and/or assumptions than those used in the Pre-sized Approach.

Under the Modeling Approach, water quality treatment BMPs are designed to treat a specific water quality design storm volume or flow rate (refer to *Volume 1*, *Section 5.4.1* and *Appendix F*) using a continuous runoff hydrologic model. Specific modeling requirements are presented in the *BMP Sizing* section for each applicable BMP in *Chapter 5*. Some non-infiltrating BMPs (sand filters and oil/water separators) use a simplified sizing approach (refer to *Section 5.8.5 and 5.8.10*). The BMPs used to meet the On-site List or the On-site Performance Standard may be included in the model and may contribute toward meeting the Water Quality Treatment Standard, if applicable.

4.1.3.4. Wetland Hydroperiod Protection

There are two methods for calculating wetland hydroperiod protection:

- Method 1 — Monitoring and Wetland Stage Monitoring
- Method 2 — Site Discharge Modeling

Both methods involve continuous simulation modeling. Refer to *Volume I, Appendix I-C* of the SWMMWW for specific details on how to evaluate wetland hydroperiod protection using these methods.

Method 1 – Monitoring and Wetland Stage Monitoring

The following calculations should be included in the wetland hydroperiod evaluation using Method 1:

- Existing water level fluctuation (WLF) based on monitored water levels
  - Mean annual
  - Mean monthly
- Estimated daily, monthly, or annual WLF based on continuous simulation modeling
- Allowable WLF change (compare with estimated WLF to verify compliance)

Method 2 – Site Discharge Monitoring

The following calculations should be included in the wetland hydroperiod evaluation using Method 2:

- Daily discharge volumes based on continuous simulation modeling
- Monthly discharge volumes based on continuous simulation modeling

4.1.3.5. Closed Depressions

The analysis of closed depressions requires careful assessment of the existing hydrologic performance in order to evaluate the impacts a proposed project will have. The applicable requirements should be thoroughly reviewed prior to proceeding with the analysis. Closed depressions generally facilitate infiltration of runoff. If a closed depression is classified as a wetland, then Minimum Requirement #8 applies (refer to *Volume 1, Section 3.5*). A continuous runoff hydrologic model must be used for closed depression analysis and design of mitigation facilities. If a closed depression is not classified as a wetland, model the ponding area at the bottom of the closed depression as an infiltration pond using an approved continuous runoff hydrologic model.

4.2. Bypass, Flow-through, and Off-site Flow General Design Requirements

4.2.1. Treatment BMPs

Treatment BMPs must be designed to treat runoff from the entire area (disturbed and undisturbed, hard surface and pervious surface, pollution-generating and non-pollution generating, on-site and off-site) draining to it. Flows from off-site and runoff from non-pollution generating areas on-site that can be kept separate may bypass the treatment BMP to reduce its required size.

Treatment BMPs located upstream of a detention system can be designed as on-line or off-line BMPs.

- **On-line BMPs:** On-line BMPs receive all of the stormwater runoff from the contributing area and do not include flow splitters. The on-line water quality design flow rate (as determined by a continuous runoff hydrologic model) is used to size on-line BMPs. On-line BMPs treat flows up to the on-line water quality design flow rate to meet the performance goal and flows higher than the on-line water quality design flow rate pass through the BMP at a lower percent removal. Runoff flow rates in excess of the water quality design flow rate can be routed through the BMP provided a net pollutant reduction is maintained, and the applicable annual average performance goal is designed to be met and velocities are not high enough to resuspend sediments. Designers must ensure that the higher flows will not damage the BMPs. If higher flows will damage the proposed BMP, the flows to the BMP must be attenuated or an offline BMP must be used.
- **Offline BMPs:** Offline BMPs make use of a flow splitter directly upstream of the BMP to regulate the amount of flow entering the BMP. The flow splitter must be designed to direct flows up to and including the off-line water quality design flow rate (as determined by a continuous runoff hydrologic model) to the BMP. The BMP must be sized to treat the off-line water quality design flow rate. For non-infiltrating BMPs not preceded by an equalization or storage basin, flows exceeding the water quality design flow rate may bypass (internal bypass is generally not acceptable) the BMP. Off-line facilities are required to prevent resuspension and washout of accumulated sediment (and associated metals and phosphorus) during large storm events (*Section 3.5*). However, during bypass events, the BMP will continue to receive and treat the water quality design flow rate. Only the higher incremental portion of flow rates are bypassed around a BMP. Design guidelines for flow splitters for use in off-line BMPs are provided in *Appendix E-2*.

Non-infiltrating BMPs located downstream of an equalization or storage basin may identify a lower water quality design flow rate provided that at least 91 percent of the total runoff volume predicted by an approved continuous runoff hydrologic model is treated to the applicable performance goals (e.g., 80 percent total suspended solids (TSS) removal at the water quality design flow rate and 80 percent TSS removal on an annual average basis).

4.2.2. Bypassing Flows Entering a Site

The following bypass-related scenarios recognize that additional considerations be taken into account when designing BMPs when off-site flows enter a project site:

1. Flow currently enters the project site but can be bypassed as part of the proposed project improvements.
2. Flow currently enters the project site but cannot be bypassed as part of the proposed project improvements.

The requirements and guidelines applicable to each scenario are outlined below.

4.2.2.1. Scenario 1 — Bypassing Flows Entering a Site

Off-site flows may bypass BMPs if all of the following conditions are met:

- Natural drainage courses are maintained.
- Existing flows to wetlands are maintained (refer to *Volume 1, Section 5.3.1*).
- Off-site flows that are naturally attenuated by the project site under predeveloped conditions must remain attenuated, either by natural means or by providing additional on-site detention to mimic the attenuated condition so that peak flows or discharge rates and duration do not increase.
- The point of discharge does not adversely impact down-gradient properties.

Refer to *Appendix E*-2 for design guidelines for flow splitters.

4.2.2.2. Scenario 2 —Flow-through a Flow Control BMP

It is preferred that flow control BMPs be sized for the entire area draining to the BMP. It is required that treatment BMPs be sized for the entire area draining to the BMP.

Additionally, off-site flows may pass through a BMP sized to meet a flow control standard with the following limitations:

- Projects must still meet the flow control standard at the point of compliance where the flow control standard is evaluated.
- If additional area is routed to a BMP, it must be clearly noted on submitted plans and drainage basin maps.
- The overflow infrastructure must be sized for the full contributing area (refer to *Section 4.3.3*).
- If the flow control BMP was sized using the modeling approach (refer to *Section 4.1.3*), and the existing 100-year peak flow rate from any upstream off-site area is greater than 50 percent of the 100-year developed peak flow rate (undetained) for the project site, then the runoff from the off-site area must not flow to the flow control BMP.
- If the flow control BMP was sized using the pre-sized approach (refer to *Section 4.1.2*), the entire area draining to the facility must not be greater than twice the area for which it is sized.
- No flow control credit is given for runoff from any off-site area in excess of the area for which the facility was sized.

4.2.3. Bypassing Flows Leaving a Site

At times it is not practical to collect all flows from a project site. All bypass areas must be clearly noted on the submitted plans when bypass of a BMP is proposed. The following bypass-related scenarios recognize that additional considerations be taken into account when it is not feasible to collect runoff from a portion of the site.

1. A flow control BMP is designed to compensate for uncontrolled bypass flows.
2. A flow control BMP cannot be designed to collect or compensate for a small bypass area.

In either scenario, the bypass drainage that is not feasible to be collected must sheet flow from the site. No concentrated drainage may flow from the site unless it is in a conveyance system directed to an approved point of discharge. Also, in no case will drainage from more than 750 square feet of impervious area at a driveway and no more than a 10-foot width of impervious area abutting a public sidewalk, measured perpendicular to the public sidewalk, be permitted to drain across a public sidewalk.

4.2.3.1. Scenario 1 – Compensate for Uncontrolled Bypass

Design of a flow control BMP can compensate for uncontrolled bypass if all of the following conditions are met:

- The flow control BMP is sized using the modeling approach to over-detain flow to compensate for the uncontrolled bypass (refer to *Section 4.1.3*).
- The modeling documents that the flow control standard is met at the point of compliance, where flow control standards are evaluated, and the controlled and uncontrolled flow join.
- When the bypass will not create significant adverse impacts to down-gradient properties.

4.2.3.2. Scenario 2 — Uncontrolled Flows Leaving the Site

It is typically feasible to compensate for uncontrolled flows with a flow control BMP as described in Scenario 1. In the rare case when it is not feasible to compensate for uncontrolled flows leaving the site, runoff may be bypassed and not compensated if all of the following conditions are met:

- When the bypass area is due to incidental grading to match surrounding roadways or properties.
- When the bypass area is less than 1,000 square feet.
- When the bypass will not create significant adverse impacts to down gradient properties.

4.3. Conveyance and Overflow General Design Requirements

4.3.1. Conveyance Design and Capacity Analysis

For design or capacity analysis of the public drainage system, early consultation with Seattle Public Utilities is recommended. Design Requirements for Public Drainage Systems are described in the Public Drainage System Requirements Director's Rule on SPU's Policy and Director's Rules web page: http://www.seattle.gov/utilities/about/policies. Requirements and recommendations for Hydrologic Analysis and Design are in *Appendix F*. Requirements for service drains and side sewers are described in the Side Sewer Directors' Rule https://www.seattle.gov/utilities/construction-resources/sewer-and-drainage/side-sewer-permits.

4.3.2. Requirements for Small Projects with No Off-site Point of Discharge

Refer to *Volume 1, Section 3.2.1* to determine the approved point of discharge. For small projects (e.g., projects with less than 5,000 sf of new plus replaced hard surface) where it has been determined by the Director that there is no off-site point of discharge, the following minimum design criteria must be met:

- The drainage control plan and a drainage report must be prepared by a licensed civil engineer;
- Infiltration is feasible per *Section 3.2*, or infiltration is determined to be feasible as documented in a stamped and signed report from a licensed professional and approved by the Director. Note: the minimum measured infiltration rates indicated in Table 3.3 in *Section 3.2* are not applicable to small projects with no off-site point of discharge. For instance, a measured infiltration rate of 5 inches/hour is not required to use drywells.
- In addition to meeting other minimum requirements for the project, the infiltration BMP must be designed to infiltrate the runoff volume from all new and replaced hard surfaces for the storm event with a 4 percent annual probability (25-year recurrence interval flow) per *Section 4.5.1.(B)*; and
- Identify the overland flow path for flows that will exceed the capacity of the infiltration BMP. Prevent the flows from causing erosion or flooding on site or on adjacent properties (refer to *Section 4.3.3*). If the flows will be directed toward an off-site building, structure, or ECA Steep Slope or Landslide Prone area, then the infiltration BMPs must be designed to fully infiltrate all flows for the full, required simulation period in the continuous runoff model (i.e., 100 percent infiltration) per *Section 4.5.1.(A)*.
- Overland flow path must be vegetated and a minimum of 10 feet long between BMP and any property line (excluding right-of-way line).
- If the project site is within the setback from an ECA Steep Slope or Landslide Prone area where infiltration is limited, a slope stability analysis is required per the Site Constraint section in *Section 3.2*.

- Alternatively, if it is demonstrated that infiltration is not feasible as indicated above, all new and replaced hard surfaces must be dispersed using Dispersion BMPs from *Section 5.3* or be constructed using Permeable Pavement Surface per *Section 5.6.2*. Stormwater modeling is not required to demonstrate the Dispersion BMPs or Permeable Pavement Surfaces meet the requirements for projects with no off-site point of discharge.

Note that the Simple Infiltration Test is not allowed for projects with no off-site point of discharge. These projects must use a Small PIT to determine the measured infiltration rate (Refer to *Appendix D*).

One option for a small project with no approved off-site point of discharge consists of an infiltration BMP (i.e., infiltration trench, drywell, or infiltration chamber/vault) situated downstream of a bioretention cell or a permeable pavement facility sized to infiltrate storms up to the conveyance standard (25-year recurrence interval flow). Refer to *Appendix E*, *Section E-10* for dry well sizing provided for this scenario.

Infiltration testing and plan preparation clarification for projects with less than 1,500 sf of new plus replaced hard surface on lots with no off-site point of discharge:

- The applicant, or their representative or contractor, is allowed to perform the infiltration testing unless the project site is within the setback from an ECA Steep Slope or Landslide Prone area where infiltration is limited (refer to the Site Constraints in *Section 3.2*) or unless testing by a licensed professional is otherwise determined to be required by the Director.
- If the applicant chooses (in lieu of a licensed professional) to conduct the infiltration testing, the applicant must conduct the infiltration test and subsurface investigation per the Small PIT and Standard Subsurface Investigation requirements in Appendix D.
- The test must be documented with the Pilot Infiltration Test Checklist and a minimum 0.3 in/hr measured soil infiltration rate must be demonstrated.
- Drywells must be sized, at a minimum, per *Appendix E, Section E-10,* or sized by a licensed civil engineer.
- The applicant is allowed to prepare the drainage control plan unless otherwise determined by the Director.

4.3.3. BMP and Conveyance Overflow Requirements

Overflows are critical to minimize flooding and protect properties, the downstream conveyance system, and receiving waters.

BMP overflow options to an approved point of discharge (refer to *Section 4.3.2*) include the following:

- Direct conveyance
- Through a downstream BMP
- Through interflow to the surface
- To surface discharge
- Combination of these measures

Overflow conveyance options include the following:

- Piped
- Daylighted through a storage reservoir
- Distributed through a flow spreader (refer to *Appendix E*)
- Discharged through overtopping of the BMP

Refer to the "Overflow" subsections for each BMP in *Chapter 5* for specific overflow/BMP outlet requirements based on the BMP selected.

Plan must include a site map that indicates all flow paths through pipes and surface topography. Consider overflows that may result from:

- Larger storms
- Failure of infiltration capacity for infiltrative BMPs
- BMP failure due to defects or problems (refer to *Appendix G*)
- Pump or electrical failures for pumped systems

Overflow requirements specific to the right-of-way include:

- Contain overflows within the roadway and direct to the drainage system or public combined sewer.
- Overflow paths must not be over sidewalks.
- Overflow paths must not be to private property, except as approved by the Director.

At a minimum, BMP overflow (e.g., piped outlets from BMP) must be designed to convey peak flows with a 4 percent annual probability (25-year recurrence interval flows). During large storm events, capacity will be limited at the approved point of discharge, and backwater calculations and installation of backwater protection may be required.

Identify the overland flow path for all BMPS and prevent flows from causing erosion or flooding on site or on adjacent properties. For overflows located within ECA Steep Slope or Landslide Prone areas, the overflow device capacity must be increased to convey the peak flows with a 1 percent annual probability (100-year recurrence interval flows) to the approved point of discharge.

4.4. Presettling and Pretreatment Requirements

Presettling and pretreatment should be evaluated for most BMPs to protect BMPs from excessive siltation and debris.

4.4.1. Description

Presettling and pretreatment are essential to effective long-term BMP performance.

- **Presettling**: Presettling consists of cells, structures or Manufactured Treatment Devices (MTDs) that are located upstream of a BMP and are intended to collect sediment that could otherwise clog or impair the function of the primary BMP. Presettling facilities (i.e., presettling cells, presettling zones) specific to BMPs are described in the BMP Design Criteria in *Chapter 5*.
- **Pretreatment**: Pretreatment consists of structures used to remove sediments, floating oils, and floating debris (such as trash) upstream of a water quality treatment BMP to reduce clogging of the BMP.
    - Hydrodynamic separators: Flow-through structures with a settling or separation unit to remove sediments and particle-bound pollutants. The BMP name refers to the application of the energy of flowing water to facilitate sediment separation and removal. Depending on the type of unit, particle settling may occur by means of swirl action or indirect filtration.
    - Floatables capture: Facilities designed to trap floating oils and debris before it enters a primary treatment BMP. These facilities take advantage of the floating properties of certain pollutants, such as oils and trash, and capture them where they can be easily removed, sending the rest of the stormwater to a separate area for further treatment.

4.4.2. Performance Mechanisms

Where the primary performance mechanism of a treatment BMP is biofiltration, infiltration, filtration, or settling, excessive sediment can reduce the effectiveness over time by reducing stormwater contact with vegetation or clogging sands and other filtration media.

4.4.3. Applicability

4.4.3.1. Presettling and Pretreatment

Presettling should be evaluated for most BMPs to protect BMPs from excessive siltation and debris. Pretreatment may be required to remove TSS for infiltration and filtration BMPs and can be used as an alternative to presettling structures or cells. Refer to the individual BMP sections in *Chapter 5* for presettling and pretreatment requirements specific to those BMPs. Pretreatment should also be considered where the basic treatment BMP or the receiving water may be adversely affected by non-targeted pollutants (e.g., oil), or may be overwhelmed by a heavy load of targeted pollutants (e.g., suspended solids). General requirements for presettling and pretreatment are summarized in Table 4.1.

Table 4.1. Presettling and Pretreatment Requirements.

BMP	Presettling Cell or Structure	Alternative Pretreatment[b]	Reference
Infiltration Trenches	S	Basic Treatment BMP or Proprietary and Emerging Water Quality Treatment or Pretreatment Technologies[a]	*Section 5.4.2*
Drywells	A	Basic Treatment BMP or Proprietary and Emerging Water Quality Treatment Technologies[a]	*Section 5.4.3*
Infiltrating Bioretention	S	Basic Treatment BMP or Proprietary and Emerging Water Quality Treatment Technologies[a]	*Section 5.4.4*
Rain Gardens	N	Not applicable	*Section 5.4.5*
Permeable Pavement Facilities	S	Basic Treatment BMP or Proprietary and Emerging Water Quality Treatment Technologies[a]	*Section 5.4.6*
Permeable Pavement Facility/Infiltration Chamber combination	S	Basic Treatment BMP or Proprietary and Emerging Water Quality Treatment Technologies[a]	*Section 5.4.6*
Perforated Stub-out Connections	S	Not applicable	*Section 5.4.7*
Infiltration Ponds	S	Basic Treatment BMP or Proprietary and Emerging Water Quality Treatment Technologies[a]	*Section 5.4.8*
Infiltration Chambers/ Vaults	S	Basic Treatment BMP or Proprietary and Emerging Water Quality Treatment Technologies[a]	*Section 5.4.9*
Infiltrating Soil Cell Bioretention	A	Basic Treatment BMP or Proprietary and Emerging Water Quality Treatment Technologies[a]	*Section 5.4.10*
Permeable Pavement Surfaces	N	Not applicable	*Section 5.6.2*
Non-infiltrating Bioretention	S	Basic Treatment BMP or Proprietary and Emerging Water Quality Treatment Technologies[a]	*Section 5.8.2*
Detention Ponds	A	Basic Treatment BMP or Proprietary and Emerging Water Quality Treatment Technologies[a]	*Section 5.7.1*
Detention Pipes	S	Not applicable	*Section 5.7.2*
Detention Vaults	S	Not applicable	*Section 5.7.3*
Detention Chambers	S	Basic Treatment BMP or Proprietary and Emerging Water Quality Treatment Technologies[a]	*Section 5.7.3*

Table 4.1 (continued). Presettling and Pretreatment Requirements.

BMP	Presettling Cell or Structure	Alternative Pretreatment[b]	Reference
Detention Cisterns	N	Not applicable	*Section 5.7.4*
Basic Biofiltration Swale	S	Basic Treatment BMP or Proprietary and Emerging Water Quality Treatment Technologies[a]	*Section 5.8.3*
Wet Biofiltration Swale	S	Basic Treatment BMP or Proprietary and Emerging Water Quality Treatment Technologies[a]	*Section 5.8.3*
Compost-amended Biofiltration Swale	S	Basic Treatment BMP or Proprietary and Emerging Water Quality Treatment Technologies[a]	*Section 5.8.3*
Continuous Inflow Biofiltration Swale	N	Not applicable	*Section 5.8.3*
Basic Sand Filter Basin	A	Treatment Train	*Section 5.8.5*
Large Sand Filter Basin	A	Treatment Train	*Section 5.8.5*
Sand Filter Vaults	A	Treatment Train	*Section 5.8.5*
Linear Sand Filters	S	Treatment Train	*Section 5.8.5*
Basic Wet Pond	A	Treatment Train	*Section 5.8.6*
Large Wet Pond	A	Treatment Train	*Section 5.8.6*
Wet Vaults	A	Treatment Train	*Section 5.8.7*
Stormwater Treatment Wetlands	A	Treatment Train	*Section 5.8.8*
Combined Detention and Wet Pond	A	Treatment Train	*Section 5.8.9*
Combined Detention and Wet Vault	A	Treatment Train	*Section 5.8.9*
Combined Detention and Stormwater Wetland	A	Treatment Train	*Section 5.8.9*
American Petroleum Institute (API baffle type) Oil/water Separator	S	Basic Treatment BMP or Proprietary and Emerging Water Quality Treatment Technologies[a]	*Section 5.8.10*
Coalescing plate (CP) Oil/water Separator	S	Basic Treatment BMP or Proprietary and Emerging Water Quality Treatment Technologies[a]	*Section 5.8.10*
Proprietary and Emerging Water Quality Treatment Technology	OPTIONAL	Basic Treatment BMP or Proprietary and Emerging Water Quality Treatment Technologies[a]	*Section 5.8.11*
Non-infiltrating Soil Cell Bioretention	A	Basic Treatment BMP or Proprietary and Emerging Water Quality Treatment Technologies[a]	*Section 5.8.12*

S – Sometimes

A – Always

N – Not Required

[a] Refer to *Section 5.8.11* for more information on approved water quality technologies.

[b] Alternative pretreatment refers to pretreatment that can be used in lieu of presettling or to achieve metals or phosphorus treatment as described in Section 4.4.3.2.

4.4.3.2. Pretreatment prior to Infiltration to Achieve Metals and Phosphorus Treatment

Specific pretreatment requirements for metals and phosphorus treatment are summarized in the following subsections.

Metals Treatment

In addition to the requirements for presettling and pretreatment summarized in Table 4.1, infiltration through soils that meet the minimum soil suitability criteria for water quality treatment (refer to *Section 4.5.2*) are considered metals treatment if preceded by a presettling cell or Basic Treatment BMP, except where presettling is not required due to the size of the contributing basin. Refer to the design criteria for the specific BMP for further information about presettling requirements. Note: Bioretention systems that are constructed using the soil mix specified in *Section 5.4.4.5* will qualify as Metals Treatment.

Phosphorus Treatment

In addition to the requirements for presettling and pretreatment summarized in Table 4.1, the following combinations can also provide phosphorus treatment:

- Infiltration through soils that meet the minimum soil suitability criteria for water quality treatment (refer to *Section 4.5.2*) preceded by a presettling cell or Basic Treatment BMP, except where presettling is not required due to the size of the contributing basin. Refer to the design criteria for the specific BMP for further information about presettling requirements.
- Infiltration through soils that do NOT meet the minimum soil suitability criteria for water quality treatment (refer to *Section 4.5.2*) if:
  - It is preceded by a Basic Treatment BMP, AND
  - There is a minimum distance of 1/4 mile between the infiltration location and the phosphorus-sensitive receiving water (or tributary to that water).

  If the infiltration soils do not meet the soil suitability criteria for water quality treatment (refer to *Section 4.5.2*) and the infiltration site is within 1/4 mile of a nutrient-critical receiving water, or a tributary to that water, treatment must be provided by a phosphorus treatment train. At the time this Manual was developed, Green Lake was the only nutrient-critical receiving water determined to be impaired due to phosphorus contributed by stormwater. In the future, the City may designate additional waterbodies as nutrient-critical receiving water as defined by the SMC, Section 22.801.150. Refer to the SDCI website to determine if any nutrient-critical receiving waters have been designated (www.seattle.gov/sdci/codes/codes-we-enforce-(a-z)/stormwater-code).

4.4.4. Site Considerations

Refer to *Chapter 5* for specific presettling requirements for some BMPs. Additional site considerations may apply depending on site conditions and other factors.

- Presettling:
  - For site considerations related to catch basins used as presettling structures, refer to City of Seattle Standard Plan No. 240, 241, or equivalent.
  - Refer to Site Considerations in *Chapter 5* for more information on presettling site consideration requirements specific to BMPs.
- Pretreatment:
  - Refer to manufacturer guidance for site considerations for hydrodynamic separators and floatables capture.

4.4.5. Design Criteria

- Presettling:
  - When required by Table 4.1, inflows must be routed through a cell, structure, or deviceupstream of the BMP to capture sediment and reduce the potential for clogging. Refer to *Chapter 5* for specific presettling requirements for some BMPs. If no specific presettling requirements are provided in Chapter 5, a catch basin or other device with equal or better presettling ability when compared to City of Seattle Standard Plan No. 240 or 241 must be used.
  - If using a catch basin for presettling, provide a 2-foot-deep minimum sump below the outlet and a downturned elbow on the outlet.
- Pretreatment:
  - Refer to Table 4.1 for pretreatment options and refer to *Chapter 5* for specific design criteria for each BMP selected.
  - Refer to manufacturer guidance for design criteria for hydrodynamic separators and floatables capture, except when using bioretention. Refer to *Appendix E* for the use of Manufactured Treatment Devices prior to bioretention.
  - Refer to BMP T6.10: Presettling Basin in Volume V of the SWMMWW for specific design criteria and site constraints and setbacks including dam safety design and review requirements for impoundments that store greater than or equal to 10 acre-feet (435,600 cubic feet or 3.26 million gallons) above the natural ground level or have an embankment height of greater than 6 feet at the downstream toe.

4.4.6. Operations and Maintenance Requirements

Presettling and pretreatment BMP operations and maintenance requirements are provided in *Appendix G* for Infiltration Facilities, Biofiltration Swales, Filter Strips, Wet Ponds, Stormwater Treatment Wetlands, Sand Filter Basins, and Sand Filter Vaults.

Refer to Ecology's website and the manufacturer for BMP-specific maintenance requirements for hydrodynamic separators (https://ecology.wa.gov/Regulations-Permits/Guidance-technical-assistance/Stormwater-permittee-guidance-resources/Emerging-stormwater-treatment-technologies).

4.5. Infiltration BMPs

Infiltration BMPs have specific sizing guidelines and soil requirements that are summarized in the following subsections.

4.5.1. Infiltration BMP Sizing

Sizing for selected infiltration BMPs is provided in the BMP Sizing sections of *Chapter 5*. Below are the general procedures for sizing an infiltration BMP to: (A) infiltrate 100 percent of runoff; (B) infiltrating the runoff volume up to the 25-year recurrence interval per *Volume 3, Section 4.3.2*; (C) meet the water quality treatment requirements; and (D) meet flow control standards. Infiltration BMPs must be designed using an approved model. Note: the infiltration BMPs in this Manual are intended for stormwater only. Foundation/footing drains and other subsurface drainage intended to collect groundwater must not be directed to a stormwater infiltration BMP. They must bypass the stormwater infiltration BMP and discharge to the approved point of discharge or to separate infiltration BMPs. Refer to Section 4.5.1.1 below for information about infiltration BMPs for foundation/footing drains and subsurface drainage.

(A) For 100 percent infiltration (e.g., for project sites without a point of discharge):

- Input dimensions of the infiltration BMP into an approved model.
- Input design infiltration rate (measured infiltration rate with correction factor applied).
- Input a riser height and diameter to represent the BMP overflow conditions (any flow through the riser indicates that you have less than 100 percent infiltration and must increase the infiltration BMP dimensions).
- Run the model and review the model-reported percentage of runoff infiltrated. If less than 100 percent infiltrated, increase BMP dimensions until 100 percent infiltration is achieved. There is no need to check duration when infiltrating 100 percent of the full continuous record runoff file. Note: 100 percent infiltration is often confused with infiltrating the volume during the 100-year recurrence interval flow, which is not the case. 100 percent infiltration goes beyond the 100-year recurrence interval to infiltrate all runoff routed to the facility for the full simulation period using the required precipitation/evaporation time series in the stormwater model.

(B) For infiltrating the runoff volume up to the 25-year recurrence interval per *Volume 3, Section 4.3.2* (for small projects with no available off-site point of discharge as determined by the Director):

- The procedure is the same as option A, except that the target is to infiltrate the runoff volume from the area of development for the storm event with a 4 percent annual probability (25-year recurrence interval flow).
- Run the model and review the model-reported post-developed/mitigated peak discharge rates for the various return frequencies. If the discharge rates up to the 25-year recurrence interval are more than zero cfs, increase BMP dimensions until the discharge rates are zero up to the 25-year recurrence interval and the discharge during the 25-year recurrence interval is equal to or less than 0.0001 cfs. Note: the percentage infiltrated may be less than 100 percent if there is an

overland flow path for flows exceeding the capacity of the BMP that meets the requirements in *Volume 3, Section 4.3.2*. If not, then 100 percent infiltration per (A) above is required.

- If water quality treatment or flow control are also required, refer to (C) and (D) below.

(C) For 91 percent infiltration (water quality treatment requirement):

- The procedure is the same as option A, except that the target is to infiltrate 91 percent of the influent runoff volume. In addition, to prevent the onset of anaerobic conditions, an infiltration BMP designed for water quality treatment purposes must be designed to drain the water quality design treatment volume within 48 hours, or if using bioretention, within 24 hours. The water quality design treatment volume is reported by the approved models.
- The drawdown time can be calculated by using a horizontal projection of the ponding area mid-depth dimension and the design infiltration rate. Refer to *Section 4.5.2* for soil requirements for water quality treatment. Infiltrating bioretention is not permitted within 1/4 mile of nutrient-critical receiving waters if the underlying soil does not meet the soil requirements outlined in *Section 4.5.2* unless High Performance Bioretention Soil Mix (HPBSM) and a polishing layer are used.

(D) To meet flow control standards with infiltration:

- This design allows less than 100 percent infiltration as long as any BMP overflows meet the numerical peak and/or duration standards outlined in *Volume 1, Section 3.2*. Set up the model as explained for 100 percent infiltration (option A). Run the model and review the flow duration and flow frequency results to determine if the standard is achieved.

4.5.1.1. Infiltrating BMPs for Foundation/Footing Drains and other Subsurface Drainage Systems

In cases where there is no available point of discharge for foundation/footing drainage and other subsurface drainage systems, some designers elect to use an infiltration BMP such as a dry well as the discharge point for the subsurface drainage. Design of infiltrating BMPs for subsurface drainage, including foundation/footing drainage, underslab drainage, subsurface wall drainage etc., is at the designer's/owner's own risk. It is recommended that designers consult with a licensed professional, such as a Geotechnical Engineer, if infiltration is used for subsurface drainage. This manual does not include sizing criteria or design guidance for infiltrating BMPs used for subsurface drainage.

Subsurface drainage and project stormwater are not permitted to share a BMP. If an infiltrating BMP is used as the point of discharge for a subsurface drainage system, the BMP must be separated from any infiltrating BMP that is sized to infiltrate stormwater by at least 10 feet. Also, infiltrating BMPs for subsurface drainage must meet all setback and site constraints requirements for infiltrating BMPs as described in *Section 3.2*.

Pre-settling in a catch basin or similar structure with a sump and downturned elbow is recommended before the BMP to prevent sediment from reaching the BMP.

4.5.2. Soil Requirements for Water Quality Treatment

The soil requirements for water quality treatment vary depending on the type of infiltration BMP. Many infiltration BMPs (e.g., infiltration ponds, infiltration trenches, and permeable pavement facilities) rely on the properties of the underlying soils (i.e., existing underneath the facility) to meet water quality treatment requirements. Bioretention systems utilize imported soils meeting specific criteria to meet water quality treatment requirements. The following sections summarize the applicable soil requirements for both categories of BMPs.

4.5.2.1. Underlying Soil Requirements for Infiltration BMPs

Infiltration ponds, infiltration trenches, and permeable pavement facilities meet the requirements for basic, phosphorus, and metals treatment provided that the following soil suitability criteria are met:

- Soil Suitability Criteria #1 — For infiltration BMPs used for treatment purposes, the measured (initial) soil infiltration rate must be 9 inches/hour or less. Design (long-term) infiltration rates up to 3.0 inches/hour can also be considered if the infiltration receptor is not a sole-source aquifer as designated by EPA Region 10, and in the judgment of the experienced licensed professional, the treatment soil has characteristics comparable to those specified in Soil Suitability Criteria #2 to adequately control target pollutants.
- Soil Suitability Criteria #2 — The underlying soil for a depth of at least 18 inches must meet the following conditions:
    - Cation exchange capacity (CEC), as determined by U.S. EPA Method 9081, of the soil must be greater than or equal to 5 milliequivalents per 100 grams of dry soil. Lower CEC content may be considered if it is based on a soil loading capacity determination for the target pollutants that is approved by the Director.
    - Organic content of the treatment soil (ASTM D 2974): Organic matter can increase the sorptive capacity of the soil for some pollutants. Soil organic content should be at least 1 percent; however, the licensed professional designing the facility must evaluate whether the organic matter content is sufficient for control of the target pollutant(s).
- Soil Suitability Criteria #3 — Waste materials of any kind, including recycled materials, must not be used as infiltration media.

If existing site soils do not meet these criteria, the appropriate type of water quality treatment BMP (Metals, Phosphorus, or Basic) is required prior to infiltration. Refer to *Volume 1, Section 5.4.2* for the water quality treatment standards to be met and *Section 3.5* of this volume to determine the type of water quality treatment BMP to use to meet those standards.

4.5.2.2. Imported Soil and Sand

Infiltrating bioretention facilities (*Section 5.4.4*) meet the requirements for basic and metals treatment and are not subject to the same underlying soil requirements for infiltration ponds, infiltration trenches, and permeable pavement facilities (i.e., soil suitability criteria #1 through #3) because they use the City-specific standards for the imported bioretention soil mix. Soil requirements for bioretention facilities are provided in *Section 5.4.4.5*.

If a permeable pavement surface, or another surface designed to be equivalent to permeable pavement surfaces such as natural or artificial turf sports fields, is being designed to provide water quality treatment and the existing subgrade does not meet requirements for treatment soil provided in *Section 4.5.2*, a 6-inch water quality treatment course (12-inch if Metals Treatment is required) must be included between the subbase and the storage reservoir. The course must be composed of a media meeting the treatment soil criteria (*Section 4.5.2*) or the sand media material specification in Table 4.2 below.

Table 4.2 Sand Media Specification

Sieve Number	Percent Passing
4	95-100
8	70-100
16	40-90
30	25-75
50	2-25
100	<4
200	<2

Note: Standard backfill for sand drains, WSDOT Std. Spec. 9-03.13, does not meet the sand medium specification.

CHAPTER 5 – BMP Design

For each BMP in this chapter, detailed technical information is organized as follows:

- **Description**: provides a description of the BMP and each of the BMP configurations.
- **Performance Mechanisms**: defines how pollutants are removed (treatment mechanisms) and/or how stormwater discharge is managed (flow control mechanisms).
- **Applicability**: lists the BMP configurations that can be designed to meet the requirements for on-site stormwater management, flow control, water quality treatment (basic, metals, oil control, phosphorus), and/or conveyance.
- **Site Considerations**: identifies the limitations associated with siting each BMP. The application of a BMP may be constrained by factors such as approximate footprint, groundwater elevation, soil characteristics, and other site-specific conditions.
- **Design Criteria**: provides descriptions and specifications for BMP components and materials.
- **BMP Sizing**: presents sizing requirements and modeling procedures for each BMP. General modeling guidance is provided in *Appendix F*.
- **Minimum Construction Requirements**: describes critical considerations during construction of the BMP, such as erosion control, landscape stabilization, and timing of BMP installation.
- **Operations and Maintenance Requirements**: provides a reference to the operations and maintenance (O&M) requirements included in *Appendix G*.

5.1. Soil Amendment BMP

5.1.1. Description

Site soils must meet minimum quality and depth requirement at project completion. This code requirement must be met by:

- Retention and protection of undisturbed soil; or
- Restoration of soil quality and depth (e.g., amending with compost) in disturbed areas

Additional guidance for this BMP can be found in Seattle Tip 531, Post Construction Soil Management, and *Building Soil: Guidelines and Resources for Implementing Soil Quality and Depth BMP T5.13* (Stenn et al. 2018), which is available at the building soil website (https://www.soilsforsalmon.org/).

5.1.2. Performance Mechanisms

Naturally occurring (undisturbed) soil, soil organisms, and vegetation provide the following important stormwater management functions:

- Water infiltration
- Nutrient, sediment, and pollutant adsorption
- Sediment and pollutant biofiltration
- Water interflow storage and transmission
- Pollutant decomposition

These functions are largely lost when development strips away underlying soil and vegetation and replaces it with minimal soil and sod. Soil amendment helps to regain greater stormwater functions in the post development landscape, provide increased treatment of pollutants and sediments that result from development and habitation, and minimize reliance on chemicals for weed/pest control or plant vigor, thus protecting water quality through prevention.

5.1.3. Applicability

Soil amendment BMP requirements are applicable to all areas subject to clearing, grading, or compaction (including construction laydown areas) that have not been covered by hard surface, incorporated into a stormwater BMP, or engineered for stability (e.g., structural fill or cut slope(s) for sediment and erosion control).Only the areas of the sites where existing vegetation and/or soil are disturbed or compacted are required to be restored.

Soil amendment can also be used to help achieve on-site stormwater management, flow control, and water quality treatment standards. Refer to *Section 5.3* for integrating soil amendment with dispersion BMPs and *Section 5.1.6* for modeling amended soils.

5.1.4. Site Considerations

On slopes exceeding 33 percent, soil amendment is not required but may be used if recommended by a licensed professional.

5.1.5. Design Criteria

This section describes the implementation options and design requirements for the soil amendment BMP. Typical cross-sections of compost-amended soil in planting bed and turf applications are shown in Figure 5.1. Design criteria are provided in this section for the following elements:

- Soil amendments
- Implementation options
- Soil retention
- Soil Management Plan

5.1.5.1. Soil Amendments

Soil organic matter is often missing from disturbed soils. Replenish organic matter by amending with compost. Standardized "pre-approved" soil amendment rates have been established for planting beds and turf areas. Alternatively, custom amendment rates may be calculated. Both options are described in further detail in the subsequent section.

All areas subject to clearing and grading that have not been covered by hard surface, incorporated into a drainage facility, or engineered as structural fill or slope must, at project completion, demonstrate the following:

- A topsoil layer, whether stockpiled soil, amended soil or imported soil, meeting these requirements:
    - An organic matter content, as measured by the loss-on-ignition test, of a minimum 8 percent (target 10 percent) dry weight in planting beds, or a minimum 4 percent (target 5 percent) organic matter content in turf areas. Acceptable test methods for determining loss-on-ignition soil organic matter include the most current version of ASTM D2974 (Test Methods for Moisture, Ash, and Organic Matter of Peat and Other Organic Soils) and TMECC 05.07A (Loss-on-ignition Organic Matter Method).
    - A pH from 6.0 to 8.0 or matching the pH of the original undisturbed soil.
    - A minimum depth of 8 inches.
    - These requirements may be met with the City of Seattle Standard Specifications: 914.1(2) Topsoil Type A — Imported; 914.1(3) Reused Amended Site Soil; 914.1(5) Planting Soil; or 914.1(6) General Turf Area Soil.
- Root zones within the dripline of existing trees to be retained must be protected from all disturbance and/or construction impacts. Refer to City of Seattle Standard Plan No. 133 and Standard Specification 8-01.3(2)B for applicable tree retention requirements. Fence and protect these root zones from stripping of soil, grading, or compaction to the maximum extent practical.
- Scarify subsoils below the topsoil layer at least 4 inches for a finished minimum depth of 12 inches of uncompacted soil. Incorporate some of the upper material to avoid stratified layers, where feasible.
- After planting: mulch planting beds with 2 to 4 inches of organic material such as arborist wood chips, medium compost, or coarse compost.

- Use compost and other materials that meet either of the two following organic content requirements:
    - The organic content for "pre-approved" amendment rates can only be met using compost that meets the definition of "composted materials" in WAC 173350 Section 220. Compost meeting the City of Seattle Standard Specification 9.14.4(8) Compost is recommended but not required. The compost must have an organic matter content of 40 percent to 65 percent, and a carbon to nitrogen ratio below 25:1. As an exception, the carbon to nitrogen ratio may be as high as 35:1 for plantings composed entirely of plants native to the Puget Sound Lowlands region.
    - Calculated amendment rates may be met through use of composted materials as defined above, or other organic materials amended to meet the carbon to nitrogen ratio requirements, and meeting the contaminant standards compost specified in WAC 173-350 Section 220. Refer to the *Building Soil* manual (Stenn et al. 2018) or website (www.buildingsoil.org) for the method of calculating custom amendment rates.

Ensure that the resulting soil is suitable for the type (species) of vegetation to be established. A qualified horticultural, soil or landscape design professional may submit a Soil Management Plan showing different amounts or types of soil amendment and mulch than those described in the "pre-approved" rates. Carbon-to-nitrogen ratios and soil pH may also be varied to suit plant needs. The Soil Management Plan must describe how the soil preparation is conducive to the type of vegetation to be established. It must still provide the required uncompacted soil depth and as much organic matter as the vegetation will tolerate, with an appropriate surface mulch after planting.

5.1.5.2. Implementation Options

The soil quality design requirements can be met by using one of the four options listed below:

1. Retain and Protect Undisturbed Soil:
    - Leave undisturbed vegetation and soil, and protect from compaction by fencing and keeping materials storage and equipment off these areas during construction. Refer to City of Seattle Standard Specification 8-01.3(2)B for protection requirements such as fencing and other applicable protection measures.
    - For all areas where soil or vegetation are disturbed, use option 2, 3, or 4.
2. Amend Soil:
    - Amend existing site *in situ* topsoil or subsoil either at default "pre-approved" rates, or at custom calculated rates to meet the soil quality guidelines based on engineering tests of the soil and amendment. The default pre-approved rates are:
        - In planting beds: place 3 inches of compost and till in to an 8-inch depth.
        - In turf areas: place 1.75 inches of compost and till in to an 8-inch depth.
        - Scarify (loosen) subsoil 4 inches below amended layer to produce a 12-inch depth of un-compacted soil.
        - After planting: apply 2 to 4 inches of arborist wood chips, medium compost, or coarse compost in the planting beds. Coarse bark mulch may be used but has lower benefits to plants and soil. Do not use fine bark because it can seal the soil surface.

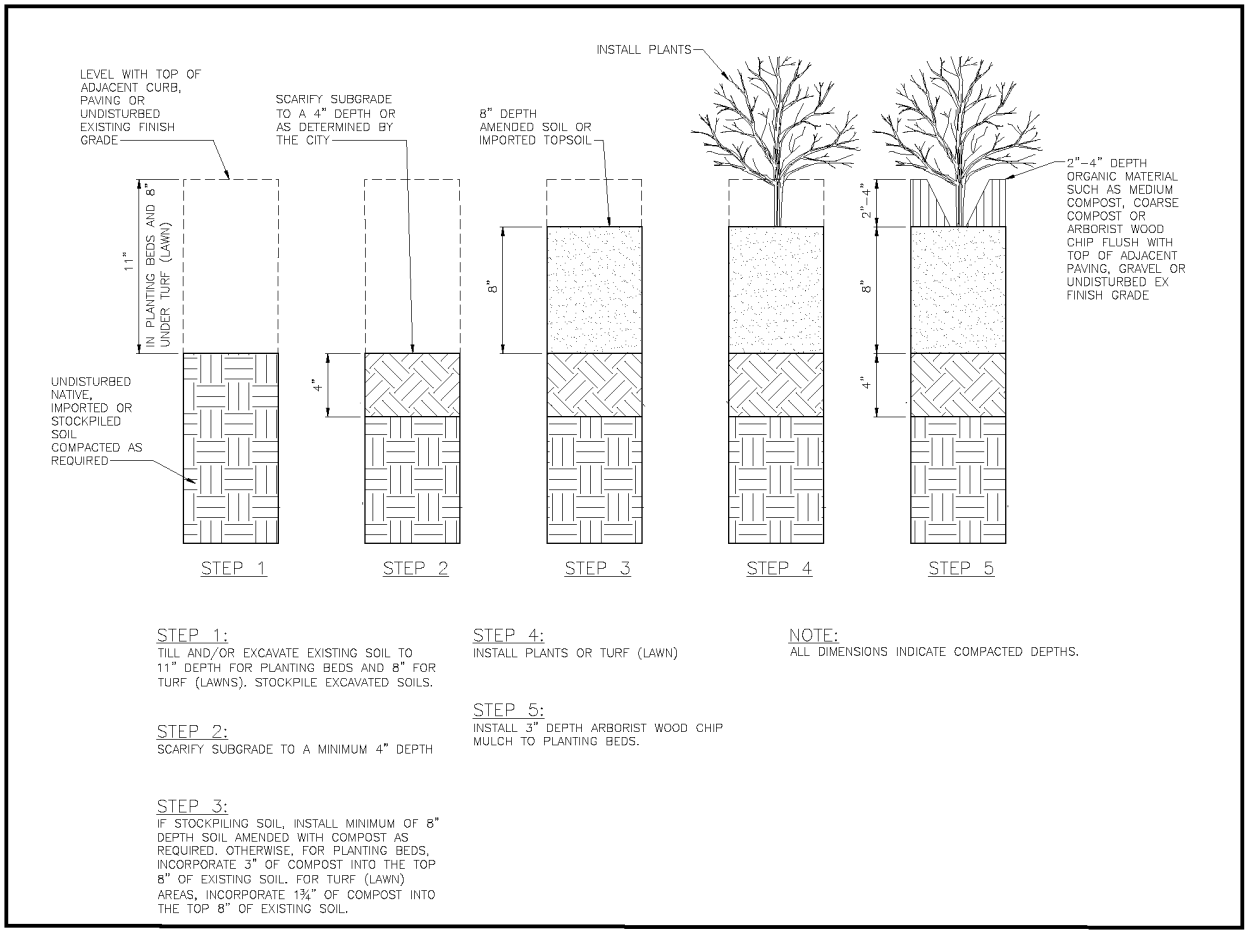


Figure 5.1. Cross-Section of Soil Amendment.

3. Stockpile Soil:
   - Stockpile existing topsoil during grading and replace it prior to planting. Amend stockpiled topsoil if needed to meet the organic matter or depth requirements either at the default "pre-approved" rate or at a custom calculated rate (refer to the Building Soil manual [Stenn et al. 2018] or website (www.buildingsoil.org), for custom calculation method). Scarify subsoil and mulch planting beds, as described in option (2) above.
4. Import Soil:
   - Import topsoil mix of sufficient organic content and install to meet depth requirements. Imported soils should not contain excessive clay or silt fines (more than 5 percent passing the No. 200 sieve) because that could restrict stormwater infiltration. The default pre-approved rates for imported topsoils are:
     - For planting beds: use a mix by volume of 35 percent compost with 65 percent mineral soil to achieve the requirement of a minimum 8 percent (target 10 percent) organic matter by loss-on-ignition test.
     - For turf areas: use a mix by volume of 20 percent compost with 80 percent mineral soil to achieve the requirement of a minimum 4 percent (target 5 percent) organic matter by loss-on-ignition test.
     - Scarify subsoil and mulch planting beds, as described in option (2) above.

Note: More than one method may be used on different portions of the same site.

5.1.5.3. Soil Retention

Retain and protect the duff layer and native topsoil in an undisturbed state to the maximum extent feasible, and protect from compaction (SMC, Section 22.805.020.D.2).

Prior to disturbance of areas not subject to soil retention requirements, remove, stockpile, and protect the duff layer and topsoil on site in a designated, controlled area, which is not adjacent to public resources and critical areas. Distribute stockpiled materials to areas shown on project plans for new tree and/or plant installation.

Root zones where tree roots limit the depth of incorporation of amendments are exempted from this requirement. Fence and protect these root zones from stripping of soil, grading, or compaction to the maximum extent practical.

5.1.5.4. Soil Management Plan

A Soil Management Plan is required and must include the following:

- A site map showing areas to be fenced and left undisturbed during construction, and areas that will be amended at the turf or planting bed rates
- Calculations of the amounts of compost, compost amended topsoil, and mulch to be used on the site.

5.1.6. BMP Sizing

When the soil amendment BMP is applied as part of a dispersion BMP design, the On-site List Requirement is met for the hard surface area that is dispersed. On-site stormwater management and flow control standards can also be met or partially met as described under the following sections:

- Full Dispersion (*Section 5.3.2*)
- Splashblock Downspout Dispersion (*Section 5.3.3*)
- Trench Downspout Dispersion (*Section 5.3.4*)
- Sheet Flow Dispersion (*Section 5.3.5*)
- Concentrated Flow Dispersion (*Section 5.3.6*)

All areas that are amended using implementation options 2, 3, or 4 from *Section 5.1.5.2* may be modeled as pasture rather than lawn (WWHM) or grass (MGSFlood).

5.1.7. Minimum Construction Requirements

Minimum construction requirements for disturbed areas include the following:

- Incorporate soil to meet Soil Amendment BMP requirements toward the end of construction. Protect amended areas from erosion or damage by work as well as any other site improvements to follow.
- Plant soil with appropriate vegetation and mulch planting beds.

Additional information is provided in the *Building Soil* manual (Stenn et al. 2018).

5.1.8. Operations and Maintenance Requirements

The most important maintenance practice is to replenish the soil organic matter by leaving leaf litter and grass clippings on-site (or by adding compost and mulch regularly). This routinely scheduled task is necessary to minimize reliance on chemicals for weed/pest control or plant vigor, thus protecting water quality.

5.2. Tree Retention and Planting

5.2.1. Description

New trees can be planted and/or existing trees can be protected and retained on a project site to achieve on-site stormwater management and/or flow control credits.

5.2.2. Performance Mechanisms

Trees provide flow control via interception, transpiration, and increased infiltration. Additional environmental benefits include improved air quality, carbon sequestration, reduced heat island effect, pollutant removal, and habitat.

5.2.3. Applicability

Retained and newly planted trees can be used to provide on-site stormwater management and flow control for hard surfaces. The degree of flow control that can be provided depends on the tree type (i.e., evergreen or deciduous), canopy area, and whether or not the tree canopy overhangs hard surfaces. Retained and newly planted trees can be applied to meet or partially meet the requirements listed below.

BMP	On-site: List	On-site: Standard	Flow Control: Forest	Flow Control: Pasture	Flow Control: Peak	Water Quality: Basic	Water Quality: Enhanced Metals	Water Quality: Oil Control	Water Quality: Phosphorus	Conveyance
Tree Planting and Retention	x	x[a]	x[a]	x[a]	x[a]					

[a] Standard may be partially achieved and additional BMPs may be needed to meet the on-site standard or flow control standard.

5.2.4. Site Considerations

Retained or newly planted trees within 20 feet of ground level hard surfaces such as driveways, patios, and parking lots can be used to provide flow control benefits and on-site stormwater management. Refer to *Appendix C* for additional infeasibility criteria for the On-site List Approach.

Retained or newly planted trees may also count toward Green Factor, landscaping, and/or tree protection requirements.

Site considerations specific to retained and newly planted trees are provided below.

5.2.4.1. Retained Trees

Setbacks of proposed infrastructure from existing trees are critical site-planning considerations. Tree protection requirements limit grading and other disturbances in proximity to the tree (refer to SMC Chapter 25.11, City of Seattle Standard Specification 107.16(2), 801.3(2)B, and City of Seattle Standard Plan No. 132 and 133).

5.2.4.2. Newly Planted Trees

Mature tree height, size, and rooting depth must be considered to ensure that the tree location is appropriate given adjacent and above- and below-ground infrastructure. See the Design Criteria for setbacks, spacing and tree location requirements.

5.2.5. Design Criteria

This section provides the design requirements for retained trees and newly planted trees.

5.2.5.1. Retained Trees

Trees can be used to provide on-site stormwater management or flow control if the requirements described below are met. Design criteria are provided in this section for the following elements:

- Tree condition, species and compatibility with construction
- Tree size
- Tree canopy area (based on dripline delineation)
- Tree location (with setbacks from ground level hard surfaces and underground utilities)

Tree Condition, Species, and Compatibility with Construction

Clearly show existing tree species and tree locations on submittal drawings. Trees to be retained must be adequately viable for long-term retention (i.e., in good health and compatible with proposed construction).

Tree Size

Retained trees must have a minimum 4-inch diameter at standard height (DSH) to meet on-site stormwater management or flow control. DSH is defined as the outside bark diameter at 4.5 feet above the ground on the uphill side of a tree. An existing tree smaller than this will be treated as a newly planted tree if the requirements presented in *Section 5.2.5.2 Newly Planted Trees* are met.

Tree Canopy Area

The canopy area of the retained tree is measured as the area within the tree dripline. A dripline is defined as Zone B Critical Root Zone in the city of Seattle Standard Plan No. 133, the diameter of which is calculated as 2 feet for every 1 inch of trunk diameter measured at 4.5 feet above grade, minimum 8 feet. If trees are clustered, overlapping canopies are not double counted.

Tree Location

Retained trees can manage on-site stormwater or flow control depending upon proximity to ground level hard surfaces. The existing tree must be located on the development site or abutting right-of-way and within 20 feet of new or replaced ground level hard surfaces (e.g., driveway, patio, parking lot). For single-family residential projects only, trees located on the development site or abutting right-of-way that are 20 feet or less from existing ground level hard surfaces in the right-of-way (e.g., sidewalk) can be used to provide on-site stormwater management or flow control. Distance from the edge of hard surfaces is measured from the

tree trunk center at ground level. Refer *Section 5.2.4.1* for other setbacks applicable to retained trees. Existing trees do not have a minimum spacing from other trees.

The City may require an arborist report if a hard surface is proposed within the interior critical root zone of the existing tree. The interior critical root zone is labeled as Zone A in the City of Seattle Standard Plan No. 133 and defined as the line encircling the base of the tree within half the diameter of the dripline. If the arborist report concludes that the hard surface should not be placed within 20 feet of the tree trunk center, but canopy overlap with hard surface is still anticipated despite a longer setback, the design may be approved.

Retained trees planted in planter boxes can contribute to on-site stormwater management and flow control if the planters provide minimum soil depth and minimum soil volume presented in Table 5.1.

5.2.5.2. Newly Planted Trees

To meet on-site stormwater management and/or flow control by planting trees on a project site, the design requirements for the elements described below must be met, including:

- Tree species
- Tree size
- Tree location (with setbacks from ground level hard surfaces structures and belowground utilities)
- Plant material and planting specifications
- Irrigation

Tree Species

Approved tree species for on-site stormwater management or flow control on private properties are listed in the SDCI Tree List posted on SDCI's Green Factor website. Trees on private property may also be selected from the bioretention tree lists in Appendix J, Section J-1 or the SDOT Tree List. Approved tree species for the right-of-way are listed in the SDOT Approved Street Tree List on their website. Tree species' height must reach a minimum of 15 feet at maturity and have a canopy of 15 feet or greater in order to be use for on-site stormwater or flow control management.

Tree species not included in the SDCI Tree List posted on SDCI's Green Factor website may be approved provided the applicant provides two references showing how each tree is appropriate for Seattle's climate. References can include written recommendations from a WSNLA-certified horticulturalist (or equal) practicing in western Washington. In the ROW, tree species not included on SDOT's Approved Street Tree List must have the documentation above and be approved by SDOT.

Note: native trees are encouraged. The SDCI Tree List and the SDOT Approved Tree List contain more options for native trees than can be found in Appendix J because the trees in Appendix J are specific to use in or around bioretention facilities.

Tree Size

New deciduous trees with a single trunk must be at least 2 inches in diameter measured 6 inches above the ground to meet on-site stormwater management or flow control. New deciduous trees with a single trunk planted in the right-of-way must be a minimum of 2inches in diameter (e.g., caliper) measured 6 inches above the ground. Multi-stemmed deciduous trees must have at least three stems and be at least 6 feet tall. New evergreen trees must be at least 5 feet tall.

Tree Location

Locate trees according to sun, soil, and moisture requirements. Select planting locations to ensure that sight distances and appropriate setbacks are maintained given mature height, size, and rooting depths.

Trees used to provide on-site stormwater management or flow control must meet the tree location requirements listed in *Section 5.2.5.1, Retained Trees*.

Tree Setbacks

Although setbacks will vary by species, some general recommendations are presented below.

- Minimum 5- foot or 1/23 the mature canopy diameter, whichever is greater, setback from structures. Refer to the tree list in *Appendix J* or the SDCI's Green Factor Tree List for canopy size.
- Minimum 5- foot setback from underground utility lines
- Minimum 2- foot setback from edge of any paved surface

Tree Spacing

To help ensure tree survival and canopy coverage, the minimum tree spacing for newly planted trees must accommodate mature tree spread (refer to the Green Factor Tree List posted on SDCI's website for parcel-based projects or the SDOT Approved Tree List for projects in the ROW). New trees with on-center spacing less than 14 feet will not be considered for on-site stormwater management or flow control.

Trees on private property must be planted no closer than the following minimum spacing:

1. 10 feet on center between small/constrained site or small trees (less than or equal to 15 feet mature canopy spread)
2. 14 feet on center between small/medium trees (greater than 15 and less than or equal to 20 feet mature canopy spread)
3. 18 feet on center between medium/large trees (greater than 20 and less than or equal to 25 feet mature canopy spread)
4. 22 feet on center between large trees (greater than 25 feet mature canopy spread)

Trees in the ROW must be spaced according to SDOT standards based on growing conditions. Alternative tree spacing can be approved for parcels if the intent is to establish a grove by providing a design and maintenance plan describing how trees will be established and submitted by either a licensed landscape architect or horticulturalist.

Tree Soil Width, Depth, and Volume

New trees planted in planters on site or specifically approved and permitted for the ROW can be used to provide on-site stormwater management or flow control if the planters provide minimum soil width, depth, and volume standards. For new trees planted in planters on site, a minimum soil width of 4 feet is required. For new trees planted in planters in the ROW, refer to Standard Plan No. 100a, 100b, and 101. Minimum soil depths and volume standards are presented in Table 5.1.

Table 5.1. Minimum Soil Requirements for Trees in Planters.

Tree Size Category[a]	Planting Area Minimum Soil Depth	Planting Area Minimum Soil Volume[b]	Example Dimensions[c]
Small/Constrained Site Trees[d,e]	36”	250 cubic feet	10 feet x 10 feet
Small Trees[d,e]	36”	500 cubic feet	12 feet x 15 feet
Small/Medium Trees	36”	1000 cubic feet	12 feet x 28 feet
Medium/Large Trees	36”	1000 cubic feet	12 feet x 28 feet
Large Trees	36”	1200 cubic feet	20 feet x 20 feet

[a] Tree size categories from the City of Seattle Green Factor.

[b] Note that these are minimum soil volume requirements. Trees will be healthier, bigger, and longer-lived if greater soil volume is provided.

[c] Surface area and example dimensions assumes minimum soil depths shown and are rounded up to meet the minimum soil volume. If adjacent paved surfaces are engineered for structural support, then a portion of the planter could be located under the paved area.

[d] Small/constrained site and small trees can only be used in planter boxes on site.

[e] Small/constrained site and small trees cannot be used to provide on-site stormwater management or flow control. However, these trees may be used or required in infiltrating bioretention, infiltrating soil cell bioretention, and non-infiltrating soil cell bioretention.

Guidance for incorporating trees into BMPs can be found in *Section 5.4.4.5* for infiltrating bioretention and *Sections 5.4.10* and *5.8.12* for infiltrating and non-infiltrating soil cell bioretention, respectively.

Plant Material and Planting Specifications

Recommended guidelines for planting materials and methods are provided in City of Seattle Standard Specifications 8-02 and 9-14, and Standard Plan No. 100a, 100b, and 101.

5.2.6. BMP Area Managed

5.2.6.1. Area Managed for On-site List Approach

Hard surface areas managed by newly planted trees meet the On-site List Requirement (refer to *Section 3.3.1*). Trees must meet the Design Criteria in *Section 5.2.5*. Retained trees meeting the requirements presented in this section may also be used to meet the on-site list requirement.

The amount of hard surface area managed by retained and newly planted trees is provided in Tables 5.2 and 5.3. The area managed can be applied to reduce the hard surface area requiring on-site stormwater management.

Table 5.2. Pre-sized On-site Stormwater Management and Flow Control Area Managed for Retained Trees.

Tree Type	Area Managed
Evergreen	20% of canopy area (minimum of 100 square feet/tree)
Deciduous	10% of canopy area (minimum of 50 square feet/tree)

Hard Surface Area Managed = Σ Canopy Area x Credit (%)/100.

Table 5.3. Pre-sized On-site Stormwater Management and Flow Control Area Managed for Newly Planted Trees.

Tree Type	Area Managed
Evergreen	50 square feet/tree
Deciduous	20 square feet/tree

Hard Surface Area Managed = Σ Number of Trees x Credit (square feet/tree).

5.2.6.2. Pre-sized Approach for Flow Control

The Pre-sized Approach may be used for projects with new and replaced hard surface areas up to 10,000 square feet. Flow control area managed credits for retained and newly planted trees are provided in Tables 5.2 and 5.3. The area managed can be applied to reduce the hard surface area requiring flow control.

To use this approach, the requirements outlined in *Section 5.2.5 Design Criteria* must be met. The total reduction of hard surface area for retained and newly planted trees must not exceed 25 percent of the new plus replaced hard surface requiring mitigation. This approach is not applicable to trees located in native vegetation areas used for flow dispersion or other flow control or on-site stormwater management credit.

5.2.6.3. Modeling Approach for On-site Performance Standard and Flow Control

When using the Modeling Approach to meet the On-Site Performance Standard or flow control standards, retained and newly planted trees (Tables 5.2 and 5.3) can be applied as explained for the *Pre-sized Approach for Flow Control*. The hard surface areas managed by the retained and newly planted trees need not be entered into the continuous runoff hydrologic model when sizing other on-site stormwater management or flow control BMPs.

5.2.7. Minimum Construction Requirements

Trees must be protected in accordance with SMC Tree Protection Chapter 25.11, City of Seattle Standard Specification 107.16(2), 801.3(2)B, and City of Seattle Standard Plan No. 132a and 133. Plans must demonstrate avoidance of all proposed construction impacts—including all ground disturbance, demolition, over excavation for shoring, access, staging, laydown, paving, structures, etc.—to the basic tree protection area for trees to be retained on adjacent parcels. Plans must show all tree protection measures such as tree protection fencing, and other measures recommended by the project's arborist for all trees to be retained. The basic tree protection area must be enclosed in fencing at least four feet tall. The fencing must be made of chain link or orange polyethylene laminar safety netting attached to metal stakes, unless an alternate option is submitted and approved for use. Signs must be posted on the fence and maintained in place until approved for removal. These signs

must be at least 8.5 inches by 14 inches and explain the purpose of the fencing and the restrictions on activity within the fencing. In addition, the Director may establish conditions for protecting a tree during construction outside the basic protection area to protect feeder roots.

Planting methods for new trees are provided in *Section 5.2.5.2 Newly Planted Trees*.

5.2.8. Operations and Maintenance Requirements

The following O&M requirements apply to retained trees:

- Retain, maintain, and protect trees on the site for the life of the development or until any approved redevelopment occurs.
- Prune when necessary, for compatibility with site uses or right of way functions, for clearances from public and privately owned infrastructure and/or to avoid damage to trees, important to preserve the health and longevity of trees. Meet industry standards for pruning (ANSI A300 standards).
- Replenish mulch annually to retain soil moisture.

The following O&M requirements apply to newly planted trees:

- Provide supplemental irrigation of 15-20 gallons of water twice a week for at least five years after planting to help ensure tree survival.
- Mulch with arborist wood chips annually to retain soil moisture. Spread mulch in a 2- to 4 inch thick layer in a donut shape around the tree spaced a hand's-width from the tree base.
- Replace dead or declining trees per planting plan or acceptable substitute.

Additional O&M requirements, including requirements for dead or declining trees, are provided in *Appendix G* (*BMP No. 27*).

5.3. Dispersion BMPs

Dispersion BMPs disperse runoff over vegetated pervious areas to provide flow control. The dispersion BMPs in this section include:

- Full dispersion
- Splashblock downspout dispersion
- Trench downspout dispersion
- Sheet flow dispersion
- Concentrated flow dispersion

Key design requirements that are common to all dispersion BMPs are provided in *Section 5.3.1*. Guidance and requirements that are specific to the different types of dispersion are provided in the subsequent sections.

5.3.1. Design Requirements for Dispersion BMPs

5.3.1.1. General Site Considerations

The following are key considerations in determining the feasibility of dispersion BMPs for a particular site:

- Dispersion flow path area — Dispersion BMPs generally require large areas of vegetated ground cover to meet flow path requirements and are not feasible in most urban settings.
- Erosion or flooding potential — Dispersion is not allowed in settings where the dispersed flows might cause erosion or flooding problems, either onsite or on adjacent properties.
- Site topography — Dispersion flow paths are prohibited in and near certain sloped areas (refer to flow path requirements below).

5.3.1.2. General Design Criteria for Dispersion Flow Paths

Flow Path design requirements that are common to all dispersion BMPs are listed below. Additional requirements that are specific to each of the dispersion types are provided in each BMP section.

- The vegetated flow path must consist of either undisturbed, well-established native landscape or lawn, or landscape or groundcover over soil that meets the Soil Amendment BMP requirements outlined in *Section 5.1*.
- To ensure that the groundcover is dense to help disperse and infiltrate flows and prevent erosion, the design plans must specify that vegetation coverage of plants will achieve 90 percent coverage within 1 year.
- The flow path topography must promote shallow sheet flow across a width of no less than 6 feet for dispersion points (i.e., splashblocks or rock pads) or the width of the dispersion device (i.e., trench or sheet flow transition zone).
- The dispersion flow path is not typically permitted within landslide-prone areas as defined by the Regulations for Environmentally Critical Areas (SMC, Section 25.09.030).

- The dispersion flow path is not typically permitted within a setback above a steep slope area (SMC, Section 25.09.020). The setback is calculated as 10 times the height of the steep slope area (to a 500foot maximum setback). Dispersion within this setback may be feasible provided a slope stability analysis is completed by a geotechnical engineer. The analysis must determine the effects that dispersion would have on the steep slope area and adjacent properties.
- The dispersion flow path is not permitted within 100 feet of a contaminated site or landfill (active or closed).
- For sites with septic systems, the point of discharge to the dispersion device (e.g., splash block, dispersion trench) must be downgradient of the drainfield primary and reserve areas.

5.3.2. Full Dispersion

On-site stormwater management, flow control, and/or water quality treatment standards may be provided using full dispersion as presented in the SWMMWW. The requirements for full dispersion are difficult to achieve in an urban setting. As an example, for the entire site of a residential development to be fully dispersed, it must preserve 65 percent in a forested or native condition and limit the impervious site coverage to 10 percent. However, if the entire site cannot be fully dispersed, portions of it may be fully dispersed if there is a vegetated flow path of at least 100 feet downstream of the surface to be dispersed. Given the large extent of vegetative cover required for full dispersion, these credits will most likely only apply to Seattle Parks and Recreation or large campus projects.

Refer to BMP T5.30 in Volume V of the SWMMWW for full dispersion applicability, site considerations, design criteria, modeling requirements, and minimum construction requirements.

5.3.3. Splashblock Downspout Dispersion

5.3.3.1. Description

Splashblock downspout dispersion consists of a splashblock or crushed rock pad used to disperse downspout flows to a downslope well-vegetated flow path of at least 50 feet.

5.3.3.2. Performance Mechanisms

Splashblock downspout dispersion can provide flow control via attenuation, soil storage, and losses to infiltration, evaporation, and transpiration.

5.3.3.3. Applicability

Splashblock downspout dispersion can be designed to provide on-site stormwater management and flow control. This BMP can be applied to meet or partially meet the requirements listed below. If the designer implements a dispersion BMP to meet water quality treatment standards, the BMP must be designed using the additional design requirements for vegetated filter strips per *Section 5.8.4*.

BMP	On-site: List	On-site: Standard	Flow Control: Forest	Flow Control: Pasture	Flow Control: Peak	Water Quality: Basic	Water Quality: Enhanced Metals	Water Quality: Oil Control	Water Quality: Phosphorus	Conveyance
Splashblock downspout dispersion	x	x[a]	x[a]	x[a]	x[a]	x[b]				

[a] Standard may be partially or completely achieved depending upon underlying soil type.

[b] Must meet additional design requirements for vegetated filter strips (refer to *Section 5.8.4*) to fully meet the water quality treatment requirement.

5.3.3.4. Site Considerations

General site considerations for determining the feasibility of dispersion BMPs for a particular site are provided in *Section 5.3.1.1*. Refer to *Appendix C* for additional infeasibility criteria for the On-site List Approach.

5.3.3.5. Design Criteria

This section provides a description and requirements for the components of splashblock downspout dispersion. Typical components of splashblock downspout dispersion are shown in Figure 5.2. Design criteria are provided in this section for the following elements:

- Contributing area
- Splashblock or rock pad
- Dispersion flow path
- Overflow

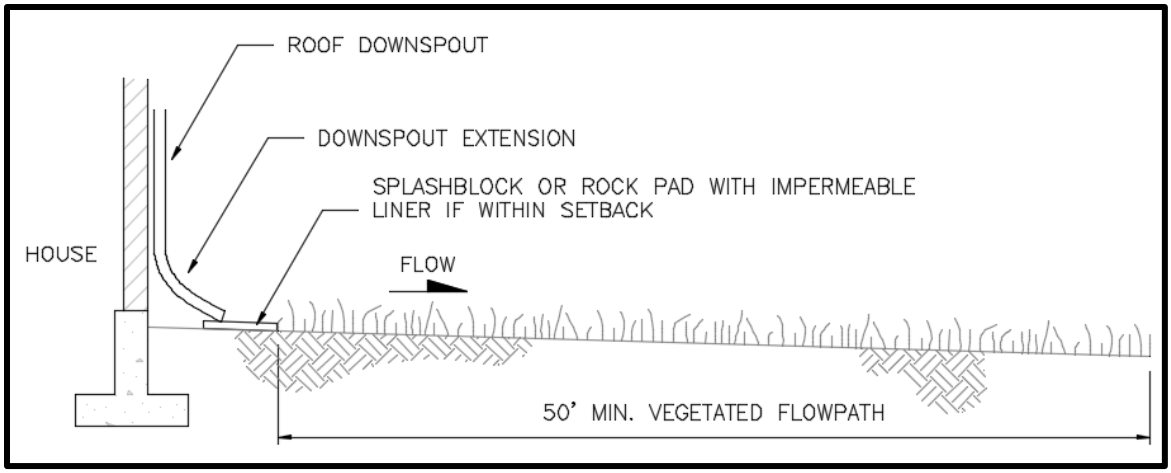


Figure 5.2. Typical Downspout Splashblock Dispersion.

Some of the critical requirements for splashblock downspout dispersion (e.g., flowpaths, setbacks) are shown in Figure 5.3.

Contributing Area

A maximum of 700 square feet of roof area may drain to each splashblock. If at least 50 percent of the roof is a vegetated roof, contributing roof areas up to 900 square feet will be allowed.

Splashblock or Rock Pad

A splashblock or a pad of crushed rock (2 feet wide by 3 feet long by 6 inches deep) must be placed at each downspout point of discharge.

There are two approved methods for splashblock downspout dispersion:

- *Splashblock/Rock Pad*: If the ground is sloped away from the foundation, and there is adequate vegetation and area for effective dispersion, splashblocks/rock pads will typically be adequate to disperse stormwater runoff.
- *Splashblock/Rock Pad with downspout extension:* If the ground is fairly level, the building includes a basement, or if foundation drains are proposed, splashblocks with downspout extensions should be used to move the point of discharge away from the foundation. Downspout extensions can include piping to a splashblock/rock pad a considerable distance from the downspout.

The dispersion device (e.g., end of splash block, edge of rock pad, or edge of dispersion trench) must be at least 5 feet from a structure. A 10-foot setback from a building with a basement is recommended. The rock pad must have an impermeable liner within this setback.

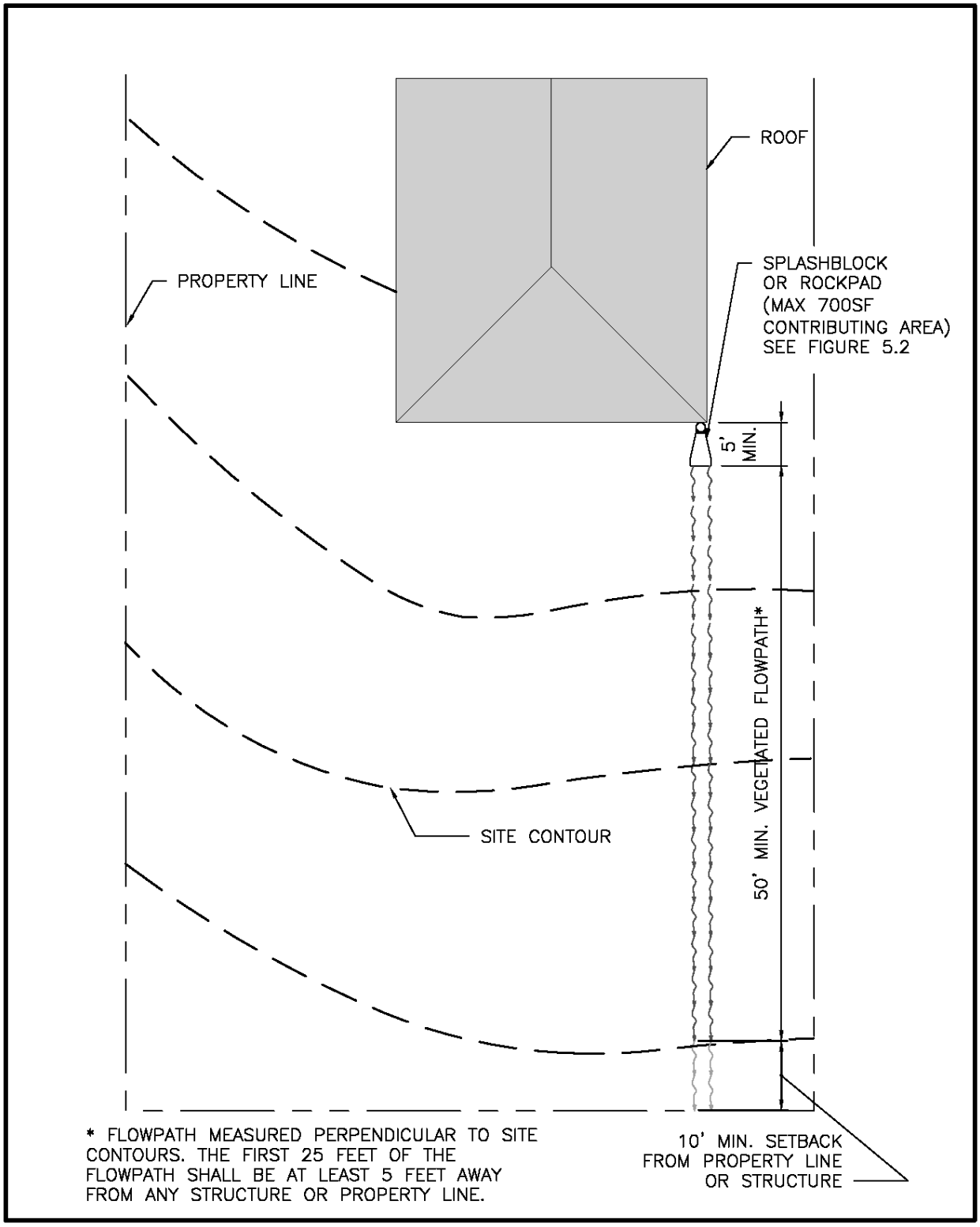


Figure 5.3. Typical Downspout Splashblock.

Dispersion Flow Path

The general minimum requirements for the dispersion flow path are provided in *Section 5.3.1.2*. Additional flow path requirements specific to splashblock downspout dispersion are listed below and shown in Figure 5.3:

- Provide a vegetated flow path of at least 50 feet between the dispersion device (e.g., splash block, rock pad) and any stream, wetland, lake, hard surface, or slope over 15 percent. Critical area buffers may count toward flow path lengths. Measure the flow path length perpendicular to site contours.
- The slope of the 50-foot vegetated flow path must not exceed 15 percent.
- Down gradient of the required 50foot flow path, an additional 10 feet must be provided before the flow path intersects a property line (except where the property line abuts the right-of-way).
- The first 25 feet of the dispersion flow path must be at least 5 feet (perpendicular to the flow path) from any structure or property line (except where the property line abuts the right-of-way).
- Provide a separate flow path for each downspout dispersion device. For the purpose of maintaining adequate separation of flows discharged from adjacent dispersion devices, space vegetated flow paths at least 20 feet apart at the upslope end and do not overlap with other flow paths at any point along the flow path lengths.
- For the purpose of measuring setbacks to structures, property lines or other flow paths, assume the flow path width to be 3 feet extending from the center line of the splashblock or rock pad. Measure setbacks from the edge of the assumed flow path.

Overflow

Identify the overland flow path for each downspout dispersion point. Consider surface flows that may extend beyond the design flow path length. Do not allow flow to cause erosion or flooding onsite or on adjacent properties (refer to *Section 4.3.3*).

5.3.3.6. BMP Credits

Credit for On-site List Approach

The hard surface area dispersed using splashblock downspout dispersion meets the On-site List Requirement (refer to *Section 3.3.1* and *Appendix C* for infeasibility criteria).

Pre-sized Approach for Flow Control

The Pre-sized Approach may be used for projects with new and replaced hard surface areas up to 10,000 square feet. Under the Pre-sized Approach (refer to *Section 4.1.2*), flow control credits may be achieved by using downspout dispersion. Credits are provided in Table 5.4, organized by flow control standard. These credits can be applied to reduce the hard surface area requiring flow control. Because the credits for dispersion are less than 100 percent, the standard is not achieved and additional flow control measures will be required. As an example, for a site subject to the Pre-developed Pasture Standard, a dispersed hard surface area would receive a 91 percent credit. Therefore, 91 percent of the hard surface area dispersed can be excluded from flow control calculations. The hard surface area (area used to size a downstream flow control BMP) would be calculated as 9 percent of the hard surface area dispersed.

Table 5.4. Pre-sized Flow Control Credits for Splashblock Downspout Dispersion.

Dispersion Type	Credit (%): Pre-developed Pasture Standard	Credit (%): Peak Control Standard
Splashblock Downspout Dispersion	74%	76%

Hard Surface Area Managed = Hard Surface Area Dispersed x Credit (%)/100.

The flow control credits outlined above are applicable only if downspout dispersion meets the minimum design requirements outlined in this section. Alternatively, dispersion can be evaluated using a continuous runoff hydrologic model as described below.

Modeling Approach for On-site Performance Standard and Flow Control

Continuous hydrologic modeling may be used to quantify the performance of splashblock downspout dispersion relative to the on-site and flow control performance standards using the procedures and assumptions listed in Table 5.5.

Table 5.5. Continuous Modeling Assumptions for Downspout Dispersion.

Variable	Assumption
Precipitation Series	SEPTS-99 unless otherwise adopted by the Director
Computational Time Step	5 minutes
HSPF Parameters	LSUR, SLSUR, NSUR must be adjusted per *Appendix F*
Flow Path Length	50 feet minimum
Flow Path Width	Match the width of the splash block or rock pad
Flow Path Slope	Proposed condition (15% maximum)
Roof Area Dispersed	Single Downspout (WWHM only): The connected roof area must be modeled as a lateral flow impervious area over the underlying soil type (e.g., till). The lateral flow elements in WWHM are available on the Mitigated Scenario screen. The lateral flow impervious area element (roof area) should be connected to the lawn/landscape lateral flow soil basin element (the vegetated flow path). Multiple Downspouts (WWHM or MGSFlood): The roof area can be modeled as 50% landscaped (lawn in WWHM; grass in MGSFlood) and 50% impervious.

Refer to *Section 5.1.6* for modeling amended soils to partially meet the flow control and/or water quality treatment requirement when runoff is dispersed on amended soil.

5.3.3.7. Minimum Construction Requirements

Protect the dispersion flow path from sedimentation and compaction during construction. If the flow path area is disturbed during construction, restore the area to meet the Soil Amendment BMP requirements in *Section 5.1*, and establish a dense cover of lawn, landscape, or groundcover.

5.3.3.8. Operations and Maintenance Requirements

Splashblock downspout dispersion O&M requirements are provided in *Appendix G* (*BMP No. 25*).

5.3.4. Trench Downspout Dispersion

5.3.4.1. Description

Trench downspout dispersion consists of a gravel-filled dispersion trench used to disperse downspout flows to a downslope well-vegetated flow path of at least 25 feet.

5.3.4.2. Performance Mechanisms

Trench downspout dispersion can provide flow control via attenuation, soil storage, and losses to infiltration, evaporation, and transpiration.

5.3.4.3. Applicability

Trench downspout dispersion can be designed to provide on-site stormwater management and flow control. This BMP can be applied to meet or partially meet the requirements listed below. If the designer implements a dispersion BMP to meet water quality treatment standards, the BMP must be designed using the additional design requirements for vegetated filter strips per *Section 5.8.4*.

BMP	On-site: List	On-site: Standard	Flow Control: Forest	Flow Control: Pasture	Flow Control: Peak	Water Quality: Basic	Water Quality: Enhanced Metals	Water Quality: Oil Control	Water Quality: Phosphorus	Conveyance
Trench downspout dispersion	x	x[a]	x[a]	x[a]	x[a]	x[b]				

[a] Standard may be partially or completely achieved depending upon underlying soil type.

[b] Must meet additional design requirements for vegetated filter strips (refer to *Section 5.8.4*) to fully meet the water quality treatment requirement.

5.3.4.4. Site Considerations

General site considerations for determining the feasibility of dispersion BMPs for a particular site are provided in *Section 5.3.1.1*. Refer to *Appendix C* for additional infeasibility criteria for the On-site List Approach.

5.3.4.5. Design Criteria

This section provides a description and requirements for the components of trench downspout dispersion. Some of the critical requirements for trench downspout dispersion (e.g., flow paths, setbacks) are shown in Figure 5.4. Design criteria are provided in this section for the following elements:

- Contributing area
- Downspout dispersion trench
- Dispersion flow path
- Overflow

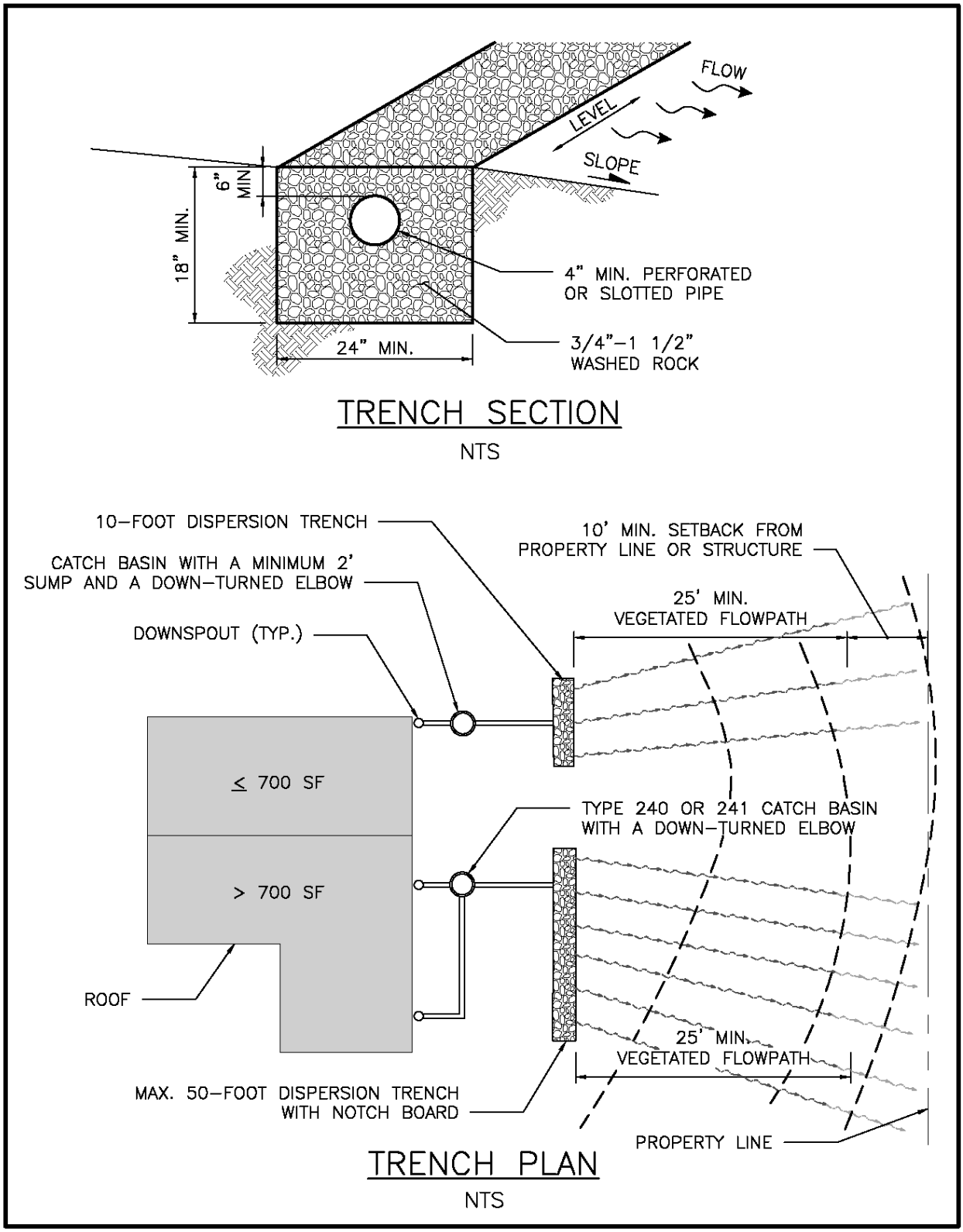


Figure 5.4. Typical Downspout Dispersion Trench.

Contributing Area

A maximum of 700 square feet of roof area may drain to each downspout dispersion trench. If at least 50 percent of the roof is a vegetated roof, contributing roof areas up to 900 square feet will be allowed.

Downspout Dispersion Trench

The minimum requirements associated with dispersion trench design include the following:

- The trench must be a minimum of 18 inches deep and 2 feet wide.
- Trenches must be filled with uniformly graded, washed gravel with a nominal size from 0.75- to 1.5-inch diameter. The minimum void volume must be 30 percent. These requirements can be met with City of Seattle Mineral Aggregate Type 4.
- The trench must be level and aligned parallel to site elevation contours to disperse the water to the downslope flow path. The trench must be constructed to prevent point discharge and erosion.
- Water must be conveyed to the trench with a solid pipe and distributed within the trench via a perforated or slotted pipe with a minimum diameter of 4 inches. Pipe cover must be a minimum of 6 inches.
- Trenches serving up to 700 square feet of roof area must be 10 feet long. For roof areas larger than 700 square feet, a dispersion trench with a dispersion device, such as a notched grade board, is recommended. Refer to BMP T5.10B in Volume V of the SWMMWW for typical plan and section views of a downspout dispersion trench with notched grade board. The total length of this design must provide at least 10 feet of trench per 700 square feet of roof area and not exceed 50 feet. If the roof is a vegetated roof, contributing areas larger than 700 square feet may be approved for a 10-foot trench.
- A setback of at least 5 feet must be maintained between any edge of the trench and any property line.
- The setback between any edge of the trench and any structure must be 5 feet. A 10-foot setback from a building with a basement is recommended.

Presettling

Stormwater inflows must be routed through a catch basin with downturned elbow (trap) and 2-foot-deep sump upstream of the dispersion trench to capture sediment and reduce the potential for clogging. Catch basins must be per City of Seattle Standard Plan No. 240, 241, or equivalent.

Dispersion Flow Path

The general minimum requirements for the dispersion flow path are provided in *Section 5.3.1.2*. Additional flow path requirements specific to trench downspout dispersion are listed below and shown in Figure 5.4:

- A vegetated flow path must be at least 25 feet between the outlet of the trench any, stream, wetland, lake, structure, hard surface, or slope over 15 percent. Critical area buffers may count toward flow path lengths. The flow path length is measured perpendicular to site contours.

- The slope of the 25-foot vegetated flow path must not exceed 15 percent.
- Down gradient of the required 25-foot flow path, an additional 10 feet must be provided before the flow path intersects a property line (except where the property line abuts the right-of-way) or encounters a structure.
- The first 25 feet of the dispersion flow path must be at least 5 feet (perpendicularly to the flow path) from any structure or property line (except where the property line abuts the right-of-way).
- Each downspout dispersion device (e.g., dispersion trench) must have a separate flow path. For the purpose of maintaining adequate separation of flows discharged from adjacent dispersion devices, vegetated flow paths must be at least 20 feet apart at the upslope end and must not overlap with other flow paths at any point along the flow path lengths.
- For the purpose of measuring setbacks to structures, property lines, and other flow paths, the flow path width must be assumed to be the length of the dispersion trench. Setbacks must be measured from the edge of the assumed flow path.
- Short retaining walls, rockeries, and uncovered decks may be allowed within the 10-foot additional setback described above if all three of the following apply:
    1. For rockeries or retaining walls, the maximum exposed height will be 3 feet or lower.
    2. For uncovered decks, the maximum height of the decking is less than 18-inches.
    3. The wall is not located in or adjacent to a steep slope or slide prone environmentally critical area (ECA)
    4. You will not damage adjoining properties or structures during or after construction of the wall.

Overflow

Identify the overland flow path for each downspout dispersion point. Consider surface flows that may extend beyond the design flow path length. Prevent flow from causing erosion or flooding on site or on adjacent properties (refer to *Section 4.3.3*).

5.3.4.6. BMP Credits

Credit for On-site List Approach

The hard surface area dispersed using trench downspout dispersion meets the On-site List Requirement (refer to *Section 3.3.1* and *Appendix C* for infeasibility criteria).

Pre-sized Approach for Flow Control

The Pre-sized Approach may be used for projects with new and replaced hard surface areas up to 10,000 square feet. Under the Pre-sized Approach (refer to *Section 4.1.2*), flow control credits may be achieved by using downspout dispersion. The credits provided in Table 5.6 can be applied to reduce the hard surface area requiring flow control as explained for splashblock downspout dispersion (refer to *Section 5.3.3.6*).

Table 5.6. Pre-sized Flow Control Credits for Trench Downspout Dispersion.

Dispersion Type	Credit (%): Pre-developed Pasture Standard	Credit (%): Peak Control Standard
Trench Downspout Dispersion	74%	76%

Hard Surface Area Managed = Hard Surface Area Dispersed x Credit (%)/100.

Modeling Approach for On-site Performance Standard and Flow Control

Continuous hydrologic modeling may be used to quantify the performance of trench downspout dispersion relative to the on-site and flow control standards using the procedures and assumptions listed in Table 5.7.

Table 5.7. Continuous Modeling Assumptions for Trench Downspout Dispersion.

Variable	Assumption
Precipitation Series	SEPTS-99 unless otherwise adopted by the Director
Computational Time Step	5 minutes
HSPF Parameters	LSUR, SLSUR, NSUR must be adjusted per *Appendix F*
Flow Path Length	25 feet minimum
Flow Path Width	Width of the dispersion device (i.e., trench); 10 feet minimum
Flow Path Slope	Existing condition
Roof Area Dispersed	WWHM only: The connected roof area should be modeled as a lateral flow impervious area over the underlying soil type (e.g., till). The lateral flow elements in WWHM are available on the Mitigated Scenario screen. The lateral flow impervious area element (roof area) should be connected to the lawn/landscape lateral flow soil basin element (the vegetated flow path). WWHM or MGSFlood: The roof area can be modeled as a basin that is 50% landscaped (lawn in WWHM; grass in MGSFlood) and 50% impervious that is connected to the point of compliance.

Refer to *Section 5.1.6* for modeling amended soils to partially meet the flow control and/or water quality treatment requirement when runoff is dispersed on amended soil.

5.3.4.7. Minimum Construction Requirements

Protect the dispersion flow path from sedimentation and compaction during construction. If the flow path area is disturbed during construction, restore the area to meet the Soil Amendment BMP requirements in *Section 5.1* and establish a dense cover of lawn, landscape or groundcover. During construction confirm the dispersion trench surface is level (e.g., laser testing or flow test).

5.3.4.8. Operations and Maintenance Requirements

Trench downspout dispersion O&M requirements are provided in *Appendix G* (*BMP No. 25*).

5.3.5. Sheet Flow Dispersion

5.3.5.1. Description

Sheet flow dispersion is one of the simplest methods of runoff control. This BMP can be used for any hard surface or pervious surface that is graded to avoid concentrating flows. Because flows are already dispersed as they leave the surface (i.e., not concentrated), they need only traverse a narrow band of adjacent vegetation for effective flow attenuation and treatment.

5.3.5.2. Performance Mechanisms

Sheet flow dispersion can provide flow control via flow attenuation, soil storage, and losses to infiltration, evaporation, and transpiration.

5.3.5.3. Applicability

Sheet flow dispersion can be designed to provide on-site stormwater management and flow control. This BMP can be applied to meet or partially meet the requirements listed below. If the designer implements a dispersion BMP to meet water quality treatment standards, the BMP must be designed using the additional design requirements for filter strips per *Section 5.8.4*.

BMP	On-site: List	On-site: Standard	Flow Control: Forest	Flow Control: Pasture	Flow Control: Peak	Water Quality: Basic	Water Quality: Enhanced Metals	Water Quality: Oil Control	Water Quality: Phosphorus	Conveyance
Sheet flow dispersion	x	x[a]	x[a]	x[a]	x[a]	x[b]				

[a] Standard may be partially or completely achieved depending upon underlying soil type.

[b] Must meet additional design requirements for vegetated filter strips (refer to *Section 5.8.4*) to fully meet the water quality treatment requirement.

5.3.5.4. Site Considerations

General site considerations for determining the feasibility of dispersion BMPs for a particular site are provided in *Section 5.3.1.1*. Sheet flow dispersion is applicable for hard surfaces with slopes less than 15 percent, such as sidewalks, driveways, sport courts, patios, roofs without gutters, or other situations where concentration of flows can be avoided. Refer to *Appendix C* for additional infeasibility criteria for the On-site List Approach.

5.3.5.5. Design Criteria

This section provides a description and requirements for the components of sheet flow dispersion. A typical plan for driveway sheet flow dispersion is shown in Figure 5.5. Design criteria are provided in this section for the following elements:

- Contributing area
- Transition zone
- Dispersion flow path
- Overflow

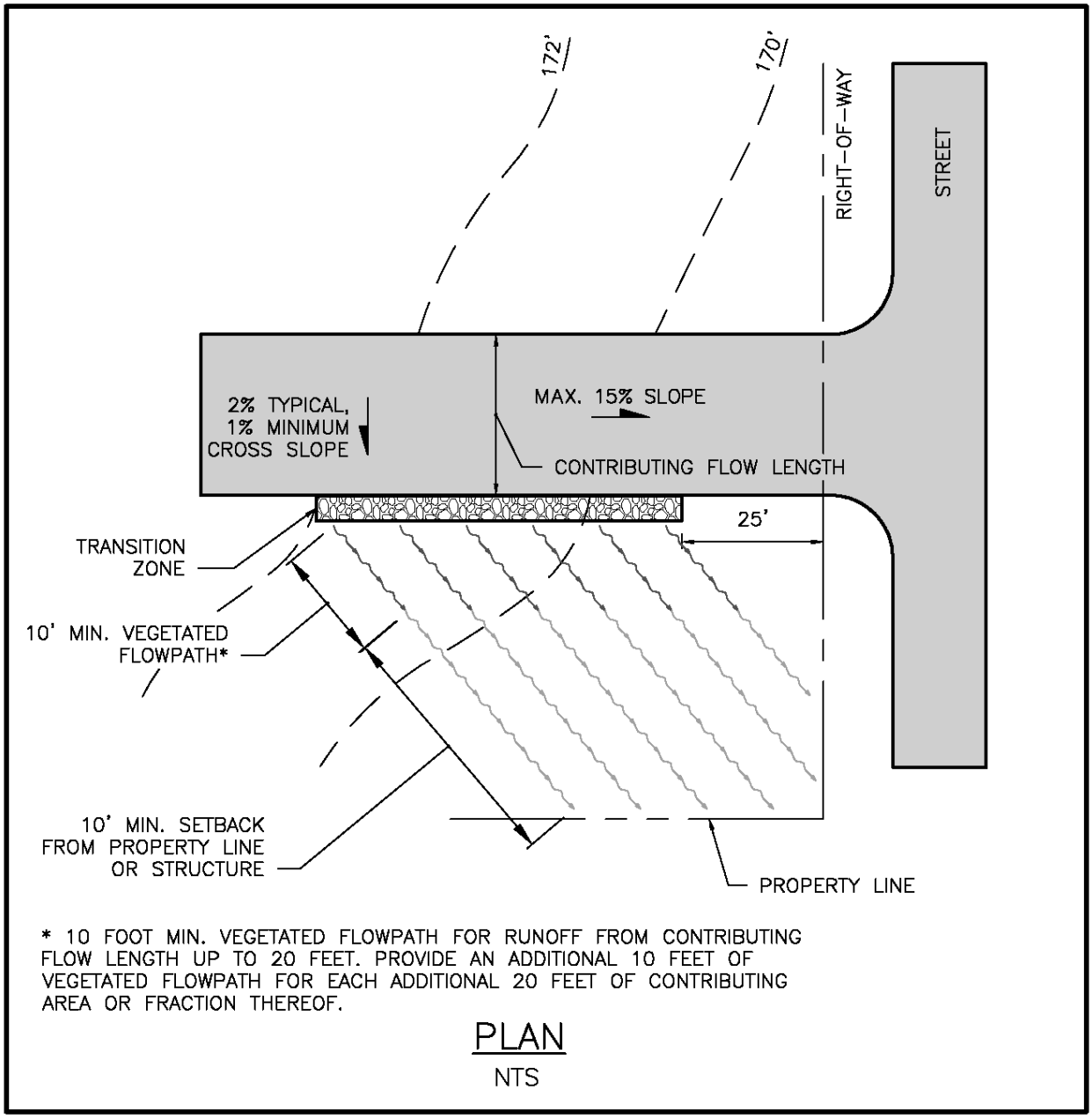


Figure 5.5. Typical Sheet Flow Dispersion for Flat and Moderately Sloping Driveways.

Contributing Area

The hard surface area contributing sheet flow to the dispersion flow path must have a slope less than 15 percent. The cross slope toward the transition zone must be a minimum of 2 percent.

Transition Zone

A 2-foot-wide transition zone to discourage channeling must be provided between the edge of the contributing hard surface area (or building eaves) and the downslope vegetation. This

may be an extension of subgrade material (crushed rock), modular pavement, drain rock, or other material approved by the Director.

Dispersion Flow Path

The general minimum requirements associated with the dispersion flow path are provided in *Section 5.3.1.2*. An additional flow path requirement specific to sheet flow dispersion is as follows:

- Provide a vegetated flow path of 10 feet to disperse sheet flow runoff from hard surface with a contributing flow length of 20 feet. If the contributing hard surface is at least 50 percent permeable pavement, the contributing flow length may be increased from 20 to 25 feet. Provide an additional 10 linear feet of vegetated flow path for each additional 20 linear feet of contributing flow length or fraction thereof.
- The slope of the vegetated flow path must not exceed 15 percent.
- Down gradient of the required flow path (per the bullet above), an additional 10 feet must be provided before the flow path intersects a property line (excluding the property line abutting the right-of-way) or encounters a structure.

Overflow

Identify the overland flow path for each dispersion point. Consider surface flows that may extend beyond the design flow path length. Prevent flow from causing erosion or flooding on site or on adjacent properties (refer to *Section 4.3.3*).

5.3.5.6. BMP Credits

Credit for On-site List Approach

The hard surface area dispersed using sheet flow dispersion meets the On-site List Requirement (refer to *Section 3.3.1* and *Appendix C* for infeasibility criteria).

Pre-sized Approach for Flow Control

The Pre-sized Approach may be used for projects with new and replaced hard surface areas up to 10,000 square feet. Under the Pre-sized Approach (refer to *Section 4.1.2*), flow control credits may be achieved by using sheet flow dispersion. The credits provided in Table 5.8 can be applied to reduce the hard surface area requiring flow control as explained for splashblock downspout dispersion.

Table 5.8. Pre-sized Flow Control Credits for Sheet Flow Dispersion.

Dispersion Type	Credit (%): Pre-developed Pasture Standard	Credit (%): Peak Control Standard
Sheet Flow Dispersion	74%	76%

Hard Surface Area Managed = Hard Surface Area Dispersed x Credit (%)/100.

Modeling Approach for On-site Performance Standard and Flow Control

Continuous hydrologic modeling may be used to quantify the performance of sheet flow dispersion relative to the on-site and flow control standards using the procedures and assumptions listed in Table 5.9.

Table 5.9. Continuous Modeling Assumptions for Sheet Flow Dispersion.

Variable	Assumption
Precipitation Series	SEPTS-99 unless otherwise adopted by the Director
Computational Time Step	5 minutes
HSPF Parameters	LSUR, SLSUR, NSUR must be adjusted per *Appendix F*
Flow Path Length	10 feet minimum
Flow Path Width	Width of the dispersion device (i.e., sheet flow transition zone); 2 feet minimum
Flow Path Slope	Existing condition
Hard Surface Area Dispersed	The hard surface area should be modeled as a lateral flow impervious area over the underlying soil type (e.g., till). In WWHM, this option is available on the Mitigated Scenario screen. The lateral flow impervious area element (representing the area that is dispersed) should be connected to the lawn/landscape lateral flow soil basin element (the vegetated flow path).

Refer to *Section 5.1.6* for modeling amended soils to partially meet the flow control and/or water quality treatment requirement when runoff is dispersed on amended soil.

5.3.5.7. Minimum Construction Requirements

Protect the dispersion flow path from sedimentation and compaction during construction. If the flow path area is disturbed during construction, restore the area to meet the Soil Amendment BMP requirements in *Section 5.1* and establish a dense cover of lawn, landscape or groundcover.

5.3.5.8. Operations and Maintenance Requirements

Sheet flow dispersion O&M requirements are provided in *Appendix G* (*BMP No. 25*).

5.3.6. Concentrated Flow Dispersion

5.3.6.1. Description

Concentrated flow dispersion BMPs disperse concentrated flows from driveways or other pavement through a vegetated pervious area to provide flow control. In a typical application, sheet flow from a ground-level impervious surface is intercepted by a berm or slot drain and conveyed to a dispersion point (i.e., rock pad or dispersion trench).

5.3.6.2. Performance Mechanisms

Concentrated flow dispersion can provide flow control via attenuation, soil storage, and losses to infiltration, evaporation, and transpiration.

5.3.6.3. Applicability

Concentrated flow dispersion can be designed to provide on-site stormwater management and flow control. This BMP can be applied to meet or partially meet the requirements listed below. If the designer implements a dispersion BMP to meet water quality treatment standards, the BMP must be designed using the additional design requirements for filter strips per *Section 5.8.4*.

BMP	On-site: List	On-site: Standard	Flow Control: Forest	Flow Control: Pasture	Flow Control: Peak	Water Quality: Basic	Water Quality: Enhanced Metals	Water Quality: Oil Control	Water Quality: Phosphorus	Conveyance
Concentrated Flow Dispersion	x	x[a]	x[a]	x[a]	x[a]	x[b]				

[a] Standard may be partially or completely achieved depending upon underlying soil type.

[b] Must meet additional design requirements for vegetated filter strips (refer to *Section 5.8.4*) to fully meet the water quality treatment requirement.

5.3.6.4. Site Considerations

General site considerations for determining the feasibility of dispersion BMPs for a particular site are provided in *Section 5.3.1.1*. Refer to *Appendix C* for additional infeasibility criteria for the On-site List Approach.

5.3.6.5. Design Criteria

This section provides a description and requirements for the components of concentrated flow dispersion. A typical plan for concentrated flow dispersion for steep driveways is shown in Figure 5.6. Design criteria are provided in this section for the following elements:

- Contributing area
- Berm or slotted drain
- Rock pad (dispersion device option 1)
- Downspout dispersion trench (dispersion device option 2)
- Dispersion flow path
- Overflow

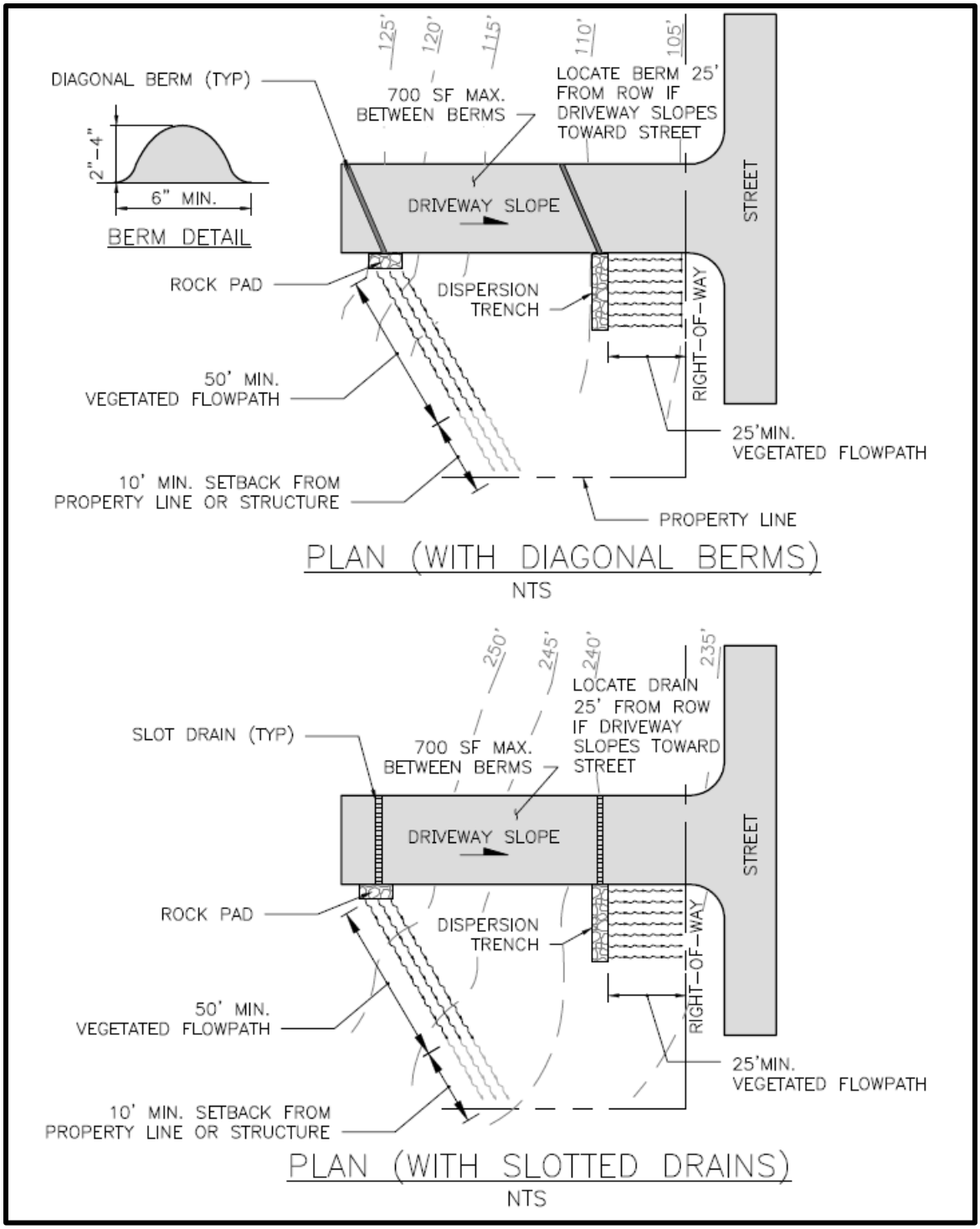


Figure 5.6. Typical Concentrated Flow Dispersion for Steep Driveways.

Contributing Area

A maximum of 700 square feet of impervious area may drain to each concentrated flow dispersion device (i.e., rock pad or dispersion trench). Larger contributing areas may be approved for other types of hard surfaces (e.g., permeable pavement). If at least 50 percent of the contributing area is permeable pavement, contributing areas up to 900 square feet will be allowed.

Berm or Slotted Drain

A slotted drain, diagonal berm, or similar measure must be provided to direct flow to the rock pad or dispersion trench.

Rock Pad (if selected)

If selected as the dispersion device, a pad of crushed rock (2 feet wide by 3 feet long by 6 inches deep) must be placed at the point of discharge. The downstream edge of rock pad must be at least 5 feet from a structure. A 10-foot setback from a building with a basement is recommended. The rock pad must have an impermeable liner within setback.

Dispersion Trench (if selected)

If selected as the dispersion device, the dispersion trench design must meet the following minimum requirements:

- The trench must be a minimum of 18 inches deep and 2 feet wide.
- The trench must be level and aligned parallel to site elevation contours to disperse the water to the downslope flow path. The trench must be constructed to prevent point discharge and erosion.
- Trenches serving up to 700 square feet of impervious area must be 10-foot-long. If the contributing area is not an impervious surface (e.g., permeable pavement), contributing areas larger than 700 square feet may be approved for a 10-foot trench. If at least 50 percent of the contributing area is permeable pavement, contributing areas up to 900 square feet will be allowed for a 10-foot trench. For contributing areas greater than the contributing areas noted above, the trench length must be calculated as a minimum of 10 feet plus a proportional trench length based on the additional contributing area. For example, trench length for trenches serving non-permeable pavement areas larger than 700 square feet must be calculated as: Total roof area in square feet x 10 feet ÷ 700 square feet.
- A setback of at least 5 feet must be maintained between any edge of the trench and any structure or property line. A 10-foot setback from a building with a basement is recommended.

Dispersion Flow Path

The minimum requirements for the dispersion flow path are listed below:

- For rock pads, a vegetated flow path of at least 50 feet must be provided between the dispersion device any stream, wetland, lake, hard surface, or slope over 15 percent. Critical area buffers may count toward flow path lengths. The flow path length is measured perpendicular to site contours.

- For dispersion trenches, a vegetated flow path of at least 25 feet must be provided between the outlet of the trench and any property line, slope over 15 percent, stream, wetland, lake, structure, or other hard surface. Critical area buffers may count toward flow path lengths. The flow path length is measured perpendicular to site contours.
- The slope of the vegetated flow path must not exceed 15 percent.
- Down gradient of the required flow path (per the bullets above), an additional 10 feet must be provided before the flow path intersects a property line (excluding the property line abutting the right-of-way) or encounters a structure.
- The first 25 feet of the dispersion flow path must be at least 5 feet from any structure or property line.
- Each dispersion device must have a separate flow path. For the purpose of maintaining adequate separation of flows discharged from adjacent dispersion devices, vegetated flow paths must be at least 20 feet apart at the upslope end and must not overlap with other flow paths at any point along the flow path lengths.
- For the purpose of measuring setbacks to structures, property lines, and other flow paths, the following must be assumed:
    - The rock pad flow path width must be assumed to be 3 feet extending from the center line of the rock pad
    - The dispersion trench flow path width must be assumed to be the length of the dispersion trench.
    - Setbacks must be measured from the edge of the assumed flow path.

Overflow

Identify the overland flow path for each dispersion point. Consider surface flows that may extend beyond the design flow path length. Prevent flow from causing erosion or flooding on site or on adjacent properties (refer to *Section 4.3.3*).

5.3.6.6. BMP Credits

Credit for On-site List Approach

The hard surface area dispersed using concentrated dispersion meets the On-site List Requirement (refer to *Section 3.3.1* and *Appendix C* for infeasibility criteria).

Pre-sized Approach for Flow Control

The Pre-sized Approach may be used for projects with new and replaced hard surface areas up to 10,000 square feet. Under the Pre-sized Approach (refer to *Section 4.1.2*), flow control credits may be achieved by using concentrated flow dispersion. The credits provided in Table 5.10 can be applied to reduce the hard surface area requiring flow control as explained for splashblock downspout dispersion.

Table 5.10. Pre-sized Flow Control Credits for Concentrated Flow Dispersion.

Dispersion Type	Credit (%): Pre-developed Pasture Standard	Credit (%): Peak Control Standard
Concentrated Flow Dispersion	74%	76%

Hard Surface Area Managed = Hard Surface Area Dispersed x Credit (%)/100.

Modeling Approach for On-site Performance Standard and Flow Control

Continuous hydrologic modeling may be used to quantify the performance of concentrated flow dispersion relative to the on-site and flow control performance standards using the procedures and assumptions listed in Table 5.11.

Table 5.11. Continuous Modeling Assumptions for Concentrated Flow Dispersion.

Variable	Assumption
Precipitation Series	SEPTS-99 unless otherwise adopted by the Director
Computational Time Step	5 minutes
HSPF Parameters	LSUR, SLSUR, NSUR must be adjusted per *Appendix F*
Flow Path Length	25 feet minimum
Flow Path Width	6 feet for dispersion points (i.e., splashblocks or rock pads) or the width of the dispersion device (i.e., trench)
Flow Path Slope	Existing condition
Hard Surface Area Dispersed	Single Downspout or Area: The hard surface area should be modeled as a lateral flow impervious area over the underlying soil type (e.g., till). The lateral flow elements in WWHM are available on the Mitigated Scenario screen. The lateral flow impervious area element (representing the area that is dispersed) should be connected to the lawn/landscape lateral flow soil basin element (the vegetated flow path). Multiple Downspouts (Option 1): In situations where multiple downspout dispersions will occur, a pad of crushed rock or dispersion trenches are used, and the flow path is at least 50 feet, the hard surface area can be modeled as 100% landscaped (lawn in WWHM; grass in MGSFlood). Multiple Downspouts (Option 2): In situations where multiple downspout dispersions will occur, dispersion trenches are used, and the flow path is at 25 to 50 feet, the hard surface area can be modeled as 50% landscaped (lawn in WWHM; grass in MGSFlood) and 50% impervious.

Refer to *Section 5.1.6* for modeling amended soils to partially meet the flow control and/or water quality treatment requirement when runoff is dispersed on amended soil.

5.3.6.7. Minimum Construction Requirements

Protect the concentrated flow dispersion flow path from sedimentation and compaction during construction. If the flow path area is disturbed during construction, restore the area to meet the Soil Amendment BMP requirements in *Section 5.1* and establish a dense cover of lawn, landscape or groundcover. If a dispersion trench is used, confirm the trench surface is level (e.g., laser testing or flow test).

5.3.6.8. Operations and Maintenance Requirements

Concentrated flow dispersion O&M requirements are provided in *Appendix G* (*BMP No. 25*).

5.3.7. Sidewalk/Trail Compost-Amended Strip

5.3.7.1. Description

The sidewalk/trail compost-amended strip consists of a compost-amended, vegetated strip (amended per *Section 5.1 Soil Amendment BMP*) located continuously adjacent to a sidewalk or trail hard surface to be mitigated. The BMP provides runoff mitigation for sheet flow from an adjacent sidewalk or trail through infiltration and evapotranspiration.

5.3.7.2. Performance Mechanisms

Sidewalk/trail compost-amended strips can provide flow control via flow attenuation, soil storage, and losses to infiltration, evaporation, and transpiration.

5.3.7.3. Applicability

Sidewalk/trail compost-amended strips are designed to meet both the On-site List Approach using the provided sizing factors and the On-site Performance Approach, using the modeling assumptions provided in *Section 5.3.7.6*. Sidewalk/trail compost-amended strips may be constructed in conjunction with other stormwater BMPs to achieve mitigation requirements other than On-site Stormwater Management. When the sidewalk/trail compost-amended strip is used to help meet flow control or water quality treatment requirements, the designer must prove performance by explicit simulation with an approved continuous simulation model.

BMP	On-site: List	On-site: Standard	Flow Control: Forest	Flow Control: Pasture	Flow Control: Peak	Water Quality: Basic	Water Quality: Enhanced Metals	Water Quality: Oil Control	Water Quality: Phosphorus	Conveyance
Sidewalk/trail compost-amended strip	x	x	x	x	x[a]					

[a] Standard may be partially achieved and additional BMPs may be needed to reach the peak flow control standard.

[b] This BMP is not intended for pollution-generating surfaces. Vegetated filter strips (refer to Section 5.8.4) and CAVFS (refer to *Section 5.8.4*) are similar BMPs that meet water quality treatment requirements.

5.3.7.4. Site Considerations

The sidewalk/trail compost-amended strip is applicable for pedestrian and multi-use trails and sidewalks. The target surface may consist of any hard surface (e.g., concrete, asphalt, and compacted gravel) that does not exceed the specified widths or longitudinal and lateral slopes. Likewise, the BMP location adjacent to the target surface must not be overly steep, must be compost-amended, and vegetated. Vegetation must be dense and healthy, but specific vegetation is left to the designer (e.g., turf or dense ground cover). Shrubs and trees are acceptable in addition to the turf or dense ground cover. Refer to *Appendix C* for additional infeasibility criteria for the On-site List Approach.

The sidewalk/trail compost-amended strip follows minimum requirements similar to those associated with dispersion and infiltration BMPs. To reduce the potential for concentrated flow entering the BMP, the sidewalk/trail compost-amended strip can only be used where the tributary sidewalk and trail lateral cross slopes (perpendicular to the edge of hard surface

adjacent to the BMP) are not less than 1 percent and not greater than 5 percent, and the longitudinal slope is not greater than 8 percent. (Note: refer to ADA requirements for sidewalk slopes in addition to technical requirements found in this manual.) In addition, the contributing hard surface may not exceed 25 feet in width.

The sidewalk/trail compost-amended strip must also be located immediately adjacent to the trail or sidewalk surface to be mitigated and have a slope not greater than 25 percent (i.e., 4 horizontal to 1 vertical) and not less than 2 percent.

The sidewalk/trail compost-amended strip design is based on the native soil design infiltration rate, as determined by site-specific testing and applied long-term infiltration rate safety factors. If no native soil infiltration testing is conducted, the designer must assume a design infiltration rate of 0.15 inch per hour.

5.3.7.5. Design Criteria

This section provides a description and requirements for the components of sidewalk/trail compost-amended strips. Typical components for sidewalk/trail compost-amended strips are shown in Figure 5.7. Design criteria are provided in this section for the following elements:

- Contributing area
- Level spreader
- Compost-amended strip
- Overflow

Contributing Area

The width of the contributing hard surface area is measured perpendicular to the edge of pavement adjacent to the BMP and must not exceed 25 feet.

Sidewalk/trail compost-amended strips allow for run-on of non-sidewalk/trail hard surfaces not greater than 10 percent of the sidewalk and trail area. The contributing area widths used to determine the sizing factor must account for any run-on surface area.

Level Spreader

Sidewalks/trails with a width greater than or equal to 10 feet require a level spreader to help ensure even distribution of flow entering the sidewalk/trail compost-amended strip. The level spreader must consist of vegetated compost-amended soil (refer to *Section 5.1*) and must be 1foot wide, as measured perpendicular to the edge of hard surface adjacent to the BMP. The level spreader lateral (i.e., between the hard surface and sidewalk/trail compost-amended strip) slope must be 2 percent or less. The top of the level spreader must be lower than the adjacent sidewalk/trail surface by at least 1 inch. The level spreader width (1 foot) can be included as part of the total required sidewalk/trail compost-amended strip width.

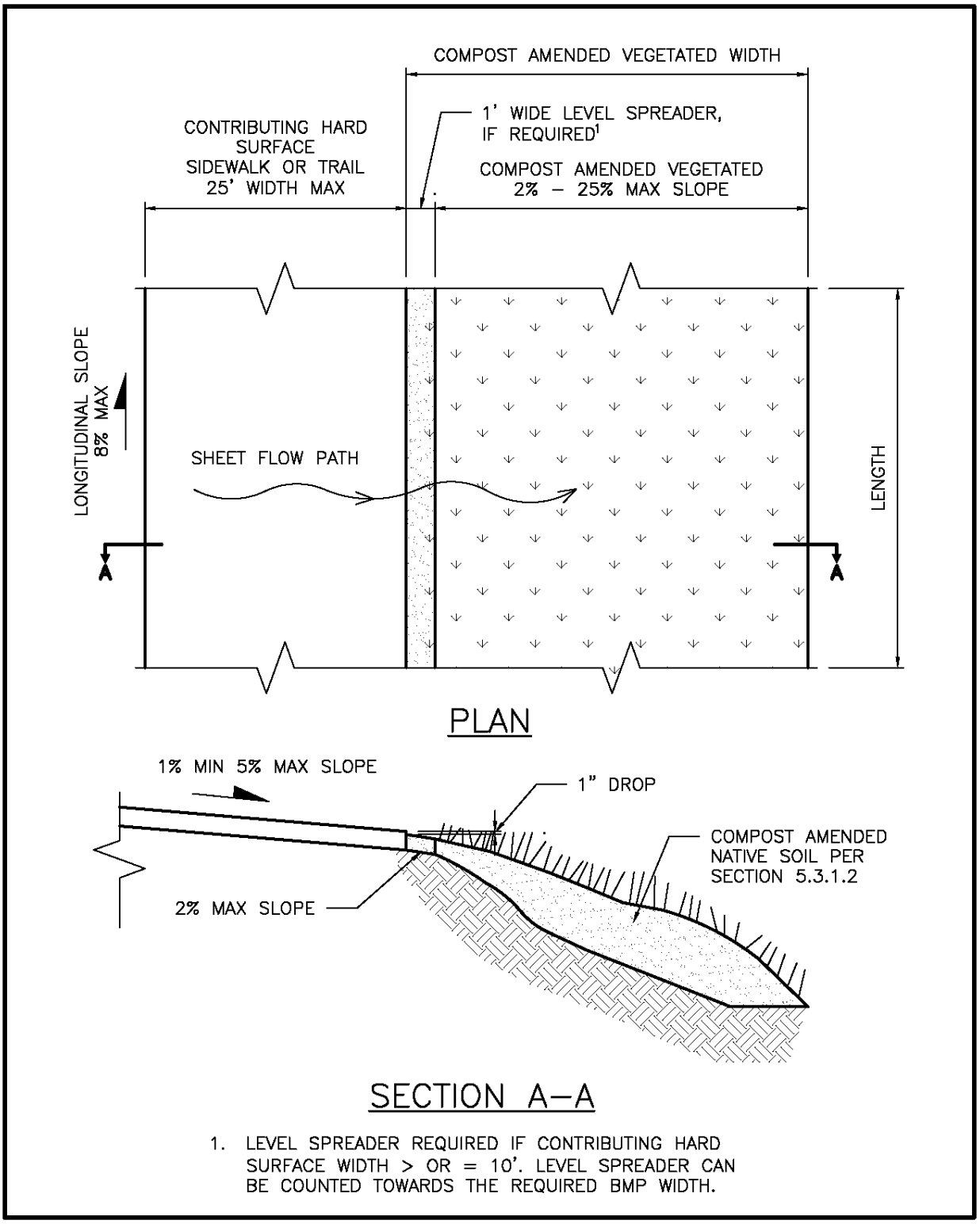


Figure 5.7. Typical Sidewalk/Trail Compost-amended Strip BMP.

Compost-amended Strip

The general minimum requirements associated with the flow path to the sidewalk/trail compost-amended strip are provided in *Section 5.3.1.2*. Additional flow path requirements specific to sidewalk/trail compost-amended strips are as follows:

- The total sidewalk/trail compost-amended strip width may not be less than 1 foot.
- The lateral slope of the sidewalk/trail compost-amended strip must not be less than 2 percent nor greater than 25 percent.
- The sidewalk/trail compost-amended strip must be amended (refer to *Section 5.1*) and vegetated. Vegetation must be dense and healthy, but specific vegetation is left to the designer (e.g., turf or dense ground cover). Shrubs and trees are acceptable in addition to the turf or dense ground cover.
- The width of the BMP is measured perpendicular to the edge of adjacent hard surface.

Overflow

The overflow flow path downstream of the sidewalk/trail compost-amended strip must be identified, and surface flows that may extend beyond the sidewalk/trail compost-amended strip must be considered. Sidewalk/trail compost-amended strip design and site design must prevent overflow from the sidewalk/trail compost-amended strip from causing erosion or flooding on site or on adjacent properties. Overland flow path must be vegetated and a minimum of 10 feet long prior to intersecting a building or property line (excluding righty-of-way line).

5.3.7.6. BMP Sizing

The sidewalk/trail compost-amended strip width may be determined using the sizing factor approach for the On-Site Standard by providing the specified ratio of BMP width to the width of the contributing area. Alternatively, explicit simulation of the sidewalk/trail composted amended strip may be used to size the appropriate strip width for the contributing area.

Sizing Factors for On-site List Approach

Sidewalk/trail compost-amended strips may be sized using the sizing factors provided in Table 5.12 to meet the On-site List Approach. Sizing factors are presented as a ratio of hard surface width to sidewalk/trail compost-amended strip width. Sidewalk/trail compost-amended strip width is calculated by multiplying the width of hard surface contributing runoff by the sizing factor.

Refer to *Section 3.3.1* and *Appendix C* for infeasibility criteria to determine sidewalk/trail compost-amended strip infeasibility.

Table 5.12. On-site List Sizing for Sidewalk/Trail Compost-amended Strips.

Sidewalk/Trail Hard Surface Width	Subgrade Soil Design Infiltration Rate[a]	Sizing Factor for Strip Width[b,c]
Less than 10 feet	0.15 inch/hour	42%
	0.3 inch/hour	29%
	0.6 inch/hour	21%
10 to 25 feet[d]	0.15 inch/hour	33%
10 to 25 feet[d]	0.3 inch/hour	21%
10 to 25 feet[d]	0.6 inch/hour and greater	13%

[a] Infiltration testing is not required for this BMP. If no testing is done, assume a subgrade soil design infiltration rate of 0.15 inch/hour. If testing is completed, the subgrade soil design infiltration rate is based on site-specific infiltration rate measurement and safety factors as detailed in *Section 3.2* and *Appendix D*.

[b] The sizing factors meet both the On-site Performance Standard requirements.

[c] Total BMP width (level spreader, if required, plus compost-amended strip) must not be less than 1 foot. BMP width is measured perpendicular to the adjacent edge of hard surface.

[d] A 1-foot-wide level spreader adjacent to the sidewalk or trail is required for sidewalk or trail widths greater than or equal to 10 feet. The 1-foot length of the level spreader can be counted toward the required BMP width determined in the table.

Modeling Approach for On-site Performance Standard

Sidewalk/trail compost-amended strips can also be sized using the forested and pasture On-site Performance Standard. Continuous runoff hydrologic modeling using a CAVFS element may be used to quantify the performance of sidewalk/trail compost-amended strips relative to the On-site Performance Standard using the procedures and assumptions listed in Table 5.13. Modeling in MGSFlood is not currently allowed for this BMP.

Table 5.13. Continuous Modeling Assumptions for Sidewalk/Trail Compost-amended Strips.

Variable	Assumption
Precipitation Series	SEPTS-99 unless otherwise adopted by the Director
Computational Time Step	5 minutes
HSPF Parameters	LSUR, SLSUR, NSUR must be adjusted per *Appendix F*
Precipitation and Evaporation Applied to BMP	Yes
Minimum Pervious Strip Depth	8 inches
Embankment Height	Dependent on width of BMP. BMP surface slope must not exceed 25 percent or be less than 2 percent.
Compost-amended Strip Slope	Must not exceed 25 percent or be less than 2 percent.
Maximum Water Depth	1 inch
Compost-amended Soil Hydraulic Conductivity	1 inch per hour
Compost-amended Soil Porosity	30 percent
Subgrade Soil Design Infiltration Rate	Design infiltration rate (*Section 3.2* and *Appendix D*). If no testing is conducted, assume an infiltration rate of 0.15 inch per hour.

Refer to *Section 5.1.6* for modeling amended soils to partially meet the flow control and/or water quality treatment requirement when runoff is dispersed on amended soil.

5.3.7.7. Minimum Construction Requirements

Protect the flow path from sedimentation and compaction during construction. If the flow path area is disturbed during construction, restore the area to meet the Soil Amendment BMP requirements (refer to *Section 5.1*) and establish a dense cover of lawn, landscape, or groundcover.

5.3.7.8. Operation and Maintenance Requirements

O&M requirements for sidewalk/trail compost-amended strips are the same as the Filter Strip (Basic and CAVFS) O&M requirements provided in *Appendix G* (*BMP No. 11*).

5.3.8. Light Rail Elevated Guideway Dispersion

5.3.8.1. Description

This BMP is a dispersion BMP that allows stormwater runoff to sheet flow off the edge of elevated guideway and over a drip edge through a dispersal device that deflects and spreads the flow. Air currents can assist in breaking up vertical flow paths, allowing the water to fall naturally to the ground (similar to rainfall). Flows are then dispersed through a dispersion area consisting of existing natural vegetation or designed landscaping under and adjacent to the elevated guideway.

5.3.8.2. Performance Mechanisms

Light Rail Elevated Guideway Dispersion can provide flow control via flow attenuation, soil storage, and losses to infiltration, evaporation, and transpiration.

5.3.8.3. Applicability

This BMP provides some amount of Flow Control. Modeling is required to determine if the Flow Control provided by this BMP will be enough to meet the Flow Control based performance standards for the project.

This BMP is not presumed to provide a level of Runoff Treatment that meets Ecology's Runoff Treatment performance goals (i.e. basic, oils, phosphorus, and/or metals treatment).

5.3.8.4. Site Considerations

Refer to Light Rail Elevated Guideway Dispersion in Volume V of the SWMMWW for site considerations.

5.3.8.5. Design Criteria

Refer to Light Rail Elevated Guideway Dispersion in Volume V of the SWMMWW for design criteria.

5.3.8.6. BMP Sizing

Refer to Light Rail Elevated Guideway Dispersion in Volume V of the SWMMWW for sizing requirements.

5.3.8.7. Minimum Construction Requirements

Refer to Light Rail Elevated Guideway Dispersion in Volume V of the SWMMWW for minimum construction requirements.

5.3.8.8. Operations and Maintenance Requirements

Refer to Light Rail Elevated Guideway Dispersion in Volume V of the SWMMWW for operations and maintenance requirements.

5.4. Infiltration BMPs

Infiltration BMPs are designed to facilitate percolation of stormwater into the ground. The infiltration BMPs in this section include:

- Infiltration trenches (*Section 5.4.2*)
- Drywells (*Section 5.4.3*)
- Infiltrating bioretention (*Section 5.4.4*)
- Rain gardens (*Section 5.4.5*)
- Permeable pavement facilities (*Section 5.4.6*)
- Perforated stub-out connections (*Section 5.4.7*)
- Infiltration ponds (*Section 5.4.8*)
- Infiltration chambers/vaults (*Section 5.4.9*)

Infiltration, where appropriate, is the preferred method for stormwater management because it attempts to restore the pre-development flow regime. Due to the geologic and topographic conditions in Seattle, not all sites are suitable for stormwater infiltration. The use of infiltration practices may be limited in some areas due to topography and potential landslide hazards. In addition, many locations in Seattle have soils that are underlain by hydraulically restrictive materials (refer to *Appendix D, Section D-2.2.4*). These relatively impervious layers may limit or preclude infiltration by causing perched groundwater conditions during the wet season.

5.4.1. General Considerations for Infiltration BMPs

This section provides general requirements that are common to all infiltration BMPs included in this manual. Additional requirements specific to the different types of infiltration BMPs are provided in *Section 5.4.2* through *5.4.9*.

Note that permeable pavement surfaces (*Section 5.6.2*) are not considered infiltration BMPs for the purpose of this manual because they do not receive significant (greater than 10 percent) runoff from other areas and manage only the rain falling on the pavement surface. Although stormwater will infiltrate into the underlying soil, the volume infiltrated is similar to that infiltrated on vegetated permeable surfaces and do not necessitate the restrictions set forth in this section. Similarly, dispersion BMPs (*Section 5.3*) are not considered infiltration BMPs for the purposes of this manual. Although stormwater will infiltrate into the underlying soil, the stormwater is dispersed across a large area (subject to setbacks) making many of the restrictions set forth in this section unnecessary. The specific restrictions and setbacks that are applicable to permeable pavement surfaces and dispersion BMPs are provided in their respective sections in *Chapter 5* of this volume. An exception is that infiltration testing is required for permeable pavement surfaces when hydrologic modeling will be conducted to evaluate performance relative to the flow control, water quality treatment, or the On-site Performance Standard. Infiltration testing may also be used to demonstrate that permeable pavement surfaces are not feasible for the On-site List.

In addition to shallow infiltration BMPs, *Appendix D* also covers provisions for deep infiltration BMPs, which may include Underground Injection Control (UIC) wells. Deep infiltration BMPs are typically used to direct stormwater past surface soil layers that have lower infiltration rates and into well-draining soil. The depth of the soil layers with lower infiltration rates can vary significantly, so the technique required to reach the well-draining soils will also vary.

UIC wells are regulated by Ecology and the UIC Program (WAC 173-218). If UIC wells are considered, refer to Volume I, Chapter 4 of the SWMMWW. Information on the UIC program can also be found on Ecology's website: https://ecology.wa.gov/Regulations-Permits/Guidance-technical-assistance/Underground-injection-control-program.

The person responsible for the infiltration facility (i.e., the property owner for private systems) must determine whether the facility is a regulated UIC well and what requirements apply.

Ecology SWMMWW Language	References
The UIC program defines a UIC well as a well that is used to discharge fluids from the ground surface into the subsurface and is one of the following: ● *A bored, a drilled or driven shaft, or dug hole whose depth is greater than the largest surface dimension; or* ● *A dug hole whose depth is greater than the largest surface dimension, or* ● *An improved sinkhole; which is a natural crevice that has been modified, or* ● *A subsurface fluid distribution system which includes perforated pipes, drain tiles or other similar mechanisms intended to distribute fluids below the surface of the ground.*	● *Volume I, Chapter 2, Section I-2.9 of the SWMMWW*
Examples of UIC wells or subsurface infiltration systems are the following: ● *Drywells* ● *Drain fields* ● *Infiltration trenches with perforated [or slotted] pipe* ● *Storm chamber systems with the intent to infiltrate* ● *French drains* ● *Bioretention systems intending to infiltrate water from a [slotted] pipe below the treatment soil* ● *Other similar devices that discharge to ground* Note: Modifications from the SWMMWW are shown in brackets for design criteria specific to the City of Seattle.	● *Volume I, Chapter 2, Section I-2.9 of the SWMMWW*

5.4.2. Infiltration Trenches

5.4.2.1. Description

Infiltration trenches are trenches backfilled with a coarse aggregate. Stormwater runoff can enter the trench as overland surface flow through a grate or exposed aggregate surface, or as concentrated flow delivered to the aggregate-filled trench using a perforated or slotted distribution pipe.

Infiltration trenches are subject to state UIC regulations when perforated pipe is used. Provided that the design and O&M criteria in this section are met, only the registration requirement applies. Where perforated pipe is not used, the registration requirement does not apply.

Ecology SWMMWW Language	References
All UIC wells must be registered except: UIC wells at single-family homes (or duplexes) receiving only residential roof runoff used to collect stormwater runoff from roof surfaces on an individual home (or duplex) or for basement flooding control or UIC wells used only to control basement flooding	• *Volume 1, Chapter 4, Section 1-4.3 of the SWMMWW*
The following are not UIC wells: • *Infiltration trenches designed without perforated pipe or a similar mechanism*	• *Volume 1, Chapter 2, Section 1-2.9 of the SWMMWW*

5.4.2.2. Performance Mechanisms

Flow control occurs through temporary storage of stormwater runoff in the spatial voids of the aggregate material and subsequent infiltration of stormwater into the underlying soils. Pollutant removal mechanisms include infiltration, filtration, adsorption, and biodegradation.

5.4.2.3. Applicability

An infiltration trench can be designed to provide on-site stormwater management, flow control and/or water quality treatment. This BMP can be applied to meet the requirements listed below.

BMP	On-site: List	On-site: Standard	Flow Control: Forest	Flow Control: Pasture	Flow Control: Peak	Water Quality: Basic	Water Quality: Enhanced Metals	Water Quality: Oil Control	Water Quality: Phosphorus	Conveyance
Infiltration Trenches	x[a]	x[a]	x[a]	x[a]	x[a]	x[a, b]	x[a, b]		x[a, c]	

[a] Infiltration trenches are only applicable where the site measured infiltration rate is at least 5 inches per hour. PGHS or PGPS may only be directed to infiltration trenches if the soil suitability criteria for the subgrade soils are met (*Section 4.5.2*).

[b] Soil suitability criteria for subgrade soils (*Section 4.5.2*) and applicable drawdown requirements (*Section 4.5.1*) also apply.

[c] Refer to treatment train options for infiltration BMPs included in *Section 4.4.3.2*.

5.4.2.4. Site Considerations

Site considerations for the applicability of infiltration trenches are provided in *Section 3.2* and *Section 4.5*. Refer to *Appendix C* for additional infeasibility criteria for the On-site List Approach.

5.4.2.5. Design Criteria

This section provides a description and requirements for the components of infiltration trenches. Refer to Figures 5.8 and 5.9 for schematics of typical infiltration trenches. Design criteria are provided in this section for the following elements:

- Trench dimensions and layout
- Aggregate material
- Geotextile
- Subgrade
- Flow entrance and presettling
- Perforated pipe
- Observation port
- Overflow

Trench Dimensions and Layout

The minimum requirements associated with the trench dimensions and layout include the following:

- The minimum depth of an infiltration trench must be 18 inches.
- The minimum width of an infiltration trench must be 24 inches. Sides of adjacent trenches must be a minimum of 5 feet apart. There is no maximum trench width.
- The maximum vertical trench depth of aggregate storage reservoir must be 36 inches.
- The bottom of the trench must be level.
- There is not a maximum width of trenches, but trenches with perforated or slotted pipe that are 8 feet or wider require multiple rows of perforated or slotted pipe. See the *Perforated Pipe* section.

To maximize the storage depth in the trench, the trench should be oriented parallel to site contour lines. The trench can be placed under a pervious or impervious surface cover to conserve space.

Aggregate Material

Trenches must be filled with uniformly graded, washed gravel with a nominal size from 0.75- to 1.5-inch diameter. The minimum void volume must be 30 percent. These requirements can be met with City of Seattle Mineral Aggregate Type 4.

Geotextile

Non-woven geotextile fabric, according to the specifications presented in *Appendix E*, must completely surround the aggregate material. A 6inch minimum layer of sand may be used as a

filter media instead of geotextile at the bottom of the trench, but geotextile is still required on the sides and top of the aggregate material.

Subgrade

The minimum measured subgrade infiltration rate for infiltration trenches is 2 inches per hour. If infiltration trenches are to be used to meet the water quality treatment requirement or if runoff from any PGHS is directed to the infiltration trench, underlying soil must meet the soil requirements outlined in *Section 4.5.2*.

During construction the subgrade soil surface can become smeared and sealed by excavation equipment. The design must require scarification or raking of the side walls and bottom of the facility excavation to a minimum depth of 4 inches after excavation to restore infiltration rate.

Flow Entrance and Presettling

Trenches designed to receive concentrated stormwater flows (refer to Figure 5.8) must include a small catch basin with downturned elbow (trap). Presettling requirements are provided in *Section 4.4.5*.

For trenches designed to receive sheet flow (refer to Figure 5.9), the site must be graded so that runoff is directed as sheet flow across a minimum 10foot grass buffer strip to remove larger sediment particles prior to runoff entering the trench. Six inches of gravel must be placed over the geotextile covering the trench aggregate to allow flows to enter the trench.

Perforated Pipe

Concentrated flows must be distributed into the aggregate material using a perforated or slotted subsurface pipe with a minimum diameter of 4 inches. Trenches that are 8 feet or wider require multiple rows of perforated pipes spaced at no more than 6 feet on-center.

Observation Port

Infiltration trenches that are designed to meet flow control and/or water quality treatment requirements and receive runoff from contributing areas of 2,000 square feet or more must be equipped with an observation port to measure the drawdown time following a storm and to monitor sedimentation to determine maintenance needs. Observation ports must consist of a 4inch minimum diameter perforated or slotted pipe that extends to the bottom of the trench (i.e., to the subgrade) and is equipped with a secure well cap.

Overflow

Trenches must have an overflow designed to convey any flow exceeding the capacity of the facility unless designed to fully infiltrate all flows for the full, required simulation period. Plans must indicate surface flow paths in case of failure of the BMP (refer to *Section 4.3.3*). If overflow is connected to the public drainage system with a pipe, a catch basin must be installed prior to the connection to the public drainage system to prevent root intrusion into public drainage main lines.

To prevent damage to overlying pavement, trenches located beneath pavement must be constructed with a trench pipe overflow connected to a catch basin with a grate cover. Design must be such that, if the trench infiltration capacity is exceeded, the trench pipe overflow would occur out of the catch basin to an approved point of discharge. The vertical elevation difference between the pavement surface and the trench pipe overflow invert must be 1 foot minimum.

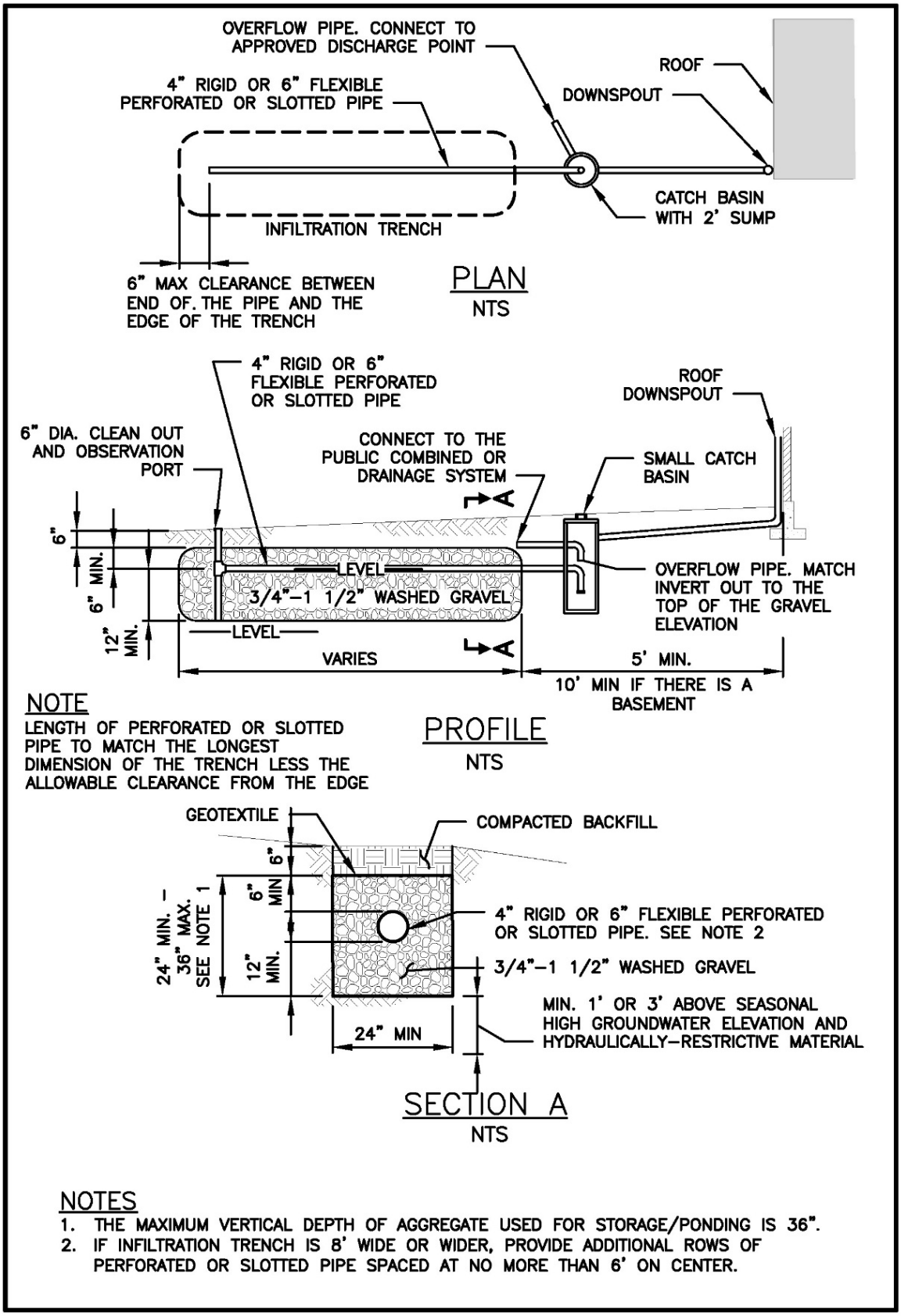


Figure 5.8. Typical Infiltration Trench Receiving Concentrated Flow.

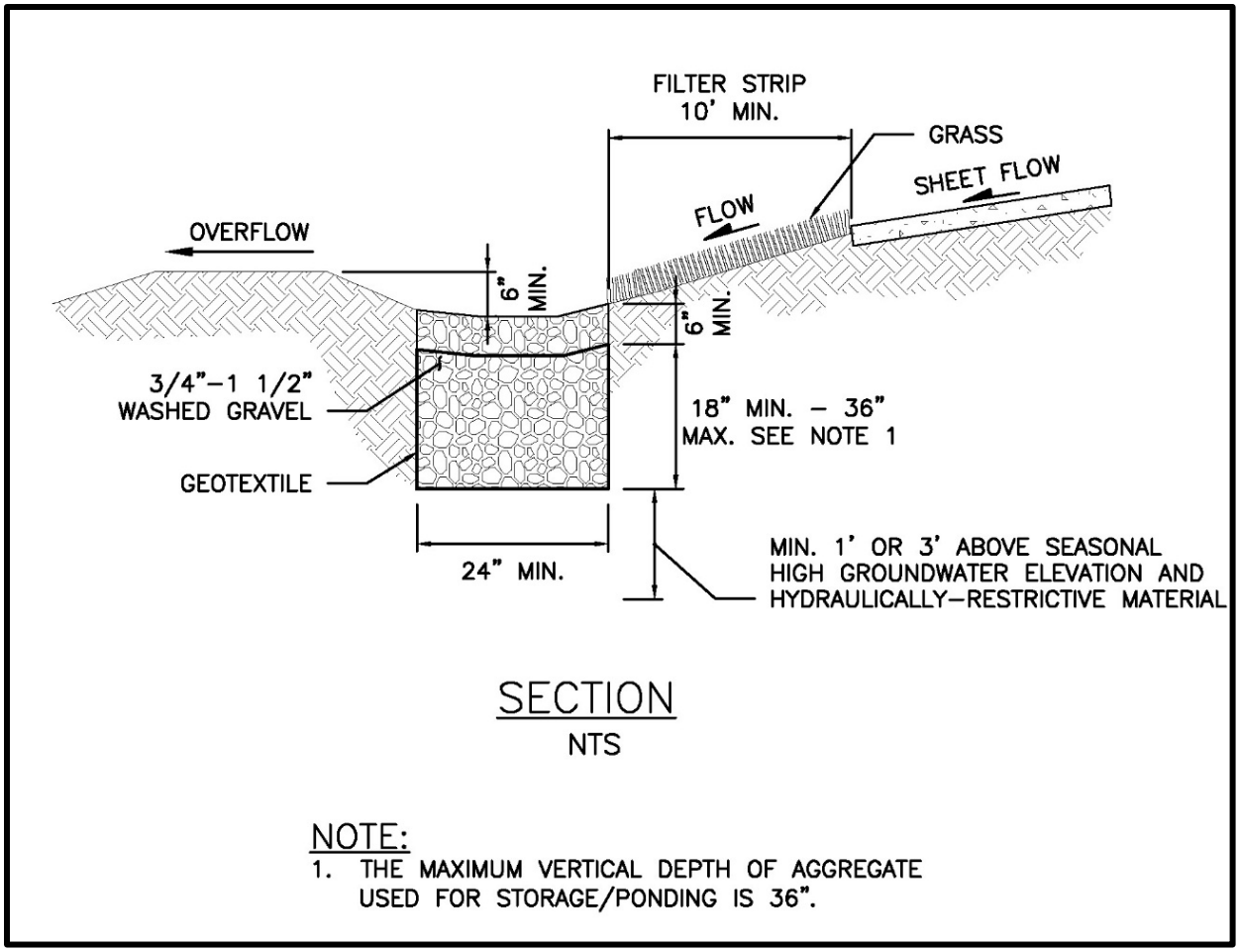


Figure 5.9. Typical Infiltration Trench Receiving Sheet Flow.

5.4.2.6. BMP Credits

Credit for On-site List Approach

Infiltration trenches can only be considered for compliance with the On-Site List Requirement (refer to *Section 3.3.1* and *Appendix C* for infeasibility criteria) when the site measured infiltration rate is at least 5 inches per hour. The hard surface area managed with an infiltration trench sized according to Table 5.14 meets the requirement. Aggregate-filled trench must be a minimum of 18 inches deep (as shown in Figures 5.8 and 5.9).

Table 5.14. On-site List Sizing for Infiltration Trenches.

Subgrade Soil Design Infiltration Rate	Sizing Factor for Infiltration Trench Area[a]
1 inch/hour	15%
2.5 inches/hour	10.5%
5 inches/hour	5.7%
7.5 inches/hour	4.8%
10 inches/hour	4%

Infiltration Trench Area = Contributing Hard Surface Area x Factor (%)/100.

Hard Surface Area Managed = Trench Area ÷ Factor (%)/100.

[a] Sizing factors developed based on Ecology sizing requirements for T5.10A in Volume V of the SWMMWW (trench length as a function of soil type). Soil types were converted to initial infiltration rates based on Ecology's Table 3.7 – Recommended Infiltration Rates based on USDA Soil Textural Classification from Ecology's 2005 SWMMWW Volume III. Design infiltration rates were calculated by applying a correction factor of 2. Trench length was converted to a sizing factor.

Sizing factors are used to calculate the infiltration trench facility area as a function of the area contributing runoff to the trench as explained below for the Pre-sized Approach. The subgrade design infiltration rate must be rounded down to the nearest rate in the sizing table.

Pre-sized Approach for Flow Control and Water Quality Treatment

The Pre-sized Approach may be used for projects with new and replaced hard surface areas up to 10,000 square feet. Under the Pre-sized Approach (refer to *Section 4.1.2*), pre-sized infiltration trenches may be used to achieve Pre-developed Pasture, Peak Control and Water Quality Treatment Standards. Sizing factors and equations for infiltration trenches receiving runoff from a hard surface are provided in Table 5.15. Factors are organized by flow control standard, trench depth, subgrade soil design infiltration rate, and contributing area. A 1.5-foot or 3-foot aggregate storage reservoir depth may be selected. The aggregate storage reservoir is the subsurface aggregate layer below the overflow invert elevation that stores water for infiltration into the underlying subgrade soils (refer to Figures 5.8 and 5.9). The design rate for the subgrade soils must be rounded down to the nearest infiltration rate in the pre-sized table (i.e., 1.0, or 2.5 inch per hour).

To use these sizing factors or equations to meet flow control standards, the facility must meet the general requirements for infiltration trenches outlined in this section, plus the following specific requirements:

- The trench area must be sized using the applicable sizing factor or equation.
- The average aggregate storage reservoir depth across the trench must be set at the designated height (1.5 or 3 feet). For intermediate ponding depths (between 1.5 and 3.0 feet), the sizing factor may be linearly interpolated.
- To use pre-sized infiltration trenches to meet the water quality treatment requirement or if any runoff from PGHS is directed to the trench, the underlying soil must meet soil requirements specified in *Section 4.5.2*.
- The aggregate storage reservoir must be composed of Mineral Aggregate Type 4 or approved equal.
- Invert of overflow must be set at top of the storage reservoir to provide the required aggregate storage reservoir depth (e.g., pipe invert set at 1.5 or 3 feet if the bottom of the trench is flat).

Table 5.15. Pre-sized Sizing Factors and Equations for Infiltration Trenches.

Trench Depth	Subgrade Soil Design Infiltration Rate	Contributing Area (sf)	Sizing Factor/Equation for Infiltration Trench Area: Pre-developed Pasture Standard	Sizing Factor/Equation for Infiltration Trench Area: Peak Control Standard	Sizing Factor/Equation for Infiltration Trench Area: Water Quality Treatment Standard[a]
1.5 feet	1.0 inch/hour	≤2,000 2,001 – 10,000	12.0% [0.0764 x A] +56.3	15.7%	5.0%
	2.5 inch/hour	≤2,000 2,001 – 10,000	5.4% [0.0311 x A] +47.2	8.1%	2.2%
3.0 feet	1.0 inch/hour	≤2,000 2,001 – 10,000	8.4% [0.0542 x A] +61.4	10.1%	3.5%
	2.5 inch/hour	≤2,000 2,001 – 10,000	3.8% [0.0241 x A] +27.7	5.5%	1.6%

A – contributing hard surface area; sf – square feet.

For Sizing Factors: Infiltration Trench Area = Contributing Hard Surface Area x Factor (%)/100.
Hard Surface Area Managed = Trench Area ÷ Factor (%)/100.

For Sizing Equations: Infiltration Trench Area (sf) = [Factor x A (sf)] + Integer.
Hard Surface Area Managed (sf) = [Trench Area (sf) – Integer]÷ Factor.

[a] Pre-sized Approach may be used to meet basic or metals water quality treatment if soil suitability criteria are met (refer to *Section 4.5.2*).

The infiltration trench facility area is calculated as a function of the area contributing runoff to the trench. As an example, to meet the Pre-developed Pasture Standard using a 1.5-foot-deep infiltration trench for a contributing area between 2,000 and 10,000 square feet where the design subgrade infiltration rate of 2.5 or more inches per hour, the trench area would be calculated as: 0.0311 x contributing hard surface area + 47.2. All area values must be in square feet.

Alternatively, infiltration trench facilities can be sized using a continuous hydrologic simulation model as described in the subsequent section.

Modeling Approach for On-site Performance Standard, Flow Control, and Water Quality Treatment

When using continuous hydrologic modeling to size infiltration trenches, the assumptions listed in Table 5.16 must be applied. It is recommended that infiltration trenches be modeled as a gravel-filled trench with infiltration to underlying soil and an overflow. The contributing area, trench area, and depth should be iteratively sized until the Minimum Requirements for On-site Stormwater Management, Flow Control, and/or Water Quality Treatment are met (refer to *Volume 1*) or where it has been determined by the Director that there is no off-site point of discharge for the project, the requirements of *Section 4.3.2* are met. General sizing procedures for infiltration facilities are presented in *Section 4.5.1*.

Table 5.16. Continuous Modeling Assumptions for Infiltration Trench Facilities.

Variable	Assumption
Precipitation Series	SEPTS-99 unless otherwise adopted by the Director
Computational Time Step	5 minutes
HSPF Parameters	LSUR, SLSUR, NSUR must be adjusted per *Appendix F*
Inflows to Facility	Surface flow and interflow from total drainage area (including impervious and pervious contributing areas) routed to facility.
Precipitation and Evaporation Applied to Facility	Yes, if sited under pervious surface (e.g., lawn). If model does not apply precipitation and evaporation to facility, include the facility area as additional impervious area in the post-developed basin area that contributes runoff to the facility.
Aggregate Storage Reservoir Depth	Average depth of aggregate below overflow invert
Aggregate Storage Reservoir Porosity	Assume maximum 30% unless test showing higher porosity is provided
Subgrade Soil Design Infiltration Rate	Design infiltration rate (*Section 4.5.2*, *Appendix D*)
Infiltration Across Wetted Surface Area	No (bottom area only)
Outlet Structure	Overflow elevation set at average maximum subsurface ponding depth. May be modeled as weir flow over riser edge. Note that freeboard must be sufficient to allow water surface elevation to rise above the overflow elevation to provide head for discharge.

5.4.2.7. Minimum Construction Requirements

During construction, it is critical to prevent clogging and over-compaction of the subgrade. Minimum requirements associated with infiltration trench construction include the following:

- **Aggregate Placement and Compaction** — Place the stone aggregate in lifts and compact using plate compactors. A maximum loose lift thickness of 12 inches is allowed. The compaction process aids in adhering the geotextile to the excavation sides, thereby, reducing soil piping, geotextile clogging, and settlement problems.
- **Potential Contamination** — Prevent natural or fill soils from intermixing with the aggregate. Remove all contaminated aggregate and replace with uncontaminated aggregate.
- **Overlap** — Following the stone aggregate placement, fold the geotextile over the stone aggregate to form a 12-inch minimum longitudinal overlap. When geotextile overlaps are required between rolls, overlap the upstream roll a minimum of 2 feet over the downstream roll in order to provide a shingled effect.

5.4.2.8. Operations and Maintenance Requirements

General O&M requirements for infiltration facilities apply to infiltration trenches. Infiltration trench O&M requirements are provided in *Appendix G* (*BMP No. 2*).

5.4.3. Drywells

5.4.3.1. Description

Drywells are similar to infiltration trenches but are typically deeper and require less surface area. Stormwater is delivered to the drywell by pipe.

Drywells are subject to state UIC regulations. Provided that the design and O&M criteria in this section are met, only the registration requirement applies.

Ecology SWMMWW Language	References
All UIC wells must be registered except: UIC wells at single-family homes (or duplexes) receiving only residential roof runoff used to collect stormwater runoff from roof surfaces on an individual home (or duplex) or for basement flooding control.	• *Volume 1, Chapter 4, Section 1-4.3 of the SWMMWW*

5.4.3.2. Performance Mechanisms

Flow control occurs through temporary storage of stormwater runoff in the spatial voids of the aggregate material, and subsequent infiltration of stormwater into the underlying soils.

5.4.3.3. Applicability

A drywell can be designed to provide on-site stormwater management and/or flow control. This BMP can be applied to meet the requirements listed below.

BMP	On-site: List	On-site: Standard	Flow Control: Forest	Flow Control: Pasture	Flow Control: Peak	Water Quality: Basic	Water Quality: Enhanced Metals	Water Quality: Oil Control	Water Quality: Phos-phorus	Convey-ance
Drywell	x[a]	x[a]	x[a]	x[a]	x[a]					

[a] Drywells are only applicable where the site measured infiltration rate is at least 5 inches per hour. PGHS or PGPS may only be directed to drywells if the soil suitability criteria for the subgrade soils are met (*Section 4.5.2*).

5.4.3.4. Site Considerations

Site considerations for the applicability of drywells are provided in *Section 3.2* and *Section 4.5*. Refer to *Appendix C* for additional infeasibility criteria for the On-site List Approach.

5.4.3.5. Design Criteria

This section following provides a description and requirements for the components of drywells. Figure 5.10 shows a typical drywell system. Design criteria are provided in this section for the following elements:

- Drywell dimensions and layout
- Aggregate material
- Geotextile
- Subgrade
- Flow entrance and presettling
- Perforated pipe
- Observation port
- Overflow

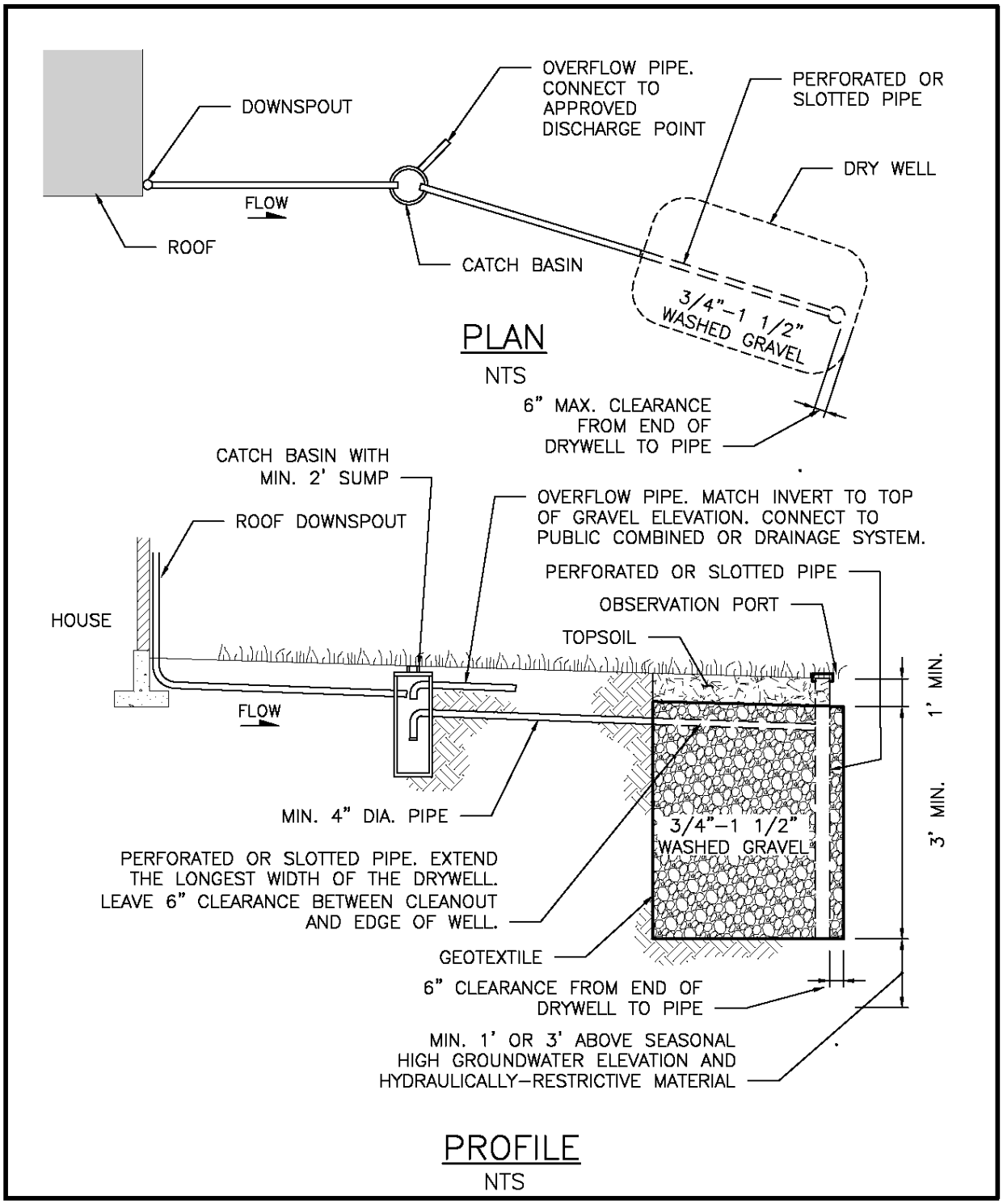


Figure 5.10. Typical Infiltration Drywell.

Drywell Dimensions and Layout

Minimum requirements associated with the drywell dimensions and layout include the following:

- The minimum depth of a drywell (aggregate and cover) must be 4 feet.
- Spacing between drywells must be a minimum of 10 feet.
- The drywell can be placed under a pervious or impervious surface cover to conserve space.

Aggregate Material

Drywells must be filled with uniformly graded, washed gravel with a nominal size from 0.75- to 1.5-inch diameter. The minimum void volume must be 30 percent. These requirements can be met with City of Seattle Mineral Aggregate Type 4.

Geotextile

Non-woven geotextile fabric, according to the specifications presented in *Appendix E*, must be placed around the walls, bottom and top of the drywell aggregate. A 6inch minimum layer of sand may be used as a filter media instead of geotextile at the bottom of the well, but geotextile is still required on the sides and top of the aggregate material.

Subgrade

The minimum measured subgrade infiltration rate for drywells is 5 inches per hour. If runoff from any PGHS is directed to the drywell, underlying soil must meet the soil requirements outlined in *Section 4.5.2*.

During construction the subgrade soil surface can become smeared and sealed by excavation equipment. The design must require scarification or raking of the side walls and bottom of the facility excavation to a minimum depth of 4 inches after excavation to restore infiltration rate.

Flow Entrance and Presettling

Flows must be delivered to the drywell aggregate using a pipe with a 4-inch minimum diameter. Stormwater inflows must be routed through a catch basin with downturned elbow (trap). Presettling requirements are provided in *Section 4.4.5*.

Observation Port

Drywells that are designed to meet flow control requirements and receive runoff from contributing areas of 5,000 square feet or more must be equipped with an observation port to measure the drawdown time following a storm and to monitor sedimentation to determine maintenance needs. Observation ports must consist of a 4inch minimum diameter perforated or slotted pipe that extends to the bottom of the drywell (i.e., to the subgrade) and is equipped with a secure well cap.

Overflow

Drywells must have an overflow designed to convey any flow exceeding the capacity of the facility unless designed to fully infiltrate all flows for the full, required simulation period.

Plans must indicate surface flow paths in case of failure of the BMP (refer to *Section 4.3.3*). If overflow is connected to the public drainage system, a catch basin must be installed prior to the connection to the public drainage system to prevent root intrusion into public drainage main lines.

To prevent damage to overlying pavement, drywells located beneath pavement must be constructed with a trench pipe overflow connected to a catch basin with a grate cover. Design must be such that, if the drywell infiltration capacity is exceeded, the trench pipe overflow would occur out of the catch basin to an approved point of discharge. The vertical elevation difference between the pavement surface and the trench pipe overflow invert must be 1 foot minimum.

5.4.3.6. BMP Sizing

Sizing for On-site List Approach

Drywells can only be selected to meet the On-site List Requirement (refer to *Section 3.3.1* and *Appendix C* for infeasibility criteria) when the site measured infiltration rate is at least 5 inches per hour. The hard surface area managed with a drywell sized according to Table 5.17 meets the requirement.

Table 5.17. On-site List Sizing for Drywells.

Aggregate Depth	Subgrade Soil Design Infiltration Rate	Sizing Factor for Facility Bottom Area[a] On-site List
4 feet	2.5 inch/hour	2.4%
	5 inches/hour	2.4%
	7.5 inches/hour	2.3%
	10 inches/hour	2.1%

Drywell Area (sf) = Contributing Hard Surface Area x Factor (%)/100.

Hard Surface Area Managed = Drywell Area ÷ Factor (%)/100.

Drywell must be a minimum of 48 inches in diameter.

[a] Sizing factors developed based on Ecology sizing requirements for T5.10A in Volume V of the SWMMWW (drywell aggregate volume as a function of soil type). Soil types were converted to initial infiltration rates based on Ecology's Table 3.7 – Recommended Infiltration Rates based on USDA Soil Textural Classification from Ecology's 2005 SWMMWW Volume III. Design infiltration rates were calculated by applying a correction factor of 2. Drywell volume was converted to a sizing factor.

Pre-sized Approach for Flow Control

The Pre-sized Approach may be used for projects with new and replaced hard surface areas up to 10,000 square feet. Under the Pre-sized Approach (refer to *Section 4.1.2*), pre-sized drywells may be used to achieve Pre-developed Pasture and Peak Control Standards. Sizing factors and equations for drywells receiving runoff from a hard surface are provided in Table 5.18. Factors are organized by flow control standard, drywell depth, subgrade soil design infiltration rates and contributing area. A 4foot or 6foot aggregate storage reservoir depth may be selected. The aggregate storage reservoir is the subsurface aggregate layer below the overflow invert elevation that stores water for infiltration into the underlying subgrade soils. The design rate for the subgrade soils must be rounded down to the nearest infiltration rate in the pre-sized table (i.e., 1.0 or 2.5 inch per hour).

To use these sizing factors or equations to meet flow control standards, the facility must meet the general requirements for drywells outlined in this section plus the following specific requirements:

- The drywell area must be sized using the applicable sizing factor or equation.
- The average aggregate storage reservoir depth in the drywell must be set at the designated height (e.g., 4 feet). For intermediate ponding depths (between 4 and 6 feet), the sizing factor may be linearly interpolated.
- If any runoff from PGHS is directed to the drywell, the underlying soil must meet soil requirements specified in *Section 4.5.2*.
- The aggregate storage reservoir must be composed of Mineral Aggregate Type 4 or approved equal.
- The invert of the overflow must be set at top of the storage reservoir to provide the required aggregate storage reservoir depth (e.g., pipe invert set at 4 feet if the bottom of the well is flat).

Table 5.18. Pre-sized Sizing Factors and Equations for Drywells.

Drywell Depth	Subgrade Soil Design Infiltration Rate	Contributing Area (sf)	Sizing Factor/Equation for Drywell Area: Pre-developed Pasture Standard	Sizing Factor/Equation for Drywell Area: Peak Control Standard
4.0 feet	1.0 inch/hour	≤ 2,000	7.0%	8.9%
		2,001 – 10,000	[0.0463 x A] + 49.1	8.9%
	2.5 inch/hour	≤ 2,000	3.1%	4.6%
		2,001 – 10,000	[0.0212 x A] + 20.2	4.6%
6.0 feet	1.0 inch/hour	≤ 2,000	4.3%	5.4%
		2,001 – 10,000	[0.032 x A] + 22.5	5.4%
	2.5 inch/hour	≤ 2,000	2.2%	3.3%
		2,001 – 10,000	[0.0172 x A] + 10.4	3.3%

A – contributing hard surface area; sf – square feet.

Drywell must be a minimum of 48 inches in diameter.

For Sizing Factors: Drywell Area = Contributing Hard Surface Area x Factor (%)/100.
Hard Surface Area Managed = Drywell Area ÷ Factor (%)/100.

For Sizing Equations: Drywell Area (sf) = [Factor x A (sf)] + Integer.
Hard Surface Area Managed (sf) = [Drywell Area (sf) - Integer] ÷ Factor.

The drywell facility area is calculated as a function of the area contributing runoff to the drywell. As an example, to meet the Pre-developed Pasture Standard using a 6-foot-deep drywell for a contributing area less than 2,000 square feet, the well area would be equal to 4.3 percent of the contributing area when the subgrade infiltration rate is between 1.0 and 2.49 inches per hour.

Alternatively, drywell facilities can be sized using a continuous hydrologic simulation model as described in the subsequent section.

Modeling Approach for On-site Performance Standard and Flow Control

Continuous hydrologic modeling may be used to size drywells using the general infiltration BMP sizing procedures presented in *Section 4.5.1* and the procedures presented for infiltration trenches in *Section 5.4.2.6*.

5.4.3.7. Minimum Construction Requirements

During construction, it is critical to prevent clogging and over-compaction of the subgrade. Minimum requirements associated with drywell construction include the following:

- **Aggregate Placement and Compaction** — Place the stone aggregate in lifts and compact using plate compactors. A maximum loose lift thickness of 12 inches is allowed. The compaction process aids in adhering the geotextile to the excavation sides, thereby, reducing soil piping, geotextile clogging, and settlement problems.
- **Potential Contamination** — Prevent natural or fill soils from intermixing with the aggregate. Remove all contaminated aggregate and replace with uncontaminated aggregate.
- **Overlap** — Following the stone aggregate placement, fold the geotextile over the stone aggregate to form a 12-inch minimum longitudinal overlap. When geotextile overlaps are required between rolls, overlap the upstream roll a minimum of 2 feet over the downstream roll in order to provide a shingled effect.

5.4.3.8. Operations and Maintenance Requirements

General O&M requirements for infiltration facilities apply to drywells. Drywell O&M requirements are provided in *Appendix G* (*BMP No 2*).

5.4.4. Infiltrating Bioretention

5.4.4.1. Description

Infiltrating bioretention facilities are shallow earthen depressions or vertical walled open-bottom boxes with a designed soil mix and plants adapted to the local climate and soil moisture conditions. Stormwater is stored as surface ponding before it filters through the underlying bioretention soil. Stormwater that exceeds the surface storage capacity overflows to an adjacent drainage system. Treated water is infiltrated into the underlying soil or, in soils with lower infiltration rates, collected by an underdrain and discharged to the drainage system. Bioretention facilities can be individual cells or multiple cells connected in series.

Two variations of infiltrating bioretention facilities are included in this section:

- **Infiltrating bioretention facility**: Bioretention facilities can have either sloped sides (e.g., an earthen depression) or vertical sides (e.g., vertical walled open-bottom box). Infiltrating bioretention cells are not lined and may or may not have an underdrain or outlet control structure (e.g., orifice).
- **Infiltrating bioretention facility series**: Bioretention facilities with sloped or vertical sides may be connected in series, with the overflows of upstream cells directed to downstream cells to provide additional flow control and/or treatment and conveyance. Individual cells are defined as separate ponding areas delineated by distinct overflow to a downstream BMP or point of discharge.

Rain gardens are similar to infiltrating bioretention facilities but are subject to fewer technical requirements (refer to *Section 5.4.5*). Bioretention facilities are considered non-infiltrating if they include a liner, low-permeability barrier, or impermeable barrier to restrict or prevent infiltration to the underlying soil (refer to *Section 5.8.2*).

5.4.4.2. Performance Mechanisms

Infiltrating bioretention provides flow control via detention, attenuation, and losses due to infiltration, interception, evaporation, and transpiration. Water quality treatment is accomplished through sedimentation, filtration, adsorption, uptake, or biodegradation and transformation of pollutants by soil organisms, soil media, and plants.

5.4.4.3. Applicability

Infiltrating bioretention facilities can be designed to provide on-site stormwater management, flow control and/or water quality treatment. This BMP can be applied to meet or partially meet the requirements listed below.

BMP	On-site: List	On-site: Standard	Flow Control: Forest	Flow Control: Pasture	Flow Control: Peak	Water Quality: Basic	Water Quality: Enhanced Metals	Water Quality: Oil Control	Water Quality: Phosphorus	Conveyance
Infiltrating bioretention without underdrain	x	x	x	x	x	x	x		x[b]	x[c]
Infiltrating bioretention with underdrain	x	x[a]	x[a]	x[a]	x[a]	x	x		x[b]	x[c]

[a] Standard may be partially or completely achieved depending upon ponding depth, degree of underdrain elevation, infiltration rate, contributing area, and use of orifice control.

[b] Refer to Soil Suitability Criteria in *Section 4.5.2*.

[c] Infiltrating bioretention facilities may be connected in series, with the overflows from upstream cells directed to downstream cells to provide conveyance.

5.4.4.4. Site Considerations

Site considerations for the applicability of infiltrating bioretention are provided in *Section 3.2* and *Section 4.5*. Additional site considerations apply for nutrient-critical receiving waters:

- **Phosphorous considerations:** Infiltrating bioretention is not permitted within 1/4 mile of nutrient-critical receiving waters if the underlying soil does not meet the soil requirements outlined in *Section 4.5.2* unless High Performance Bioretention Soil Mix (HPBSM) and a polishing layer are used. Bioretention with an underdrain is not permitted if the underdrained water would be routed to a nutrient-critical receiving water unless High Performance Bioretention Soil Mix (HPBSM) and a polishing layer are used. See City of Seattle Standard Specifications for more information about HPBSM and polishing layer.
- Refer to *Appendix C* for additional infeasibility criteria for the On-site List Approach.

5.4.4.5. Design Criteria

This section provides a description, recommendations, and requirements for the components of bioretention facilities. Typical components of bioretention facilities without underdrains and configured sloped and vertical sides are shown in Figures 5.11 and 5.12, respectively. Typical components of bioretention facilities with underdrains and configured sloped and vertical sides are shown in Figures 5.13 and 5.14, respectively. The vertical sides of bioretention facilities may be constructed from concrete, steel or fiberglass and must be UV and corrosion resistant and able to withstand earth pressure if below ground. Alternative

material may be used with the permission of the director. Refer to *Appendix C* for additional infeasibility criteria for the On-site List Approach. Further guidance can be found in SPU's Green Stormwater Infrastructure Manual for Capital Improvement Projects and Seattle Streets Illustrated, the Right-of-Way Improvements Manual (refer to SDOT/SDCI Director's Rules 04-2017/31-2017).

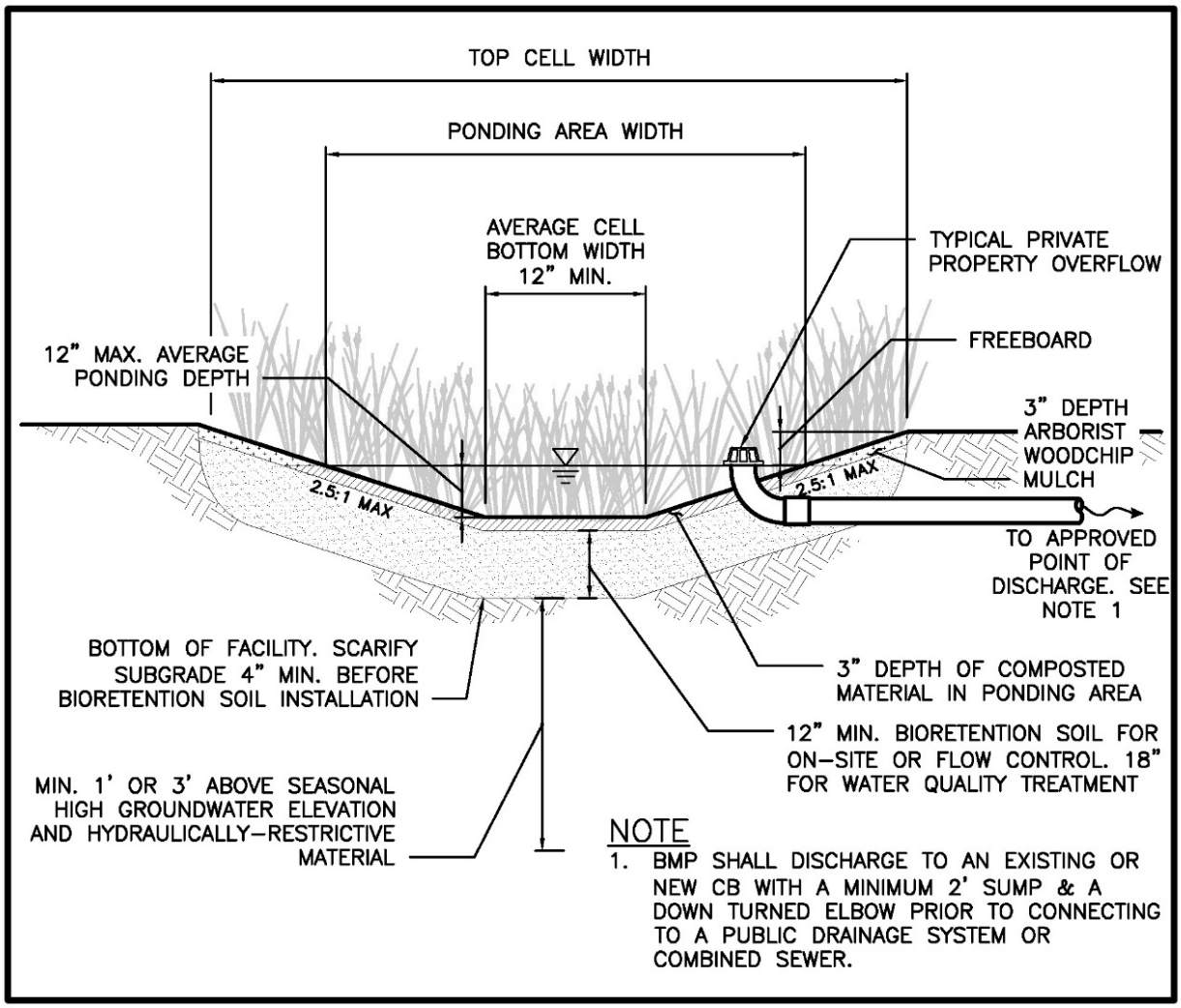


Figure 5.11. Infiltrating Bioretention Facility with Sloped Sides (without Underdrain).

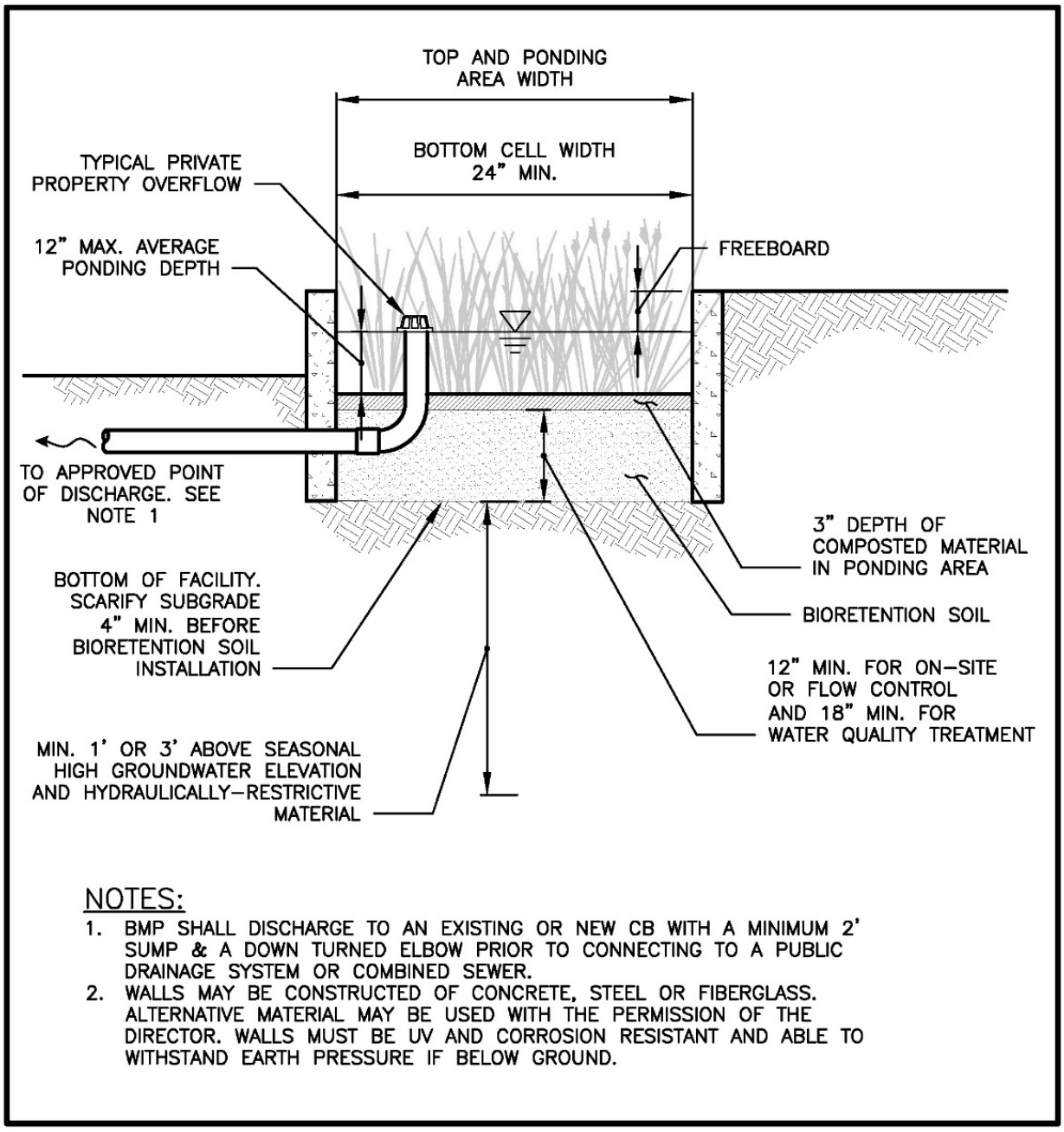


Figure 5.12. Infiltrating Bioretention Facility with Vertical Sides (without Underdrain).

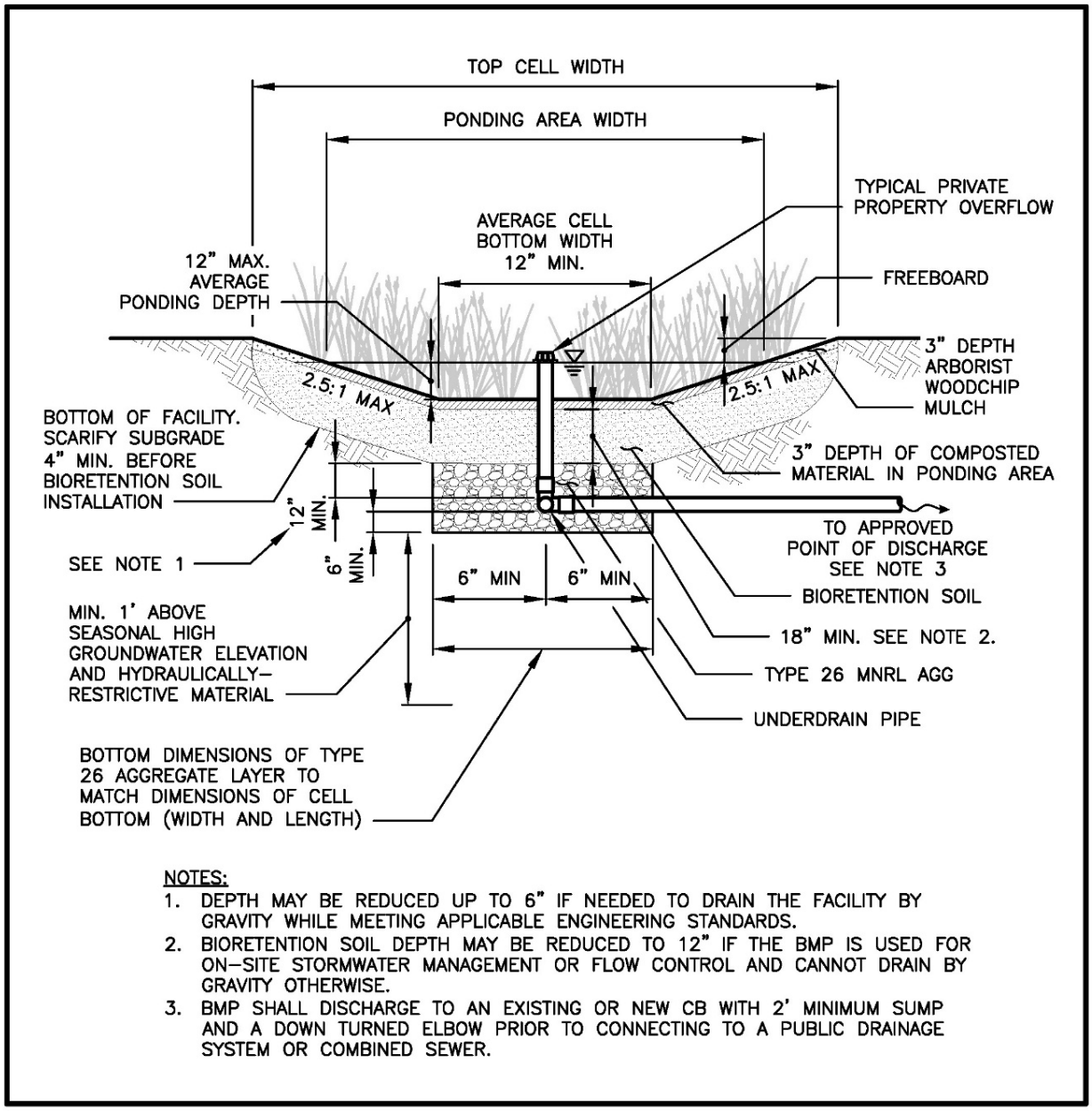


Figure 5.13. Infiltrating Bioretention Facility with Sloped Sides (with Underdrain).

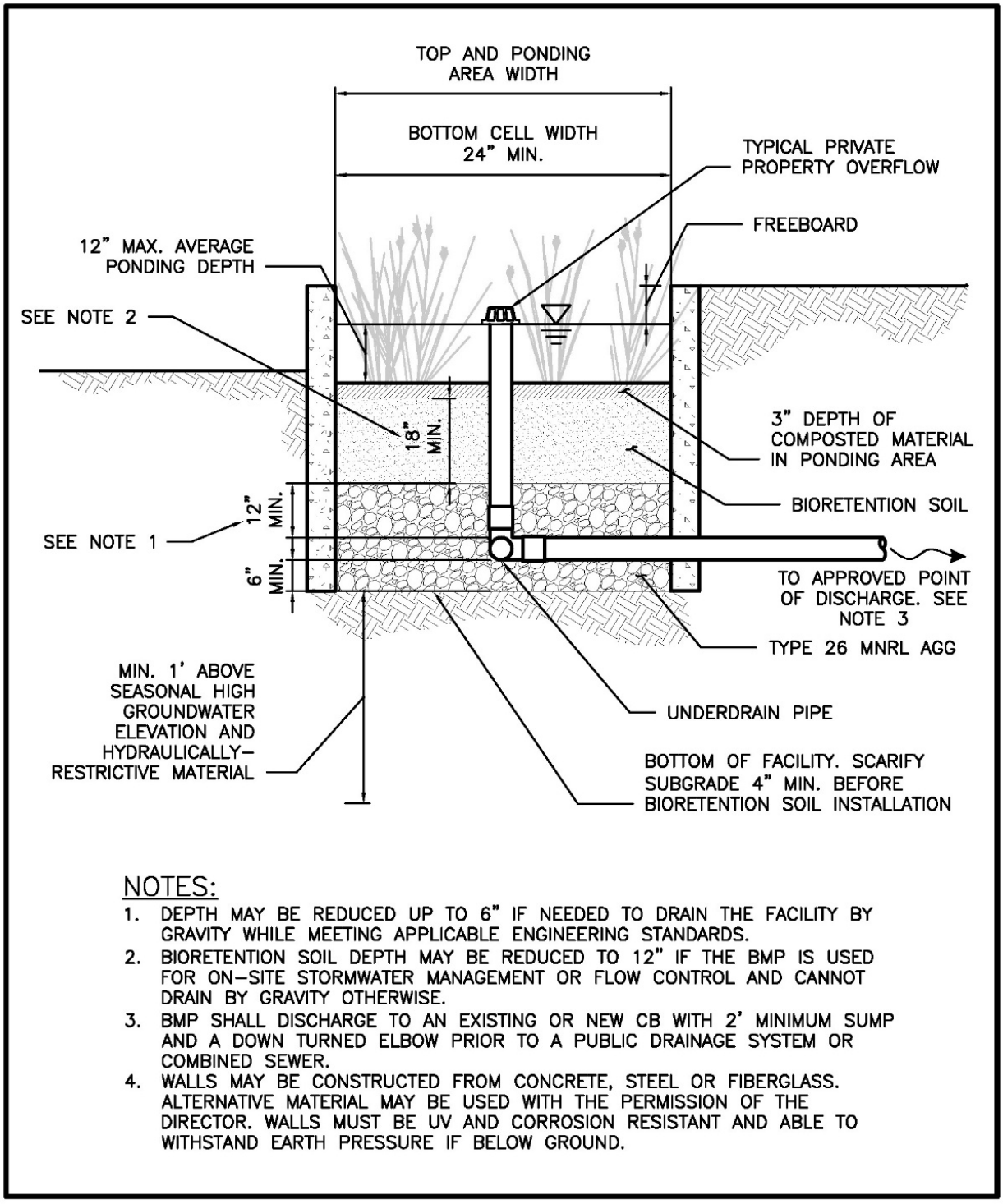


Figure 5.14. Infiltrating Bioretention Facility with Vertical Sides (with Underdrain).

Design criteria are provided in this section for the following elements:

- Contributing area
- Flow entrance
- Presettling
- Ponding area
- Bioretention soil
- Subgrade
- Underdrain (if required)
- Flow restrictor (optional)
- Overflow
- Liners (optional)
- Plants and Trees
- Mulch layer
- Planter box material

The Low Impact Development Technical Guidance Manual for Puget Sound (Puget Sound LID Manual) provides additional guidance on bioretention design.

Contributing Area

The bioretention facility should be sized for the contributing area routed to the facility. It is recommended that facilities not be oversized because the vegetation in oversized facilities may not receive sufficient stormwater runoff to thrive, increasing maintenance. If a designer chooses to oversize the bioretention facility beyond the area required to meet the performance standard(s), the maximum allowable size (cell bottom area as a percent of the contributing area) is twice the size required to meet the Pre-developed Pasture Standard. The bottom area of the facility that is required to meet the performance standard(s) and the standard(s) being met must be clearly noted on submitted plans and differentiated from the surrounding landscape.

Stormwater flows from other areas (beyond the area for which the facility is sized) should be bypassed around the facility in order to reduce sediment loading to the cell and the potential for bioretention soil clogging and increased maintenance needs.

For water quality treatment facilities, if bypass is not feasible, facilities must be sized to treat runoff from the entire area draining to the facility.

It is also preferred that on-site and flow control facilities be sized for the entire area draining to the facility where feasible. Additional flows may pass through a bioretention facility sized

to meet a flow control standard or on-site stormwater management requirement with the following limitations:

- The maximum area (i.e., areas beyond the area for which the facility is sized) that may pass through a bioretention facility must not exceed twice the area for which it is sized due to sediment loading concerns;
- No flow control or on-site stormwater management credit is given for runoff from any area in excess of the area for which the facility was sized;
- If additional area is routed to a facility, it must be clearly noted on submitted plans;
- The overflow infrastructure must be sized for the full contributing area (refer to *Section 4.3.3*);
- Presettling calculations must demonstrate that the water velocities in the vegetated areas of the facility do not exceed 2 feet per second during peak flows with 4 percent annual probability (the 25-year recurrence interval flow) (calculated through the narrowest vegetated cross section of the facility).

Flow Entrance

Flow entrances must be sized to capture flow from the drainage area and designed to both reduce the potential for clogging at the inlet and prevent inflow from causing erosion in the facility. Four primary types of flow entrances can be used for bioretention facilities: dispersed flow (e.g., vegetated buffer strips), sheet flow, curb cuts, and concentrated flow (e.g., piped flow). Where feasible and appropriate within the site context, vegetated buffer strips are the preferred entrance type because they slow incoming flows and provide initial settling of particulates.

The minimum requirements associated with the flow entrance design include the following:

- For facilities in the right-of-way, the flow entrance elevation must be above the overflow elevation.
- For sheet flow into a facility, a minimum 1-inch drop from the edge of a contributing hard surface to the vegetated flow entrance is required. This drop is intended to allow for less frequent maintenance by allowing some sediment/debris buildup at the edge where flow enters the facility. Refer to City of Seattle Standard Plan No. 292 and 293.
- The following requirements apply to roadway and parking lot curb cut flow entrances:
    - The curb cut width must be sized based on the drainage area, longitudinal slope along the curb, and the cross slope at the inlet.
    - The minimum curb cut width must be 8 inches for non-right-of-way applications (e.g., parking lots) and 10 inches in the right-of-way (refer to the City of Seattle Plan Nos. 295a, 295b, 295c, and 295d).
    - The curb cut must have either a minimum of 8 percent slope from the outer curb face extending to a minimum of 12 inches beyond the back of curb or provide a minimum of a 2-inch vertical drop from the back of curb to the vegetated surface of the facility.

- If concentrated flows are entering the facility (e.g., pipe or curb cut), flow energy dissipation (e.g., rock/cobble pad or flow dispersion weir) must be incorporated to reduce the potential for erosion at the inlet.
- Concentrated flows from contributing areas that exceed 20,000 square feet must be split into multiple flow entrances to distribute the flows more evenly into the bioretention cell.

Presettling

Presettling to capture debris and sediment load from contributing drainage areas is required at the flow entrance for some bioretention facilities. By providing presettling separate from the bioretention, maintenance can be targeted to remove sediment build-up. Additional technical details are included in SPU Design Standards and Guidelines Chapter 8.

The minimum requirements associated with the presettling design include the following:

- The minimum presettling requirements for bioretention facilities which are owned or maintained by a Phase I Municipal Stormwater Permittee are provided in Table 5.19.
- The minimum presettling requirements for bioretention facilities sited in all other settings are provided in Table 5.20.
- If the cell will receive flows from impervious areas beyond the area for which the facility is sized, the presettling measures must be designed for the entire area draining to the facility.

Table 5.19. Presettling Requirements for Bioretention Facilities Owned or Maintained by Phase I Municipal Stormwater Permittees.

Contributing Basin Size and Slope	Presettling Requirement for Bioretention Facilities
Total Basin Size[a] <1.5 acre OR Total Basin Size[a] 1.5–3 acres and <50% EIA OR Total Basin Size[a] 3–6 acres and <50% EIA and average basin slope[b] <5 percent	No presettling required.
Total Basin Size[a] 1.5–3 acres and >50% EIA OR Total Basin Size[a] 3–6 acres and average basin slope[b] >5 percent (and either <=50% EIA or >50% EIA)	Extended Sump required.[c]
Total Basin Size[a] >6 acres	MTD, Extended Sump, or “fat pipe” required, or engineered design if approved by the Director.[c]

[a] Total basin size: the total area (pervious and impervious) contributing runoff to a single cell or series of connected cells from both piped inflow and sheet flow from adjacent surfaces. The size of the basin producing the runoff is considered irrespective of any flow splitters that may be in use.

[b] Basin slope: overall slope estimated across an entire city block.

[c] See Appendix E for technical requirements. Appendix E include adjusted design flow rates for Manufactured Treatment Devices (MTDs) or engineered presettling devices to be used for the purpose of presettling in this application. For engineer-designed presettling, assume D50 = 80 microns.

Table 5.20. Presettling Requirements for Bioretention Facilities Not Owned or Maintained by Phase I Municipal Stormwater Permittees.

Impervious Area (square feet) Contributing Runoff to a Single Flow Entrance	Presettling Requirements
<20,000	No presettling is required. Designer to determine if site specific presettling is needed based on upstream area conditions.
≥20,000 and <40,000	A catch basin (such as City of Seattle Standard Plan No. 240 or 241) with a minimum 2foot sump may be used as the presettling zone. Where the pipe (from the catch basin) daylights into the bioretention cell, provide energy dissipation within the cell. Alternatively, a presettling device with an equivalent sump volume or an engineered pre-settling device may also be used.[a]
≥40,000	Presettling requirements are project specific, to be determined by designer and approved by the Director.[a]

a For engineer-designed presettling, assume D50 = 80 microns.

Ponding Area

The ponding area provides surface storage for storm flows and the first stages of pollutant treatment within the bioretention facility. The minimum requirements for ponding area design for facilities with both side slopes and vertical sides include:

- The bottom area of an individual cell must be no larger than 800 square feet (limitation is to ensure that bioretention facilities are small-scale and distributed). The bottom of an individual cell may be larger than 800 square feet if the facility serves a regional area and with the permission of the Director.
- The bottom area of an individual cell must be no less than 4 square feet.
- The average ponding depth must be no less than 2 inches.
- The ponding depth must be no more than 12 inches unless it meets the maximum drawdown time criteria and is approved by the Director. In right-of-way areas with high pedestrian traffic, the ponding depth may be restricted to 6 inches or less.
- The surface pool drawdown time must be a maximum of 24 hours (drain time is calculated as the maximum ponding depth divided by the subgrade soil design infiltration rate). Note that facilities sized using the On-site List and Pre-sized Approach meet this requirement.
- The bottom slope must be no more than 3 percent. Weirs can be used for steps in grade as long as the maximum slope between weirs is no more than 3 percent.

Additional minimum requirements for ponding area design specific to bioretention facilities with side slopes include the following:

- The maximum planted side slope is 2.5H:1V. In the ROW, if the facility is on a curbless street and less than 50 feet of an intersection, the maximum planted sides slope is 3H:1V. If total facility depth exceeds 3 feet, the maximum planted side slope is 3H:1V. If steeper sides are necessary, rockery, concrete walls, or steeper soil wraps may be used.

- If berming is used to achieve the minimum top facility elevation needed to meet ponding depth and freeboard needs, maximum berm slope is 2.5H:1V, and minimum berm top width is 6 inches. Soil used for berming where the permanent restoration is landscape must meet the bioretention soil specification and be compacted to a minimum of 90 percent dry density.
- For trees planted within or alongside slopes of the bioretention cell, the maximum side slope around the tree is 1H:1V.
- The average bottom width for the facility must be no less than 12 inches.

Additional minimum requirements for ponding area design specific to bioretention facilities with vertical sides include the following:

- The facility width (planted area between walls) must be no less than 2 feet, and the minimum length must be 4 feet. For plant health, the recommended minimum facility width is 4 feet.
- Depending on the depth from the surrounding grade or top of wall to the bottom of ponding/top of mulch, guardrails/handrails may be required at vertical sides of bioretention facilities by other codes and Director's Rules (e.g., Seattle Building Code, Seattle Residential Code, SDOT Streets Illustrated/Right-of-Way Improvement Manual, etc.) Note: For bioretention with vertical walls, if the vertical wall requires more than a 22-inches drop to provide the required bottom area and/or accommodate gravity flow from inlet pipes, this would be allowed, with handrails if required, but it can be considered infeasible for demonstrating infeasibility of on-site stormwater management BMPs.

To address traffic and pedestrian safety concerns, refer to City of Seattle Standard Plan No. 292 and 293 for bioretention facilities in the right-of-way. The following additional minimum requirements also apply to bioretention facilities in the right-of-way:

- A minimum of one access path across planting strip must be provided between the street and public sidewalk for each parcel. Access paths must be a minimum of 5 feet wide. It is preferred that the access path is within 15 feet of the structure access point (such as path to doorway or stairs).
- Bioretention cells must not impact driveway/alley access. A 2-foot minimum setback must be provided from the pavement edge of the driveway curb cut wing to the top (top of slope) of bioretention cell.
- A 2-foot minimum setback must be provided from the edge of paving for the public sidewalk/curb ramp at the intersection to the top of slope of the bioretention cell. Curb ramp improvements are required whenever the construction of bioretention cells and associated street improvements remove pavement within the crosswalk area of the street or sidewalk, impact curbs, sidewalks, curb ramps, curb returns or landings within the intersection area or affect access to or use of a public facility.

Bioretention Soil

The minimum requirements associated with bioretention soil design include:

- The bioretention soil must meet City of Seattle Standard Specification 7-21 unless another mix is approved by the Director. Soil must be a well-blended mixture of 28 to

32 percent fine compost by volume and 68 to 72 percent mineral aggregate by volume. The mixture must be well blended to produce a homogeneous mix and have an organic matter content of 3 to 7 percent determined using the Loss on Ignition Method. Materials must meet the criteria provided below.

- Fine compost for bioretention soil must meet the criteria below:
  - Gradation. Fine compost must meet the following size gradations by dry weight when tested in accordance with the U.S. Composting Council *Testing Methods for the Examination of Compost and Composting* (*TMECC*) *Test Method 02.02-B, Sample Sieving for Aggregate Size Classification*:

Sieve Size	Percent Passing: Minimum	Percent Passing: Maximum
2″	100%	
1″	99%	100%
5/8″	90%	100%
1/4″	75%	100%

  - pH. The pH must be between 6.0 and 8.5 when tested in accordance with TMECC 04.11-A; “1:5 Slurry pH.”
  - Physical Contaminants. Manufactured inert material (concrete, ceramics, metal, etc.) must be less than 1.0 percent by weight as determined by TMECC 03.08A “percent dry weight basis.” Film plastics must be 0.1 percent or less, by dry weight.
  - Organic Content. Minimum organic matter content must be 40 percent by dry weight basis as determined by TMECC 05.07-A; Loss-On-Ignition Organic Matter Method.
  - Salinity. Soluble salt contents must be less than 5.0 mmhos/cm tested in accordance with TMECC 04.10-A; “1:5 Slurry Method, Mass Basis.”
  - Maturity. Maturity must be greater than 80 percent in accordance with TMECC 05.05-A; “Germination and Vigor.” The Engineer may also evaluate compost for maturity using the Solvita Compost Maturity Test at time of delivery. Fine Compost must score a number 6 or above on the Solvita Compost Maturity Test. Coarse Compost must score a 5 or above on the Solvita Compost Maturity Test.
  - Stability. Stability must be 7 or below in accordance with TMECC 05.08-B; “Carbon Dioxide Evolution Rate.”
  - Feedstocks. The compost product must contain a minimum of 65 percent by volume from recycled plant waste as defined in WAC 173-350-100 as “yard waste,” “crop residues,” and “bulking agents.” A maximum of 35 percent by volume of “post-consumer food waste” as defined in WAC 173-350-100 may be substituted for recycled plant waste. A minimum of 10 percent food waste in compost is required. The Engineer may approve compost products containing up to 35 percent biosolids or manure feedstocks for specific projects or soil blends, but these feedstocks are not allowed unless specified and not allowed in compost used for bioretention soils.
  - C:N. Fine compost must have a carbon to nitrogen ratio of less than 25:1 as determined using TMECC 04.01 “Total Carbon” and TMECC 04.02D “Total Kjeldhal

Nitrogen." The Engineer may specify a C:N ratio up to 35:1 for projects where the plants selected are entirely Puget Sound native species. Compost may be mixed with fir or hemlock bark meeting requirements of City of Seattle Standard Specification 9-14.4(3) to raise the C:N ratio above 25:1. Coarse compost must have a carbon to nitrogen ratio between 20:1 and 45:1.

- Mineral aggregate for bioretention soil must be analyzed by an accredited lab using the sieve sizes noted below, and must meet the following gradation:

Sieve Size	Percent Passing
3/8″ Square	100
U.S. No. 4	60 – 100
U.S. No. 10	40 – 100
U.S. No. 40	15 – 50
U.S. No. 200	2 – 5

- Bioretention soil depth where no underdrain is used must be a minimum 18 inches for water quality treatment and 12 inches for on-site stormwater management and flow control.
- Bioretention soil depth where an underdrain is used must be a minimum 18 inches depth but may be reduced to a depth of 12 inches if it is needed to drain by gravity and the facility is used to meet on-site stormwater management or flow control.
- Other bioretention soil mixes that may be used, as approved by the Director, include High Performance Bioretention Soil Mix (HPBSM). HPBSM has the advantage over the default mix that includes compost in that it reduces the concern resulting from the potential export of nutrients. Refer to SWMMWW.
- A polishing layer may be used, as approved by the Director, with HPBSM. Refer to SWMMWW. Note: the polishing layer used with HPBSM meets Phosphorous Water Quality Treatment Standard.

Filter fabrics/geotextile must not be used between the bioretention soil layer and the underlying subgrade. Exceptions may be allowed when specified by a licensed professional as defined in *Appendix D, Section D-1* and documented in the geotechnical design recommendations.

Subgrade

The minimum measured subgrade infiltration rate for infiltrating bioretention facilities without underdrains is 0.6 inch per hour. For infiltrating bioretention facilities with underdrains, the minimum measured subgrade infiltration rate is 0.3 inch per hour where used to meet the On-site List Approach (there is no minimum rate where used to meet other standards).

During construction the subgrade soil surface can become smeared and sealed by excavation equipment. The design must require scarification or raking of the side walls and bottom of the facility excavation to a minimum depth of 4 inches after excavation to restore infiltration rate.

Underdrain (If Required)

Underdrain systems (refer to Figures 5.13 and 5.14) must be installed if the subgrade soils have a measured infiltration rate of less than 0.6 inch per hour. Designs utilizing underdrains provide less infiltration and flow control benefits. To improve performance, the underdrain may be further elevated (beyond the 6 inches shown in Figures 5.13 and 5.14); the subsurface gravel reservoir under the pipe may be widened to extend across the entire facility bottom; and/or a flow restrictor may be used.

The underdrain pipe diameter will depend on hydraulic capacity required. The underdrain can be connected to a downstream BMP, such as another bioretention cell as part of a connected system, or to an approved point of discharge.

The minimum requirements associated with the underdrain design include:

- Slotted pipe per City of Seattle Standard Plan No. 291.
- Underdrain pipe must have a minimum diameter of 6 inches in the ROW and 4 inches outside of the ROW.
- Underdrain pipe slope must be no less than 0.5 percent.
- Pipe must be placed in filter material and have a minimum cover depth of 12 inches and bedding depth of 6 inches. Refer to Figures 5.13 and 5.14 for required pipe bedding dimensions. Cover depth may be reduced up to 6 inches in order to discharge stormwater from the facility under gravity flow conditions while meeting the applicable engineering standards.
- Filter material must meet the specifications of City of Seattle Mineral Aggregate Type 26 (gravel backfill for drains, City of Seattle Standard Specifications).
- Underdrains must be equipped with cleanouts and observation ports as follows:
    - For right-of-way projects, underdrains must have a cleanout per City of Seattle Standard Plans at the upstream end and a combined cleanout and observation ports per City of Seattle Standard Plan No. 281 a minimum of every 100 feet along the pipe. No cleanouts are required within a run from underdrain maintenance hole to underdrain maintenance hole except at bends.
    - For non-right-of-way projects, underdrains must have a cleanout at the upstream end (Figure 5.15) and a combined cleanout and observation ports (City of Seattle Standard Plan No. 281) a minimum of every 100 feet along the pipe. Cleanouts and observation ports must be non-perforated pipe (sized to match underdrain diameter) and must meet the requirements in the Side Sewer Directors' Rule.
- The subsurface gravel reservoir beneath the underdrain pipe must extend across the entire facility bottom for infiltrating bioretention.

Flow Restrictor (Optional)

A flow restrictor assembly may be installed at the outlet of an underdrain system to further detain outflow. When used, the orifice diameter shall be sized to achieve the desired

performance goal. The minimum requirements associated with the flow restrictor design include:

- An inspection chamber (catch basin or maintenance hole with clearances per City of Seattle Standard Plan No. 270 and 272A) must be installed at the flow control assembly to allow for access and maintenance. Alternative structures may be used, as approved by the Director if a maintenance plan is provided that shows how the orifice will be accessed and maintained.
- A minimum orifice diameter of 0.25 inch. Note that an orifice diameter smaller than 0.5 inch is allowed for this subsurface application because the bioretention soil serves as a filter, making clogging of the orifice less likely.

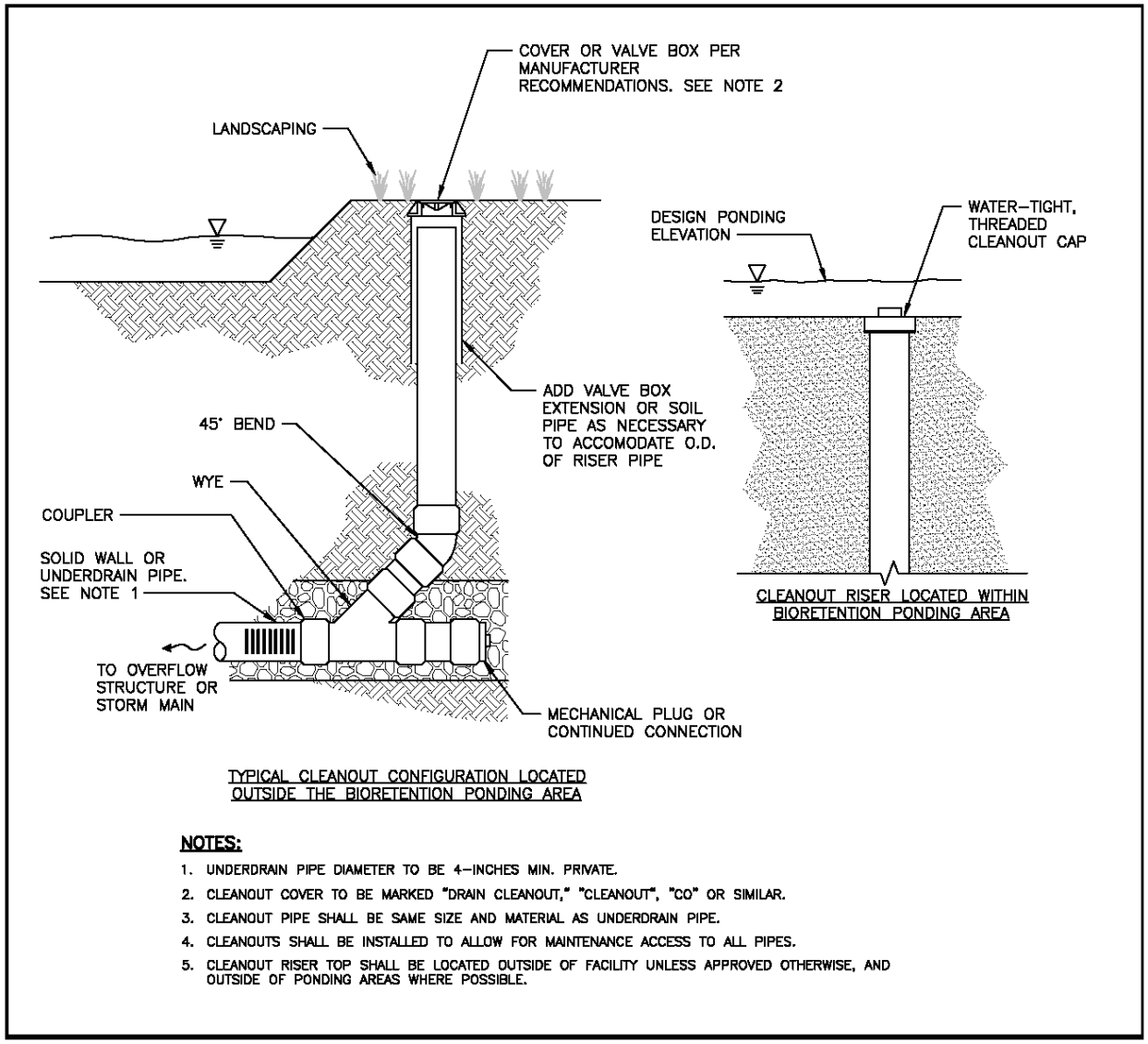


Figure 5.15. Stormwater Facility Cleanout for Facility Outside of the Right-of-way.

Overflow

A bioretention facility overflow controls overtopping with a pipe, an earthen channel, a weir, or a curb cut installed at the designed maximum ponding elevation and is connected to a downstream BMP or an approved point of discharge.

The minimum requirements associated with the overflow design include the following:

- Overflows must convey any flow exceeding the capacity of the facility unless designed to fully infiltrate all flows for the full, required simulation period. Plans must indicate surface flow paths in case of failure of the BMP (refer to *Section 4.3.3*).
- Freeboard must be provided to ensure that any overtopping of the facility is safely conveyed to an approved point of discharge without flooding adjacent properties or sidewalks. The minimum freeboard measured from the invert of the overflow point (e.g., standpipe, earthen channel, curb cut) (as specified below) to the lowest overtopping elevation of the facility is:
  - 4 inches measured from the invert of the overflow point for contributing drainage areas less than 3,000 square feet
  - 6 inches measured from the invert of the overflow point for contributing drainage areas from 3,000 square feet to 15,000 square feet
  - 9 inches measured from the invert of the overflow point for contributing drainage areas from greater than 15,000 square feet to 20,000 square feet
  - For contributing drainage areas greater than 20,000 square feet or when the overflow riser diameter is less than the minimum required, a licensed civil engineer must verify that the freeboard is at least 6 inches of above the 25-year recurrence interval water surface elevation (demonstrated with hydrologic modeling) and that the overflow will convey any flow exceeding the capacity of the facility. See the consideration for overflows with grates, such as atrium or dome grates, in the drain pipe riser bullet points below.
  - With a curb and gutter, freeboard may be reduced if the project can demonstrate that any overtopping of the facility for larger events (greater than the 25-year recurrence interval) would be consistent with *Section 4.3.3*.
- The drain riser pipe, if used, must have a minimum diameter of:
  - 4 inches for contributing drainage areas less than 3,000 square feet
  - 6 inches for contributing drainage areas from 3,000 square feet to less than 7,500 square feet
  - 8 inches for contributing drainage areas from 7,500 square feet to less than 10,000 square feet
  - 12 inches for contributing drainage areas from 10,000 square feet to 20,000 square feet
  - For contributing drainage areas greater than 20,000, a licensed civil engineer must verify that the freeboard is at least 6 inches above the 25-year recurrence interval water surface elevation (demonstrated with hydrologic modeling) for the selected riser diameter and that that the overflow can convey any flow exceeding the capacity of the facility.

  - When modeling any bioretention facility, the riser diameter used in the hydrologic models must be reduced by at least 50 percent to account for losses from the atrium, dome, beehive or other type of grate that will be fitted on the overflow riser. An alternative reduction factor may be used if product information for the specific grate is available. Also, if available, the engineer must verify with the manufacturer that the grate has capacity to convey all flows in the simulation period given without overtopping the facility walls/edges (i.e., top of freeboard).
- Alternative overflow freeboard depths and drain riser pipe diameters may be proposed by a licensed civil engineer if hydrologic models are provided to demonstrate that the overflow can convey all flows in the required simulation period without overtopping the facility walls/edges (i.e., top of freeboard).
- If the cell will receive flows from impervious areas beyond the area for which the facility is sized, the overflow conveyance infrastructure and freeboard require engineering design to safely convey runoff from the entire area draining to the facility.

Liners (Optional)

Infiltrating bioretention facilities infiltrate stormwater into the underlying soil. However, adjacent roads, foundations, slopes, utilities, or other infrastructure may require that certain infiltration pathways are restricted to prevent excessive hydrologic loading. Two types of hydraulic restricting layers can be incorporated into bioretention facility designs:

- Clay (bentonite) liners as low permeability liners
- Geomembrane liners which completely block flow

Refer to *Appendix E, Section E-7* for more information about liners.

For infiltrating bioretention facilities, the hydraulic restriction layer must be limited to only the extent necessary to protect adjacent area as described above and must not be used across the entire facility bottom (refer to *Section 5.8.2, Non-infiltrating Bioretention*). The horizontal footprint of the hydraulic restriction layer must be excluded from the infiltration area (bottom area and/or side slopes) represented for hydrologic modeling.

Plants and Trees

In general, the predominant plantings used in bioretention facilities are species adapted to stresses associated with wet and dry conditions. Soil moisture conditions will vary within the facility from saturated (bottom of cell) to relatively dry (rim of cell). Accordingly, wetland plants may be planted in the lower areas and drought-tolerant species planted on the perimeter of the facility or on mounded areas. Trees selected from the bioretention BMP plant list (*Appendix J*) are allowed and encouraged as part of bioretention. An example of a bioretention facility with a tree incorporated into the design is shown in Figure 5.16.

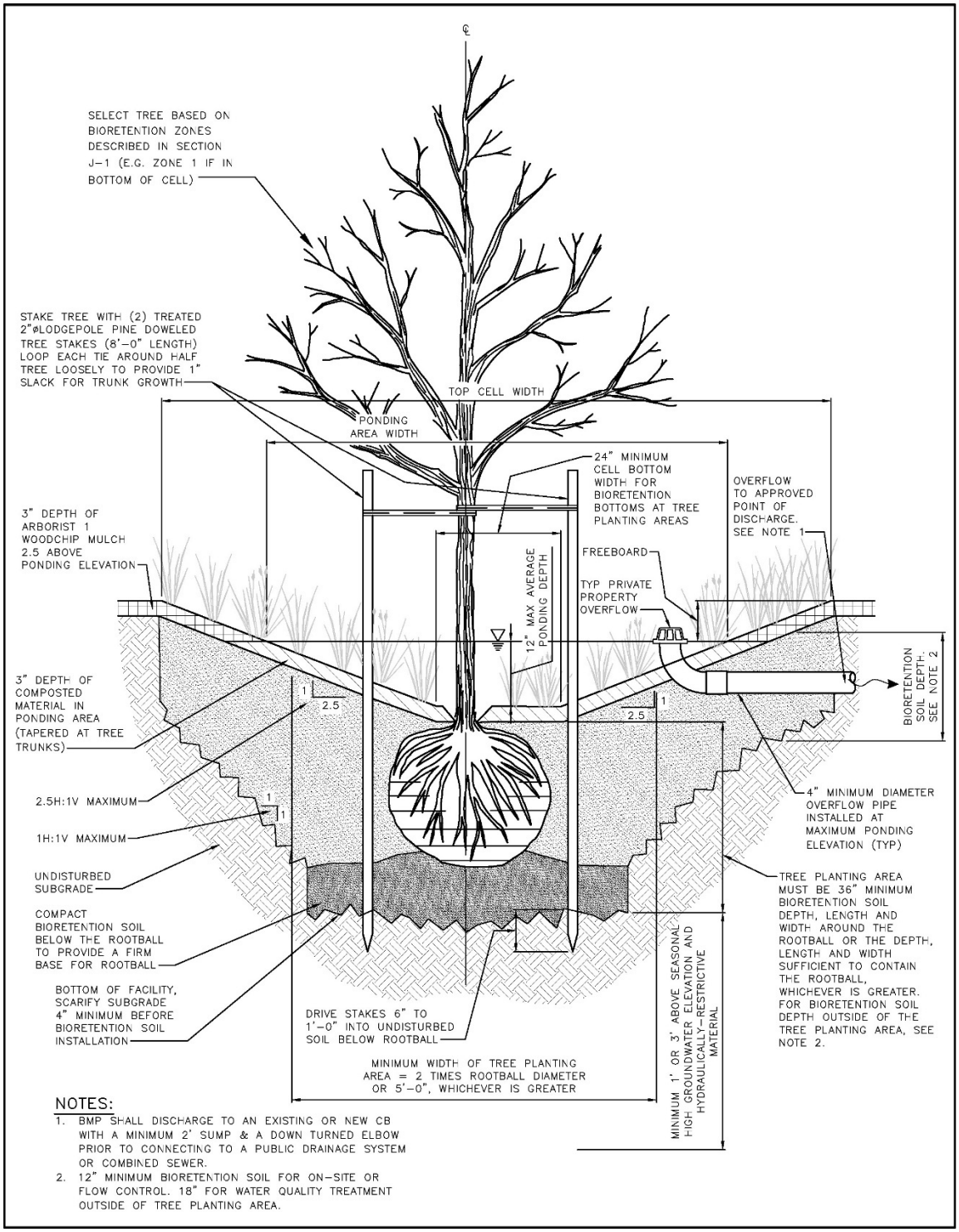


Figure 5.16 Example of Infiltrating Bioretention Facility with Tree and Side Slopes (without Underdrain).

The minimum requirements associated with the vegetation (plants and trees) design include the following:

- The design plans must specify that vegetation coverage of plants will achieve 90 percent coverage within 2 years. For this purpose, cover is defined as canopy cover and should be measured when deciduous plants are in bloom.
- For facilities receiving runoff from 5,000 square feet or more hard surface, plant spacing and plant size must be designed by a licensed landscape architect to achieve specified coverage.
- The plants and trees must be sited according to sun, soil, wind, and moisture requirements. (refer to *Appendix J*).
- If a bioretention facility will be located in a full shade area (i.e., receiving less than 3 hours of direct sunlight per day), then a licensed landscape architect must provide input on the plant and tree selection and layout. If a licensed landscape architect determines that plants and tree(s) will not survive in the fully shaded location, 3 inches of clean, washed drainage gravel backfill for drains (Type 26) or mulch may be used as a top dressing in lieu of plants and tree(s).
- At a minimum, provisions must be made for supplemental irrigation/watering during the first two growing seasons following installation and in subsequent periods of drought.
- Plants and trees for bioretention facilities sited in the right-of-way must be selected from the bioretention plant list in *Appendix J*.
- Tree(s) in bioretention must also meet the following requirements:
    - Location:
        - Select planting locations to ensure that sight distances and appropriate setbacks are maintained given mature height, size, and rooting depths.
        - Select planting locations based on bioretention zones in Appendix J.
    - Setbacks:
- Setbacks from structures, underground utility lines, and paved surfaces must be permit Section 5.2.5.2 – Tree Setbacks.
    - Spacing:
        - Spacing requirements must be per *Section 5.2.5.2* - Tree Spacing.
    - Tree Planting Area:
        - Provide a tree planting width of two times the rootball or five feet, whichever is greater.
        - Provide a tree planting area with a minimum 36-inch bioretention soil depth, length, and width around the rootball OR a depth, length, and width sufficient to contain the rootball.
- Tree planting area soil volumes must meet the requirements in *Section 5.2.5.2*, Table 5.1.

Refer to the Puget Sound LID Manual for guidance on plant selection and recommendations for increasing survival rates. Recommended planting lists can be found in the Puget Sound LID

Manual, SDOT's Approved Tree List, and the Seattle Green Factor plant list (refer to SDCI's website).

Mulch Layer

Properly selected organic mulch material reduces weed establishment, regulates soil temperatures and moisture, and adds organic matter to the soil. Compost and arborist wood chip mulch are required for different applications within the bioretention cell. Compost mulch is an excellent slow-release source of plant nutrients and does not float, but compost does not suppress weed growth as well as bulkier, higher carbon mulches like arborist wood chips. Arborist wood chips are superior to bark mulch in promoting plant growth, feeding beneficial soil organisms, reducing plant water stress, and maintaining surface soil porosity.

The minimum requirements associated with organic mulch include:

- Organic mulch in the bottom of the cell and up to the ponding elevation must consist of coarse or medium compost (per City of Seattle Standard Specification 914.4(8)). Medium compost must meet the requirements for fine compost provided in the *Bioretention Soil Section* and the following gradation by dry weight:

Sieve Size	Percent Passing: Minimum	Percent Passing: Maximum
1″	100%	100%
5/8″	85%	100%
1/4″	70%	85%

  Coarse compost must meet the requirements for fine compost provided in the *Bioretention Soil Section* and the following gradation by dry weight:

Sieve Size	Percent Passing: Minimum	Percent Passing: Maximum
3″	100%	
1″	90%	100%
3/4″	70%	100%
1/4″	40%	6%

- Organic mulch on cell slopes above the ponding elevation and the around the rim area must consist of arborist wood chip mulch (per City of Seattle Standard Specification 914.4(4)). Arborist wood chip mulch must meet the criteria below:
  - Arborist wood chip mulch must be coarse ground wood chips (approximately 0.5 inch to 6 inches along the longest dimension) derived from the mechanical grinding or shredding of the aboveground portions of trees. It may contain wood, wood fiber, bark, branches, and leaves; but may not contain visible amounts of soil. It must be free of weeds and weed seeds Including but not limited to plants on the King County Noxious Weed list available at: www.kingcounty.gov/weeds, and must be free of invasive plant portions capable of resprouting, including but not limited to horsetail, ivy, clematis, knotweed, etc. It may not contain more than 0.5 percent by weight of manufactured inert material (plastic, concrete, ceramics, metal, etc.).

- Arborist wood chip mulch, when tested, must meet the following loose volume gradation:

Sieve Size	Percent Passing: Minimum	Percent Passing: Maximum
2″	95%	100%
1″	70%	100%
5/8″	0%	50%
1/4″	0%	40%

No particles may be longer than 8 inches.

- Depth must be 3 inches for both types of organic mulch

In bioretention areas outside of roadway right-of-way where vegetation is not viable due to siting, or where higher flow velocities are anticipated, an aggregate mulch may be used. Where higher flow velocities are anticipated, the use of mineral aggregate is to dissipate flow energy and protect underlying bioretention soil. Aggregate mulch varies in size and type, but 1- to 1.5-inch gravel (rounded) decorative rock is typical. The aggregate mulch must be washed rock (free of fines) and the area covered with aggregate mulch must not exceed one-fourth of the facility bottom area. Aggregate mulch must be free-draining and applied in a manner to maintain the permeability of the bioretention. Therefore, areas where it is applied must not be considered hard surface.

As an alternative to mulch, a dense groundcover may be used. Mulch is required in conjunction with the groundcover until groundcover is established.

Planter Box Material

Planter boxes, such as those shown in figures 5.12, 5.14, and 5.36 may be constructed from concrete, steel or fiberglass. Alternative materials may be used with the permission of the Director. Material must be UV and corrosion resistant and able to withstand earth pressure if below ground. See Figure 5.17 for example of a planter with metal walls.

Figure 5.17. Example of Bioretention Planter with Metal Wall Material.

5.4.4.6. BMP Sizing

Sizing for On-site List Approach

Infiltrating bioretention may be selected to meet the On-site List Requirement (refer to *Section 3.3.1* and *Appendix C* for infeasibility criteria). To meet the requirement, bioretention must be sized according to the sizing factors provided in Table 5.21.

Factors are organized by cell ponding depth, cell side slope, and subgrade design infiltration rate. To select the appropriate sizing factor:

- The subgrade design infiltration rate must be rounded down to the nearest rate in the sizing table.
- The design ponding depth must be rounded down to the nearest depth in the sizing table, or sizing factors may be linearly interpolated for intermediate ponding depths (e.g., between 3 and 4 inches ponding).

Table 5.21. On-site List Sizing for Infiltrating Bioretention with and without Underdrains.

Bioretention Configuration	Average Ponding Depth	Subgrade Soil Design Infiltration Rate	Sizing Factor for Facility Bottom Area: Without Underdrain[a]	Sizing Factor for Facility Bottom Area: With Underdrain[b]
Sloped sides	2 inches	0.15 inch/hour	NA[c]	6.8%[d]
		0.3 inch/hour	4.5%	5.0%
		0.6 inch/hour	4.5%	5.0%
		1.0 inch/hour	4.5%	5.0%
		2.5 inch/hour	4.5%	5.0%
	6 inches	0.15 inch/hour	NA[c,f]	4.7%[d]
		0.3 inch/hour	3.5%	3.9%
		0.6 inch/hour	3.5%	3.9%
		1.0 inch/hour	3.5%	3.9%
		2.5 inch/hour	3.5%	3.9%
	12 inches	0.15 inch/hour	NA[c,f]	2.8%[d]
		0.3 inch/hour	NA[f]	2.6%
		0.6 inch/hour	2.3%	2.6%
		1.0 inch/hour	2.3%	2.6%
		2.5 inch/hour	2.3%	2.6%
Vertical sides	2 inches	0.15 inch/hour	NA[c,f]	9.2%[d]
		0.3 inch/hour	6.2%[e]	6.9% [d]
		0.6 inch/hour	5.0%[g]	5.6%[g]
		1.0 inch/hour	5.0%[g]	5.6%[g]
		2.5 inch/hour	5.0%[g]	5.6%[g]
	6 inches	0.15 inch/hour	NA[c,f]	7.2%[d]
		0.3 inch/hour	5.0%	5.6%
		0.6 inch/hour	5.0%[g]	5.6%[g]
		1.0 inch/hour	5.0%[g]	5.6%[g]
		2.5 inch/hour	5.0%[g]	5.6%[g]
	12 inches	0.15 inch/hour	NA[c,f]	5.7%[d]
		0.3 inch/hour	NA[f]	5.6%
		0.6 inch/hour	5.0%	5.6%
		1.0 inch/hour	5.0%	5.6%
		2.5 inch/hour	5.0%	5.6%

NA – not applicable.

[a] Sizing factors are based on achieving a minimum wetted surface area of 5 percent, as per Ecology's requirements, unless otherwise noted.

[b] Sizing factors are based on a minimum wetted surface area of 5 percent multiplied by a factor of 1.11, as per Ecology's requirements, unless otherwise noted.

[c] Underdrain systems must be installed if the subgrade soils have a measured infiltration rate of less than 0.6 inch per hour (note that the infiltration rates listed in the table are design rates).

[d] Sizing factor increased to the sized required to meet the On-site Performance Standard for a pre-developed condition of forest on till and multiplied by a factor of 1.11.

[e] Sizing factor increased beyond the minimum wetted surface area of 5 percent to meet the On-site Performance Standard for a pre-developed condition of forest on till.

[f] Ponding depth and infiltration rate combination do not achieve drawdown requirements.

[g] To maximize flow control benefit, 12-inch vertical side walls are recommended for design infiltration rates exceeding 0.3 inch per hour.

Bioretention Facility Bottom Area = Contributing Hard Surface Area x Factor (%)/100.

Hard Surface Area Managed = Bioretention Facility Bottom Area ÷ Factor (%)/100.

The facility must meet the general requirements for infiltrating bioretention outlined in this section plus the following specific requirements:

- The bottom area must be sized using the applicable sizing factor.
- It is preferred that the bottom area is flat, but up to 3 percent slope is permitted.
- For facilities with sloped sides, the side slopes within the ponded area must be no steeper than 2.5H:1V.
- For facilities without underdrains, the bioretention soil depth must be a minimum of 12 inches for flow control and 18 inches for water quality treatment. For facilities with underdrains, the amended soil must have a minimum depth of 18 inches.
- The average ponding depth for the cell must be no less than the selected ponding depth.
- Low-permeability or impermeable liner must not be used except to protect adjacent roads, foundations, slopes, utilities, or other infrastructure from excessive hydrologic loading. Liner must not be used across the entire facility bottom.

The *bottom area* for the cell is calculated as a function of the hard surface area routed to it. As an example, the bottom area of the bioretention cell with vertical sides would be equal to 5.3 percent of the hard surface area routed to it when the ponding depth is an average of 6 inches and the design infiltration rate is equal to greater than 0.3 inch per hour.

For facilities with sloped sides, top area is calculated as a function of the cell bottom area and the side slopes up to the total facility depth (i.e., ponding and freeboard depth).

Pre-sized Approach for Flow Control and Water Quality Treatment

The Pre-sized Approach may be used for projects with new and replaced hard surface areas up to 10,000 square feet. Under the Pre-sized Approach (refer to Section 4.1.2), simple equations are used to calculate the size of “pre-designed” bioretention facilities subject to specific design requirements (e.g., side slope, ponding depth). Sizing factors and equations for infiltrating bioretention without underdrains and with underdrains are provided in Tables 5.22 and 5.23, respectively. Note that the modeling conducted to develop sizing factors and equations for bioretention with underdrains did not include infiltration to underlying soil due to modeling constraints at the time of publication.

Pre-sized infiltrating bioretention facilities without underdrains may be used to achieve the Pre-developed Pasture, Peak Control, and Water Quality Treatment Standards. Pre-sized infiltrating bioretention facilities with underdrains may be used to achieve the Peak Control and Water Quality Treatment Standards. Sizing factors are organized by side slopes (i.e., sloped sides or vertical sides), performance standard, facility ponding depth, subgrade soil design infiltration rate (for facilities without underdrains), and contributing area. To select the appropriate sizing factor or equation:

- The design ponding depth must be rounded down to the nearest depth in the sizing table, or sizing factors may be linearly interpolated for intermediate ponding depths (e.g., between 6 and 12 inches ponding).
- For facilities without underdrains, the subgrade design infiltration rate must be rounded down to the nearest infiltration rate in the pre-sized table (i.e., 0.15, 0.3, 0.6, 1.0, or 2.5 inches per hour).

Table 5.22. Pre-sized Sizing Factors and Equations for Infiltrating Bioretention Without Underdrains.

Bioretention Configura-tion	Average Ponding Depth	Subgrade Soil Design Infiltration Rate	Contributing Area (sf)	Sizing Factor/Equation for Facility Bottom Area: Pre-developed Pasture Standard	Sizing Factor/ Equation for Facility Bottom Area: Peak Control Standard	Sizing Factor/ Equation for Facility Bottom Area: Water Quality Treatment Standard[a]
Sloped sides	2 inches	0.15 inch/hour	≤2,000	22.9%	NP	8.8%
			2,001 – 10,000	[0.1600 x A] + 139.6	NP	8.8%
		0.3 inch/hour	≤2,000	18.4%	NP	6.9%
			2,001 – 10,000	[0.1319 x A] + 106	NP	6.9%
		0.6 inch/hour	≤2,000	9.5%	NP	3.1%
			2,001 – 10,000	[0.0756 x A] + 38.8	NP	3.1%
		1.0 inch/hour	≤2,000	8.3%	NP	2.7%
			2,001 – 10,000	[0.0650 x A] + 34.7	NP	2.7%
		2.5 inch/hour	≤2,000	3.6%	NP	1.3%
			2,001 – 10,000	[0.0251 x A] + 19.7	NP	1.3%
	6 inches	0.15 inch/hour	≤ 2,000	NA[a]	NA[a]	NA[a]
			2,001 – 10,000	NA[a]	NA[a]	NA[a]
		0.3 inch/hour	≤2,000	10.4%	14%	1.5%
			2,001 – 10,000	[0.0830 x A] + 38.7	14%	[0.0431 x A] - 62.9
		0.6 inch/hour	≤2,000	6.2%	9.6%	0.7%
			2,001 – 10,000	[0.0560 x A] + 10.2	9.6%	[0.0259 x A] - 43.7
		1.0 inch/hour	≤2,000	5.3%	8.6%	0.7%
			2,001 – 10,000	[0.0480 x A] + 8.8	8.6%	[0.0224 x A] - 36.5
		2.5 inch/hour	≤2,000	2.1%	4.7%	0.5%
			2,001 – 10,000	[0.0177 x A] + 3.5	4.7%	[0.0092 x A] - 9.7
	12 inches	0.15 inch/hour	≤2,000	NA[a]	NA[a]	NA[a]
			2,001 – 10,000	NA[a]	NA[a]	NA[a]
		0.3 inch/hour	≤2,000	NA[a]	NA[a]	NA[a]
			2,001 – 10,000	NA[a]	NA[a]	NA[a]
		0.6 inch/hour	≤2,000	3.3%	7.0%	1.1%
			2,001 – 10,000	[0.0395 x A] - 16.1	7.0%	1.1%

Table 5.22 (continued). Pre-sized Sizing Factors and Equations for Infiltrating Bioretention Without Underdrains.

Bioretention Configura-tion	Average Ponding Depth	Subgrade Soil Design Infiltration Rate	Contributing Area (sf)	Sizing Factor/Equation for Facility Bottom Area: Pre-developed Pasture Standard	Sizing Factor/ Equation for Facility Bottom Area: Peak Control Standard	Sizing Factor/ Equation for Facility Bottom Area: Water Quality Treatment Standard[a]
Sloped sides	12 inches	1.0 inch/hour	≤2,000	2.8%	6.1%	1.0%
			2,001 – 10,000	[0.0335 x A] - 13.3	6.1%	1.0%
		2.5 inch/hour	≤2,000	1.0%	2.8%	0.4%
			2,001 – 10,000	[0.0110 x A] - 3	2.8%	0.4%
Vertical sides	2 inches	0.15 inch/hour	≤2,000	NAa	NAa	NAa
			2,001 – 10,000	NAa	NP	NAa
		0.3 inch/hour	≤2,000	NAa	NP	NAa
			2,001 – 10,000	NAa	NP	NAa
		0.6 inch/hour	≤2,000	NAa	NP	NAa
			2,001 – 10,000	NAa	NP	NAa
		1.0 inch/hour	≤ 2,000	20.0%	NP	6.8%
			2,001 – 10,000	[0.2021 x A] - 2.2	NP	6.8%
		2.5 inch/hour	≤2,000	9.1%	NP	3.1%
			2,001 – 10,000	[0.0920 x A] - 1.8	NP	3.1%
	6 inches	0.15 inch/hour	≤2,000	NA[a]	NA[a]	NA[a]
			2,001 – 10,000	NA[a]	NA[a]	NA[a]
		0.3 inch/hour	≤2,000	15.8%	16.8%	6.6%
			2,001 – 10,000	[0.0957 x A] + 126	16.8%	6.6%
		0.6 inch/hour	≤2,000	10.7%	13.3%	4.5%
			2,001 – 10,000	[0.0671 x A] + 81.2	13.3%	4.5%
		1.0 inch/hour	≤ 2,000	9.3%	11.9%	4.0%
			2,001 – 10,000	[0.0585 x A] + 70.5	11.9%	4.0%
		2.5 inch/hour	≤2,000	4.1%	6.6%	2.0%
			2,001 – 10,000	[0.0280 x A] + 24.6	6.6%	2.0%
	12 inches	0.15 inch/hour	≤2,000	NA[a]	NA[a]	NA[a]
			2,001 – 10,000	NA[a]	NA[a]	NA[a]
		0.3 inch/hour	≤2,000	NA[a]	NA[a]	NA[a]
			2,001 – 10,000	NA[a]	NA[a]	NA[a]
Vertical sides	12 inches	0.6 inch/hour	≤2,000	8.1%	9.7%	3.6%
			2,001 – 10,000	[0.0518 x A] + 57.6	9.7%	3.6%

Table 5.22 (continued). Pre-sized Sizing Factors and Equations for Infiltrating Bioretention Without Underdrains.

Bioretention Configura-tion	Average Ponding Depth	Subgrade Soil Design Infiltration Rate	Contributing Area (sf)	Sizing Factor/Equation for Facility Bottom Area: Pre-developed Pasture Standard	Sizing Factor/ Equation for Facility Bottom Area: Peak Control Standard	Sizing Factor/ Equation for Facility Bottom Area: Water Quality Treatment Standard[a]
Vertical sides	12 inches	1.0 inch/hour	≤2,000	7.0%	8.6%	3.2%
			2,001 – 10,000	[0.0454 x A] + 49.4	8.6%	3.2%
		2.5 inch/hour	≤2,000	3.0%	4.6%	1.6%
			2,001 – 10,000	[0.0237 x A] + 10.9	4.6%	1.6%

NP – sizing factors not provided; NA – not applicable; A – contributing hard surface area; sf – square feet.

For Sizing Factors: Bioretention Facility Bottom Area = Contributing Hard Surface Area x Factor (%)/100.
Hard Surface Area Managed = Bioretention Facility Bottom Area ÷ Factor (%)/100.

For Sizing Equations: Bioretention Facility Bottom Area (sf) = [Factor x A (sf)] + Integer.
Hard Surface Area Managed (sf) = [Bioretention Bottom Area (sf) - Integer]÷ Factor.

[a] Ponding depth and infiltration rate combination do not achieve drawdown requirements.

Table 5.23. Pre-sized Sizing Factors and Equations for Infiltrating Bioretention with Underdrains.

Bioretention Configura-tion	Average Ponding Depth	Contributing Area (sf)	Sizing Factor/Equation for Facility Bottom Area: Pre-developed Pasture Standard	Sizing Factor/Equation for Facility Bottom Area: Peak Control Standard	Sizing Factor/Equation for Facility Bottom Area: Water Quality Treatment
Sloped sides	2 inches	0 – 10,000	NA[a]	NA[a]	1.3%
	6 inches	≤2,000	NA[a]	NA[a]	[0.0059 x A] - 3.215
		2,001 – 10,000	NA[a]	NA[a]	[0.0097 x A] - 11.297
	12 inches	≤2,700	NA[a]	3.0%[b]	0.4%
		2,701 – 10,000	NA[a]	NA[a]	[0.0052 x A] - 12.092
Vertical sides	6 inches	0 – 10,000	NA[a]	NA[a]	1.2%
	12 inches	0 – 10,000	NA[a]	4.5%[b]	1.0%

NA – not applicable

For Sizing Factors: Bioretention Facility Bottom Area = Contributing Hard Surface Area x Factor (%)/100.
Hard Surface Area Managed = Bioretention Facility Bottom Area ÷ Factor (%)/100.

For Sizing Equations: Bioretention Facility Bottom Area (sf) = [Factor x A (sf)] + Integer.
Hard Surface Area Managed (sf) = [Bioretention Bottom Area (sf) – Integer]÷ Factor.

[a] Bioretention facilities with underdrains are not capable of achieving the standard unless orifice controls are used. The Modeling Approach may be used to more accurately represent additional performance due to infiltration, which is neglected in the Pre-sized approach.

[b] When used to meet the Peak Control Standard, the facility size must not be larger than prescribed by the sizing factor (or sizing factor range) because flow control performance may be diminished for larger facilities (larger facilities will not pond water sufficiently to slow flows).

To use these pre-sized facilities to meet performance standards, the bioretention facility must meet the general requirements outlined in this section plus the following specific requirements:

- The bottom area must be sized using the applicable sizing factor or equation.
- It is preferred that the bottom area is flat, but up to 3 percent slope is permitted.
- For facilities with sloped sides, the side slopes within the ponded area must be no steeper than 2.5H:1V.
- For facilities without underdrains, the bioretention soil depth must be a minimum of 12 inches for flow control and 18 inches for water quality treatment. For facilities with underdrains, the amended soil must have a minimum depth of 18 inches.
- The average ponding depth for the cell must be no less than the selected ponding depth.

The bottom area for the cell is calculated as a function of the hard surface area routed to it. As an example, to meet the Pre-developed Pasture Standard using a bioretention facility without an underdrain, with sloped sides, and an average ponding depth of 6 inches for a contributing area between 2,000 and 10, 000 square feet where the design subgrade infiltration rate is between 1 and 2.49 inches per hour, the bioretention bottom area would be calculated as: 0.0561 x contributing hard surface area + 32.7. All area values must be in square feet. The bottom area of the same facility sized for a contributing area less than 2,000 square feet would be equal to 7.3 percent of the hard surface area routed to it.

Modeling Approach for On-site Performance Standard, Flow Control, and Water Quality Treatment

When using continuous simulation hydrologic modeling to size bioretention cells, the assumptions listed in Table 5.24 must be applied. Refer to the *Approval Status of Continuous Simulation Models* section of the SWMMWW for a list of currently approved models. If MGSFlood is used, the "Ecology Bioretention" element must be used to represent bioretention. The contributing area, cell bottom area, and ponding depth should be iteratively sized until the Minimum Requirements for On-site Stormwater Management, Flow Control and/or Treatment are met (refer to *Volume 1, Project Minimum Requirements*) or where it has been determined by the Director that there is no off-site point of discharge for the project, the requirements of *Section 4.3.2* are met. General sizing procedures for infiltration facilities are presented in *Section 4.5.1*.

Table 5.24. Continuous Modeling Assumptions for Infiltrating Bioretention.

Variable	Assumption
Precipitation Series	SEPTS-99 unless otherwise adopted by the Director
Computational Time Step	5 minutes
HSPF Parameters	LSUR, SLSUR, NSUR must be adjusted per *Appendix F*
Inflows to Facility	Surface flow and interflow from total drainage area (including impervious and pervious contributing areas) routed to facility
Precipitation and Evaporation Applied to Facility	Yes. WWHM and MGSFlood both apply precipitation and evaporation to the facility automatically. If model does not apply precipitation and evaporation to facility automatically, then modelers must add the facility area to the post developed impervious contributing area to account for this additional precipitation and evaporation (note that this will underestimate the evaporation of ponded water).

Table 5.24 (continued). Continuous Modeling Assumptions for Infiltrating Bioretention.

Variable	Assumption
Bioretention Soil Type	SWMMWW 6in/hr or SWMMWW 12 in/hr (see below for safety factor)
Bioretention Soil Infiltration Rate	The design infiltration rate must be 6 inches per hour. Apply a saturated hydraulic conductivity (KSat) safety factor of 2 when using the SWMMWW 12 in/hr bioretention soil type.
Bioretention Soil Porosity	Use the default Bioretention Soil Porosity included in WWHM and MGSFlood for the SWMMWW 12in/hr soil type.
Bioretention Soil Depth	For facilities without underdrains, the soil must have a minimum of 12 inches for flow control and minimum of 18 inches for water quality treatment. For facilities with underdrains, the soil must have a minimum depth of 18 inches.
Subgrade (Native) Soil Design Infiltration Rate	Design infiltration rate (*Section 4.5.2*, *Appendix D*)
Underdrain (if required)	If an underdrain is simulated, a gravel aggregate layer must be included for the underdrain layer media. The default underdrain invert elevation is located at the bottom of the lowest soil layer unless a height or offset is specified. If the underdrain is elevated above the bottom extent of the aggregate layer, water stored in the aggregate below the underdrain invert may be modeled to provide storage and infiltrate to subsurface soil. For the purposes of this manual, underdrains meeting the bedding requirements shown in Figures 5.13 and 5.14 are considered “elevated” by 6 inches. In order to model the underdrain with underlying storage and infiltration, the aggregate gravel reservoir must extend across the bottom of the facility. The underdrain pipe could be further elevated for improved flow control performance.
Underdrain Layer Media Type	Gravel
Overflow Structure	The overflow elevation must be set at the maximum ponding elevation (excluding freeboard). It may be modeled as weir flow over a riser edge. Note that the total facility depth (including freeboard) must be sufficient to allow water surface elevation to rise above the overflow elevation to provide head for discharge. Vertical risers with grates must be modeled with a riser diameter that is reduced by at least 50-percent of the overflow diameter that will be constructed to account for losses from the grate. See *Overflow* under *Section 5.4.4.5* for more information.

5.4.4.7. Minimum Construction Requirements

During construction, it is critical to prevent clogging and over-compaction of the subgrade and bioretention soils. Minimum requirements associated with bioretention facility construction include the following:

- Place bioretention soil per the requirements of City of Seattle Standard Specifications.
- Do not excavate or place soil during wet or saturated conditions.

Refer to the Puget Sound LID Manual for additional guidance on bioretention construction.

5.4.4.8. Operations and Maintenance Requirements

Bioretention O&M requirements are provided in *Appendix G* (*BMP No. 23*).

5.4.5. Rain Gardens

5.4.5.1. Description

Rain gardens are shallow, landscaped depressions with compost amended soil or imported bioretention soil and plants adapted to the local climate and soil moisture conditions. Stormwater is stored as surface ponding before it filters through the underlying amended soil. Stormwater that exceeds the surface storage capacity overflows to an adjacent drainage system. Treated water is infiltrated into the underlying soil. Rain gardens call be individual cells or multiple cells connected in series.

Rain gardens are infiltration BMPs and must be designed according to the requirements in *Section 3.2* and *Section 4.5*.

Rain gardens are similar to infiltrating bioretention facilities (refer to *Section 5.4.4*) with the following exceptions:

- Rain gardens may only be used to meet the On-site List Approach.
- Rain gardens cannot be used on projects choosing to meet the On-site Performance Standard or projects that trigger flow control or water quality treatment requirements.
- Rain gardens may not have a liner or underdrain.
- The maximum ponding depth is 6 inches except for in the right-of-way where the maximum ponding depth is 3 inches.
- Rain gardens may have compost amended soil rather than imported bioretention soil.
- There are no presettling requirements.
- Within the right-of-way, rain gardens are not an allowable BMP if incidental runoff from PGHS exceeds 10 percent of the contributing area.
- Observation ports are not required.

5.4.5.2. Performance Mechanisms

Like infiltrating bioretention, rain gardens provide flow control via detention, attenuation, and losses due to infiltration, interception, evaporation, and transpiration. Some water quality treatment is provided through sedimentation, filtration, adsorption, uptake, or biodegradation and transformation of pollutants by soil organisms, soil media, and plants (note that rain gardens cannot be used to achieve water quality treatment).

5.4.5.3. Applicability

As shown in the table below, rain gardens can only be applied to meet the on-site stormwater management requirement using the On-site List Approach. To meet flow control, water quality treatment or the On-site Performance Standards, an infiltrating bioretention facility may be used (refer to *Section 5.4.4*).

BMP	On-site: List	On-site: Standard	Flow Control: Forest	Flow Control: Pasture	Flow Control: Peak	Water Quality: Basic	Water Quality: Enhanced Metals	Water Quality: Oil Control	Water Quality: Phosphorus	Conveyance
Rain garden	x									x[a]

[a] Rain gardens may be connected in series, with the overflows from upstream cells directed to downstream cells to provide conveyance.

5.4.5.4. Site Considerations

Site considerations for the applicability of rain gardens are provided in *Section 3.2* and *Section 4.5*. Refer to *Appendix C* for additional infeasibility criteria for the On-site List Approach.

5.4.5.5. Design Criteria

This section provides a description, recommendations, and requirements for the components of rain gardens. Typical components of a rain garden are shown in Figure 5.18. Design criteria are provided in this section for the following elements:

- Contributing area
- Flow entrance
- Ponding area
- Compost amended or imported bioretention soil
- Subgrade
- Overflow
- Plants
- Mulch layer

For additional guidance on rain garden design and construction, refer to the *Rain Garden Handbook for Western Washington Homeowners* (WSU 2013, or as revised). Sizing guidance provided in the handbook is not applicable (refer to *Section 5.4.5.6* for sizing requirements).

Contributing Area

A single rain garden cell or a series of cells must not receive runoff from more than 5,000 square feet of impervious area. This area limitation is to ensure that rain gardens are small-scale and distributed. In no case will the area contributing runoff to a rain garden consist of more than 10 percent PGHS within the right-of-way.

The rain garden cell area should be sized for the contributing area routed to the cell. It is recommended that cells not be oversized because the vegetation in oversized cells may not receive sufficient storm water runoff for irrigation, increasing maintenance requirements.

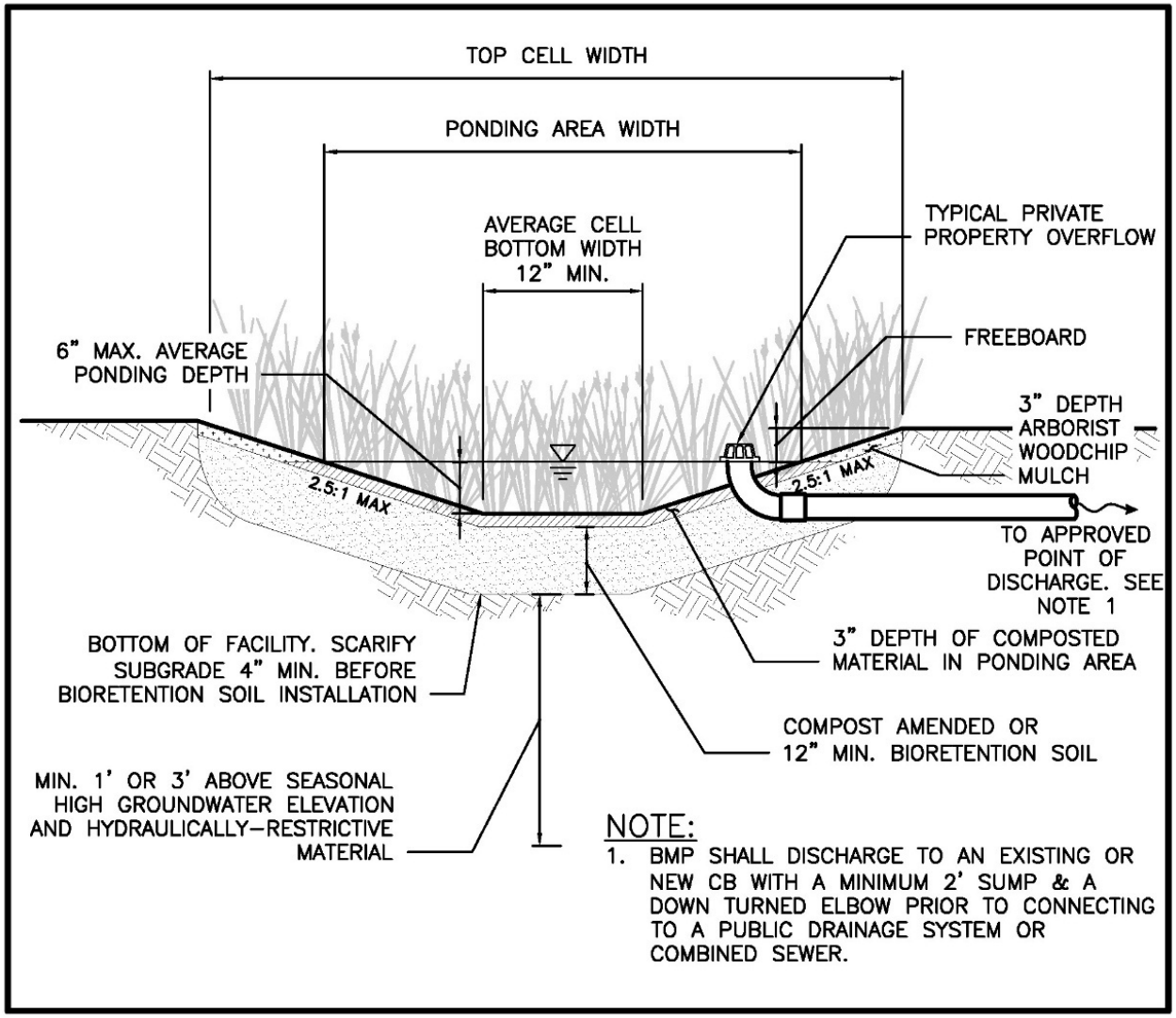


Figure 5.18. Typical Rain Garden.

Stormwater flows from other areas (beyond the area for which the rain garden is sized) should be bypassed around the cell in order to reduce sediment loading to the cell and the potential for clogging. While it is preferred that rain gardens be sized to manage only the area draining to the cell, excess flows may be routed through a rain garden with the following limitations:

- The maximum impervious drainage area that may be routed to a rain garden must not exceed twice the area for which it is sized, limited to a maximum of 5,000 square feet. Additional runoff contributions from pervious areas are acceptable. No on-site stormwater management credit is given for runoff from areas beyond the design area.
- Additional runoff routed to a rain garden must be clearly noted on submitted plans.

Flow Entrance

Flow entrances must be sized to capture flow from the drainage area and designed to both reduce the potential for clogging at the inlet and prevent inflow from causing erosion in the rain garden cell. Four primary types of flow entrances can be used for rain gardens:

- Dispersed flow (e.g., vegetated buffer strips)
- Sheet flow
- Curb cuts
- Concentrated flow (e.g., piped flow)

Vegetated buffer strips are the preferred entrance type because they slow incoming flows and provide initial settling of particulates. Refer to the Puget Sound LID Manual for guidance on flow entrances.

The minimum requirements associated with the flow entrance design include the following:

- For rain gardens, the flow entrance elevation must be above the overflow elevation.
- For sheet flow into a rain garden, a minimum 1-inch drop from the edge of a contributing hard surface to the vegetated flow entrance is required. This drop is intended to allow for less frequent maintenance by allowing some sediment/debris buildup at the edge where flow enters the rain garden.
- The following requirements apply to parking lot curb cut flow entrances:
    - The minimum curb cut width must be 8 inches.
    - The curb cut must have either a minimum of 8 percent slope from the outer curb face extending to a minimum of 12 inches beyond the back of curb or provide a minimum of 2inch vertical drop from the back of curb to the vegetated surface of the cell.
- If concentrated flows are entering the cell (e.g., pipe or curb cut), flow energy dissipation (e.g., rock/cobble pad or flow dispersion weir) must be incorporated to reduce the potential for erosion at the inlet.

Ponding Area

The ponding area provides surface storage for storm flows and the first stages of pollutant treatment within the cell. The minimum requirements associated with the cell ponding area design include the following:

- The bottom area of a cell must be no less than 4 square feet, except where used to manage sidewalk runoff in the ROW planting strip where the minimum area can be reduced to 2 square feet if needed to eliminate check dams.
- The average ponding depth must be no less than 2 inches and no more than 6 inches.
- The maximum planted side slope is 2.5H:1V. If total cell depth exceeds 3 feet, the maximum planted side slope is 3H:1V. If steeper sides are necessary, rockery, concrete walls, or steeper soil wraps may be used.
- If berming is used to achieve the minimum top cell elevation needed to meet ponding depth and freeboard needs, maximum berm slope is 2.5H:1V, and minimum berm top

width of is 6 inches. Soil used for berming where the permanent restoration is landscape must be imported bioretention soil or amended subgrade soil and compacted to a minimum of 90 percent dry density.

- For trees planted within or alongside slopes of a rain garden cell, the maximum side slope around the tree is 1H:1V.
- The average bottom width for the rain garden must be no less than 12 inches.
- The bottom slope must be no more than 3 percent.

Refer to CAM 1190 for additional guidance for siting rain gardens within the right-of-way.

Compost-amended or Imported Bioretention Soil

Proper soil specification, preparation, installation, and maintenance are critical factors for rain garden performance. To meet rain garden soil requirements, the subgrade soil may be amended with compost or the subgrade soil may be over excavated and replaced with imported bioretention soil.

To determine if the subgrade soil is suitable for amending with compost, a simple soil texture test can be performed. When digging the test hole for the subgrade soil infiltration test do the following:

- Squeeze moist soil into a ball. If the soil falls apart or can be broken up easily and is gritty feeling, this suggests a sandier, well-draining soil. This type of soil is suitable for amending and use in the rain garden.
- If the soil is sticky, smooth, and forms a ball that can be worked like modeling clay, this suggests poor-draining soil with high clay content. If the soil is smooth, pliable but not sticky then it is likely a silty soil and moderate to poor draining. These soils are less suitable for amending and must be replaced with 12 inches of imported bioretention soil per City of Seattle Standard Specification 721 (refer to *Section 5.4.4.5*).
- If the soil is dry, add water a few drops at a time, break down the chunks to work the water into soil, and then perform the soil texture test.

If the subgrade soil is suitable, amend existing site topsoil or subsoil per *Section 5.1.5.1*.

Subgrade

The minimum measured subgrade infiltration rate for rain gardens is 0.3 inch per hour.

If subgrade soil is over excavated to place imported bioretention soil, the subgrade soil surface can become smeared and sealed by excavation equipment during construction. The design must require scarification or raking of the side walls and bottom of the rain garden excavation to a minimum depth of 4 inches after excavation to restore infiltration rate.

Overflow

A rain garden must have an overflow. The rain garden overflow can be provided by a drain pipe, earthen channel or curb cut installed at the designed maximum ponding elevation and connected to a downstream BMP or an approved point of discharge.

The minimum requirements associated with the overflow design include the following:

- Overflows must convey any flow exceeding the capacity of the cell unless designed to fully infiltrate all flows for the full, required simulation period. Plans must indicate surface flow paths in case of failure of the BMP (refer to *Section 4.3.3*).
- Freeboard must be provided to ensure that overflows are safely conveyed to an approved point of discharge without flooding adjacent properties or sidewalks. The minimum freeboard measured from the invert of the overflow point (e.g., standpipe, earthen channel, curb cut) to the lowest overtopping elevation of the cell is 2 inches for contributing drainage areas less than 3,000 square feet and 4 inches for contributing drainage areas from 3,000 square feet to 5,000 square feet.
- The drain pipe, if used, must have a minimum diameter of 4 inches.
- For cells in the right-of-way with ponding depths of 3 inches or less (e.g., Sidewalk Projects), it is acceptable to allow overflow over the curb to the roadway conveyance system.
- If the cell will receive flows from areas beyond the area for which the rain garden is sized (refer to the *Contributing Area* subsection), the overflow conveyance infrastructure must safely convey runoff from the total drainage area.

Plants

In general, the predominant plantings used in rain gardens are species adapted to stresses associated with wet and dry conditions. Soil moisture conditions will vary within the rain garden from saturated (bottom of cell) to relatively dry (rim of cell). Accordingly, wetland plants may be planted in the lower areas and drought-tolerant species planted on the perimeter of the rain garden or on mounded areas.

The minimum requirements associated with the vegetation design include the following:

- The plans must specify that vegetation coverage of plants will achieve 90 percent coverage within 2 years. For this purpose, coverage should be measured when deciduous plants are in bloom.
- The plants must be sited according to sun, soil, wind and moisture requirements.
- At a minimum, provisions must be made for supplemental irrigation/watering during the first two growing seasons following installation and in subsequent periods of drought.
- Plants for rain gardens sited in the right-of-way must be selected from bioretention plant list (*Appendix J*).

Refer to the Rain Garden Handbook for Western Washington Homeowners and the Puget Sound LID Manual for guidance on plant selection and recommendations for increasing survival rates.

Mulch Layer

Properly selected organic mulch material reduces weed establishment, regulates soil temperatures and moisture, and adds organic matter to the soil. Compost and arborist wood chip mulch are required for different applications within the rain garden cell. Compost mulch

is an excellent slow-release source of plant nutrients and does not float, but compost does not suppress weed growth as well as bulkier, higher carbon mulches like arborist wood chips. Arborist wood chips are superior to bark mulch in promoting plant growth, feeding beneficial soil organisms, reducing plant water stress, and maintaining surface soil porosity.

Organic mulch must consist of the following:

- Compost (per City of Seattle Standard Specification 9-14.4(8)) in the bottom of the rain garden cell and up to the ponding elevation
- Arborist wood chip mulch (per City of Seattle Standard Specification 9-14.4(4)) on cell slopes above the ponding elevation and the around the rim area
- A minimum of 2 inches and a maximum of 3 inches for both types of organic mulch

Rain garden designs may use aggregate mulch. This may be desirable in areas where higher flow velocities are anticipated, an aggregate mulch may be used to dissipate flow energy and protect underlying soil. Aggregate mulch varies in size and type, but 1- to 1.5-inch gravel (rounded) decorative rock is typical. Aggregate mulch must be washed (free of fines) and the area covered with aggregate mulch must not exceed one fourth of the rain garden bottom area.

As an alternative to mulch, a dense groundcover may be used. Mulch is required in conjunction with the groundcover until groundcover is established. Mulch is not required for turf-vegetated cells.

5.4.5.6. BMP Sizing

Sizing for On-site List Approach

Rain gardens may be selected to meet the On-site List Requirement (refer to *Section 3.3.1* and *Appendix C* for infeasibility criteria). To meet the requirement rain gardens must be sized according to the sizing factors provided in Table 5.25. Sizing factors are based on achieving a minimum wetted surface area of 5 percent of the contributing area or meeting the On-site Performance Standard for a pre-developed condition of forest on till (whichever is greater).

Factors are organized by cell ponding depth, cell side slope, and subgrade design infiltration rate. To select the appropriate sizing factor:

- The subgrade design infiltration rate must be rounded down to the nearest rate in the sizing table.
- The ponding depth must be rounded down to the nearest depth in the sizing table, or sizing factors may be linearly interpolated for intermediate ponding depths (e.g., between 3 and 4 inches ponding).

The rain garden must meet the general requirements for rain gardens outlined in this section plus the following specific requirements:

- The bottom area must be sized using the applicable sizing factor.
- It is preferred that the bottom area be flat, but up to 3 percent slope is permitted.

- For facilities with sloped sides, the side slopes within the ponded area must be no steeper than 2.5H:1V.
- The rain garden soil depth must be a minimum of 12 inches.
- The average ponding depth for the cell must be no less than the selected ponding depth.

The *bottom* area for the rain garden is calculated as a function of the hard surface area routed to it. As an example, the bottom area of the rain garden would be equal to 3.5 percent of the hard surface area routed to it when the design infiltrating rate is 0.6 inch per hour and the ponding depth is an average of 6 inches. For facilities with sloped sides, top area is calculated as a function of the cell bottom area and the side slopes up to the total rain garden depth (i.e., ponding and freeboard depth).

Table 5.25. On-site List Sizing for Rain Gardens.

Rain Garden Configuration	Average Ponding Depth	Subgrade Soil Design Infiltration Rate	Sizing Factor for Rain Garden Bottom Area[a]: On-site List
Sloped sides	2 inches	0.15 inch/hour	6.1%[b]
		0.3 inch/hour	4.5%
		0.6 inch/hour	4.5%
		1.0 inch/hour	4.5%
		2.5 inch/hour	4.5%
	6 inches	0.15 inch/hour	NA[c]
		0.3 inch/hour	3.5%
		0.6 inch/hour	3.5%
		1.0 inch/hour	3.5%
		2.5 inch/hour	3.5%
Vertical sides	6 inches	0.15 inch/hour	NA[c]
		0.3 inch/hour	5.0%
		0.6 inch/hour	5.0%
		1.0 inch/hour	5.0%
		2.5 inch/hour	5.0%

NA – not applicable

[a] Sizing factors are based on achieving a minimum wetted surface area of 5 percent unless otherwise noted.

[b] Sizing factor increased beyond the minimum wetted surface area of 5 percent to meet the On-site Performance Standard for a pre-developed condition of forest on till.

[c] Ponding depth and infiltration rate combination do not achieve drawdown requirements.

Rain Garden Bottom Area = Contributing Hard Surface Area x Factor (%)/100.

5.4.5.7. Minimum Construction Requirements

During construction, it is critical to prevent clogging and over-compaction of the subgrade, bioretention soils or amended soils. Minimum requirements associated with rain garden construction include the following:

- Amend subgrade soil per *Section 5.1* or place bioretention soil per the requirements of City of Seattle Standard Specifications.
- Do not excavate, place soil, or amend soil during wet or saturated conditions.

5.4.5.8. Operations and Maintenance Requirements

Rain garden O&M requirements are provided in *Appendix G* (*BMP No. 29*).

5.4.6. Permeable Pavement Facilities

5.4.6.1. Description

Permeable pavement is a paving system that allows rainfall to infiltrate into an underlying aggregate storage reservoir, where stormwater is stored and infiltrated to the underlying subgrade or removed by an overflow drainage system. Two categories of permeable pavement BMPs are included in this manual: permeable pavement facilities (provided in this section) and permeable pavement surfaces (provided in *Section 5.6.2*).

The main difference between permeable pavement facilities and permeable pavement surfaces is that permeable pavement surfaces are not intended to have a significant amount of run-on from other surfaces and they have an aggregate base with a depth as little as 3 inches where permeable pavement facilities are sized to infiltrate drainage from impervious run-on areas that are 2 to 5 times the area of the BMP and require an aggregate base storage reservoir with a minimum depth of 6 inches. The deeper reservoir course allows permeable pavement facilities to more easily meet performance standards for a larger percentage of the project because it can infiltrate runoff from other hard surfaces such as roofs. Also, in this manual, permeable pavement facilities are considered infiltrating facilities, while permeable pavement surfaces are considered a surface runoff reduction method, which makes the on-site stormwater management infeasibility criteria different.

A permeable pavement facility consists of a pervious wearing course (e.g., porous asphalt, pervious concrete) and an underlying storage reservoir.

Due to the permeable nature of a permeable pavement facility, future application of an impervious surface (e.g., fog seal, chip seal or other types of impervious overlay) over top of the facility is prohibited.

Infiltration facilities that are equivalent to permeable pavement facilities may be allowed under impermeable pavements or landscaping in lieu of permeable pavement. See Section 5.4.6.5 – Design Criteria – BMPs Equivalent to Permeable Pavement Facilities.

5.4.6.2. Performance Mechanisms

Flow control occurs through temporary storage of stormwater runoff in the voids of the aggregate material and subsequent infiltration of stormwater into the underlying soils. Pollutant removal mechanisms include sedimentation, infiltration, filtration, adsorption, and biodegradation.

5.4.6.3. Applicability

Permeable pavement facilities can be designed to provide on-site stormwater management, flow control and/or water quality treatment. This BMP can be applied to meet or partially meet the requirements listed below.

BMP	On-site: List	On-site: Standard	Flow Control: Forest	Flow Control: Pasture	Flow Control: Peak	Water Quality: Basic	Water Quality: Enhanced Metals	Water Quality: Oil Control	Water Quality: Phosphorus	Conveyance
Permeable Pavement Facility	x	x	x	x	x	x[a]	x[a]		x[b]	

[a] Underlying soil must meet the treatment soil requirements outlined in *Section 4.5.2* or a water quality treatment course must be included per *Section 5.4.6.5*.

[b] Refer to treatment train options for infiltration BMPs included in *Section 4.4.3.2*.

5.4.6.4. Site Considerations

Unlike many facilities that require dedicated space on a site, permeable pavement facilities are part of the usable lot area and can replace conventional pavements, including:

- Sidewalks and pedestrian plazas
- Pedestrian and bike trails
- Driveways
- Most parking lots
- Low volume roads, alleys, and access drives

Site considerations for the applicability of permeable pavement facilities include:

- **Setbacks and restrictions**: Permeable pavement facilities must meet the siting and infiltration rate requirements for infiltration facilities presented in *Section 3.2 and Section 4.5*. For areas where permeable pavement facilities are not permitted, permeable pavement surfaces may be used because they do not take additional run-on and are not categorized as infiltration facilities (refer to *Section 5.6.2*).
- **Site topography:** The recommended maximum surface (wearing course) slope for permeable pavement facilities is 6 percent to allow efficient storage of water within the subbase. For vehicular traction, the maximum surface slope varies by wearing course type (refer to industry guidelines). Minimum wearing course slope must be 1 percent unless provision is made for positive drainage in event of surface clogging.

  The recommended maximum subgrade slope for permeable pavement applications is 6 percent. Subgrades that are sloped require subsurface check dams to promote storage in the subgrade (refer to *Section 5.4.6.5 — Subsurface Check Dam* and Figure 5.20). At steeper subgrades slopes, design and construction become more complex and the construction cost increases.

- **Land use**: Because permeable pavement can clog with sediment, permeable paving facilities are not recommended where sediment and pollutant loading is unavoidable, including the following conditions:
  - Excessive sediment contamination is likely on the pavement surface (e.g., construction areas, landscaping material yards).

  - It is infeasible to prevent stormwater run-on to the permeable pavement from unstabilized erodible areas without presettling.
  - Regular, heavy application of sand is anticipated for maintaining traction during winter, or the facility is in close proximity to areas that will be sanded. A minimum 7-foot clearance is required between a permeable pavement facility and the travel lane of sanded arterial roads.
  - Sites where the risk of concentrated pollutant spills are more likely (e.g., gas stations, truck stops, car washes, vehicle maintenance areas, industrial chemical storage sites).

- **Accessibility**: As for standard pavement design, ADA accessibility issues must be addressed when designing a permeable pavement facility, particularly when using pavers.
- **Wearing Course Maintenance**: See Appendix G for maintenance requirements for permeable pavement. Fog seal, chip seal and other impervious overlays are not permitted on top of permeable pavement.
- Refer to *Appendix C* for additional infeasibility criteria for the On-site List Approach.

5.4.6.5. Design Criteria

This section provides descriptions, recommendations, and requirements for the common components of permeable pavement facilities. Typical components of a permeable pavement facility are shown in Figure 5.19 and an example of permeable pavement facility with check dams is shown in Figure 5.20. Some, or all, of the components may be used for a given application depending on the permeable pavement type (e.g., porous asphalt, pavers, etc.), site characteristics and restrictions, and design objectives.

Design criteria are provided in this section for the following elements:

- Contributing area
- Flow Entrance/presettling
- Wearing course
- Leveling course
- Storage reservoir
- Subgrade
- Subsurface check dams
- Overflow
- Geotextile
- Water quality treatment course (if required)
- Observation/maintenance port
- Underdrain (optional)
- Edge treatment

The structural design of permeable pavement to support anticipated loads is outside the scope of this manual.

The Puget Sound LID Manual provides additional guidance on permeable pavement design.

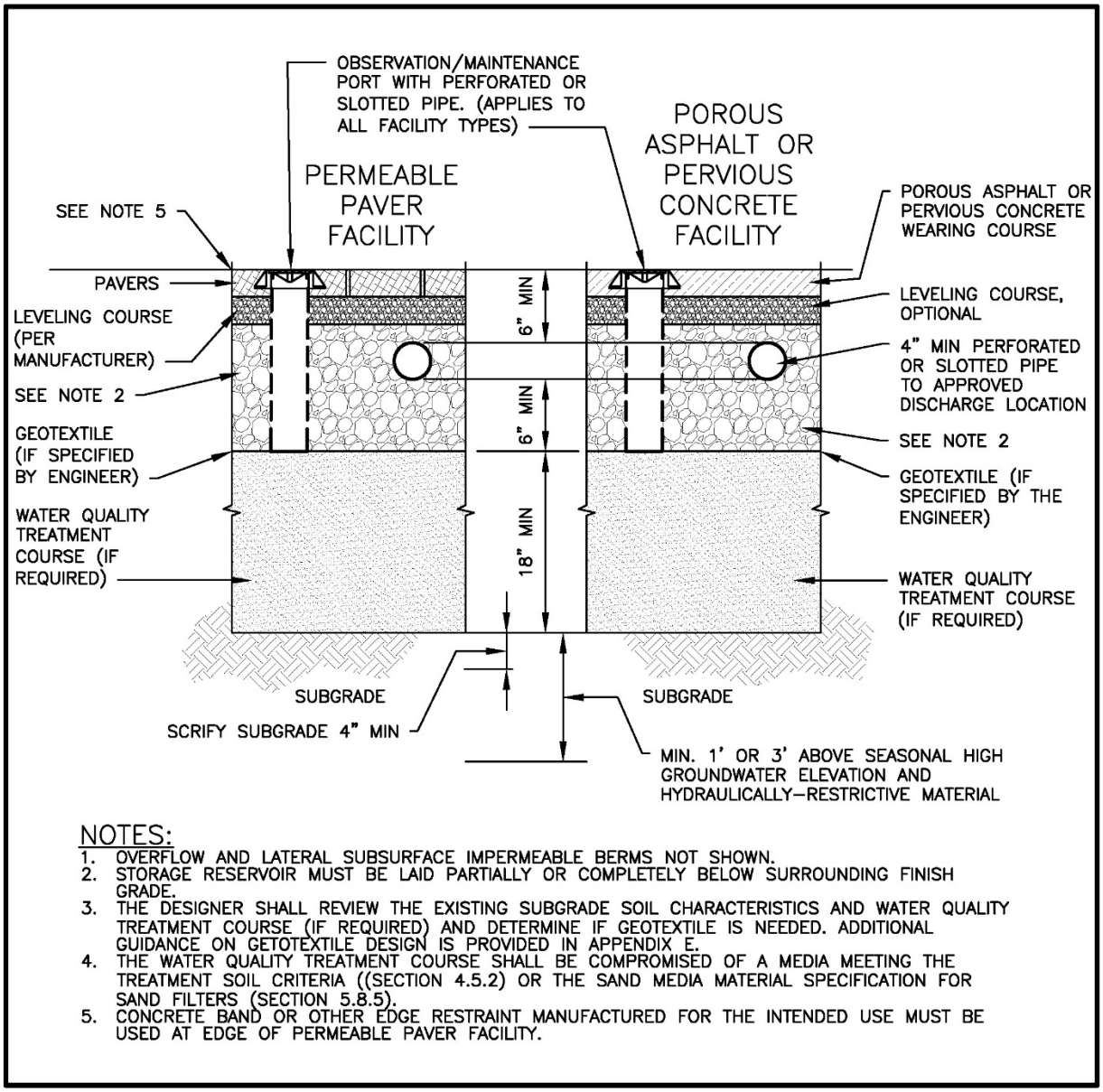


Figure 5.19. Permeable Pavement Facility.

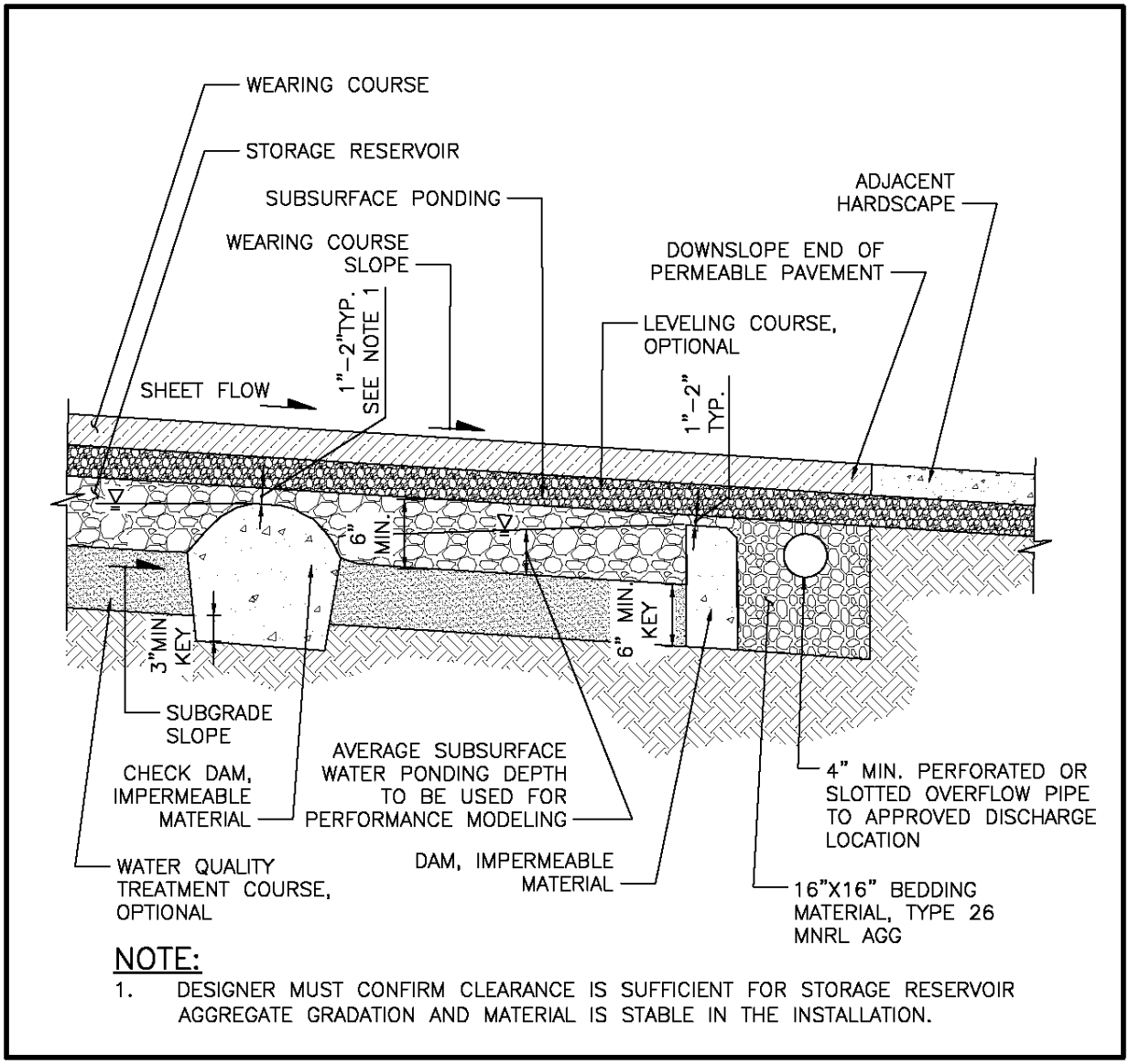


Figure 5.20. Example Permeable Pavement Facility with Checkdams.

Contributing Area

Permeable pavement facilities may be designed to manage (meet stormwater requirements for) runoff from other contributing areas (run-on). When designed to receive run-on, permeable pavement areas must be protected from sedimentation which can cause clogging and diminished facility performance. The minimum requirements associated with the contributing area include the following:

- The area contributing run-on must be no larger than specified by surface type below:
  - Pollution-generating hard surfaces (e.g., roadways, parking lots): maximum run-on ratio of 2:1
  - Non-pollution generating hard surfaces (e.g., roofs, sidewalks) and stabilized pervious surfaces: maximum run-on ratio of 5:1

  - For a mix of surface areas, the maximum run-on ratio must be area-weighted (e.g., a contributing area composed of half parking lot and half roof would be subject to a maximum run-on ratio of 3.5:1)

- To prevent sediment flowing onto the pavement, run-on must not occur from erodible/unstabilized areas or from impervious areas that receive run-on from unstabilized areas.
- Run-on must not occur from contributing areas from which sediment or pollutant loads are unavoidable. Refer to land use restrictions listed in the *Site Considerations* subsection.

Flow Entrance/Presettling

Run-on should be directed to the permeable pavement facility in a distributed manner (e.g., sheet flow) rather than through concentrated flow, where possible. This can be accomplished by dispersing the flow over the permeable pavement or by piping the runoff to the permeable pavement facility for subsurface distribution using slotted pipes. Specific requirements associated with the run-on flow entrance area provided below.

- If the run-on flow is concentrated and the contributing area exceeds 1,000 square feet, run-on must be dispersed to permeable pavement. Acceptable methods include sheet flow (e.g., dispersion trench) or subsurface delivery to the storage reservoir.
- If the run-on flow is concentrated and the contributing area is 1,000 square feet or less, concentrated run-on is permitted. However, the designer must consider the concentrated flow velocity, permeable pavement slope and permeable pavement flow path to ensure that the run-on will be captured by the pavement.
- If subsurface delivery is used, stormwater inflows must be routed through a catch basin with downturned elbow (trap). Presettling requirements are provided in *Section 4.4.5*. After presettling, flows must be distributed to the storage reservoir via slotted drain pipe that runs the length of the permeable pavement facility. For permeable pavement facilities wider than 8 feet, the slotted distribution pipes must be located at a minimum of 6 feet on-center.
- Where run-on flows onto permeable pavement and flow is concentrated, these areas must be identified in the O&M plan as requiring more frequent cleaning and inspection to ensure overall facility performance.

If run-on flow from an impervious surface is dispersed (e.g., via sheet flow), the flow path length on the contributing impervious surface must not be more than 5 times the flow path length on the permeable pavement. The minimum flow path length on the permeable pavement must be 4 feet.

Wearing Course

The surface layer of a permeable pavement facility is the wearing course. Categories of wearing courses include:

- **Porous Asphalt**: Porous asphalt concrete is open-graded asphalt with reduced fines and air pockets encased within it that allow water to drain to the base below. Similar to conventional asphalt, porous asphalt is laid with traditional asphalt paving equipment. Simple applications include a single wearing course.

- **Pervious Concrete***:* Pervious cement concrete is similar to porous asphalt in that the mixture omits or substantially reduces the fines to create stable air pockets encased within it. Pervious concrete typically has a rougher surface than impermeable concrete or porous asphalt.
- **Permeable Pavers***:* Permeable pavers consist of paver blocks made of permeable material or paver blocks with gaps between them that allow water to drain to the base below. The most common form of permeable pavers are permeable interlocking concrete paver blocks. These are modular blocks with gaps between them that are filled with a permeable material (typically small clean stone).
- **Grid Systems***:* Open-celled paving grids consist of a rigid grid composed of concrete or a durable plastic that is filled with gravel or vegetation. The support base and the ring walls prevent soil compaction and reduce rutting and erosion by supporting the weight of traffic and concentrated loads. Vegetated grid systems are filled with a mix of sand, gravel, and topsoil and planted with a variety of non-turf forming grasses or low-growing groundcovers. Gravel-filled grid systems are filled with a clean aggregate mix specified by the manufacturer. The fill material must be at least a minimum of 2 inches deep.
- **Gravel walkways or areas:** Gravel walkways or areas that are not subject to vehicular load and consist of one of the following materials:
  - City of Seattle Mineral Aggregate Type 22 or 24
  - Modified AASHTO Grading #57 per *Washington State Department of Transportation Standard Specification for Road, Bridge and Municipal Construction*, 2020 (WSDOT 2020) Section 9-03.1(4)C, with 0 to 2 percent passing #200 wet sieve; percent fracture must be in accordance with requirements per WSDOT 2020 9-03.9(2)

Minimum requirements associated with the wearing course design include the following:

- A minimum wearing course surface slope of 1 percent is required (2 percent recommended) to ensure positive surface drainage should the surface become clogged. Wearing course surface slopes less than 1 percent may be approved when the engineered drainage plan documents no harm from surface ponding.
- For sidewalks in the right-of-way, the wearing course surface slope must be no more than 6 percent.
- For pervious concrete applications in the right-of-way, the pervious concrete area must be no less than 250 square feet.
- Wearing course material for pavers and grid systems must be on the Allowable Permeable Pavement Wearing Course Materials for Stormwater Credit list on the SDCI website (www.seattle.gov/sdci/codes/codes-we-enforce-(a-z)/stormwater-code) or an approved equal.
- Cast-in-place pavers or pre-cast paver stones may be used as a wearing course on private property if each paver is surrounded with an area of free-draining aggregate that is at least 10 percent of the area of the paver and the required storage reservoir below the paver is maintained. The free-draining aggregate surrounding each paver must meet the requirements of the storage reservoir or the leveling course aggregates. Note: since these pavers may be prone to movement under loads (e.g., vehicles or heavy pedestrian traffic), they may not be suitable for certain

applications. The minimum required spacing between pavers is estimated by multiplying the required area by 2 and dividing by the perimeter of the paver per the following equation:

  - Spacing (between pavers) = 2 X Paver Area (square inches) X (10 percent) / Perimeter Length of Paver (inches). For pervious concrete, City of Seattle Standard Specifications must be used for projects in the right-of-way. For projects outside of the right-of-way, the City of Seattle Standard Specifications or an approved equivalent must be used.

- For porous asphalt, refer to the Puget Sound LID Manual for additional guidance on wearing course design.
- Acceptance Testing:
  - For projects with less than 5,000 square feet of new plus replaced hard surface, infiltration capacity may be demonstrated using a bucket test wherein a bucket of water is thrown on the surface. If anything other than a scant amount of water puddles or runs off the surface, testing is required as described below.
  - For projects with 5,000 square feet or more new plus replaced hard surface a minimum initial uncorrected infiltration rate of 100 inches per hour is required, unless otherwise approved for vegetated grid systems. To improve the probability of long-term performance, significantly higher measured infiltration rates are desirable.
  - For measuring initial surface infiltration rates for porous asphalt or pervious concrete, the Standard Test Method for Infiltration Rate of In Place Pervious Concrete (ASTM C1701) or the infiltration rate field test from the City of Seattle standard specification for pervious concrete must be used.
  - For measuring initial surface infiltration rates for permeable pavers, the Standard Test Method for Surface Infiltration Rate of Permeable Unit Pavement Systems (ASTM C1781) must be used.
  - For grid systems, refer to manufacturers testing recommendations.

Leveling Course

Depending upon the type of wearing course, a leveling course (also called a bedding or choker course) may be required. A leveling course is often required for grid systems, permeable pavers, and pervious concrete. This course is a layer of aggregate that provides a more uniform surface for laying pavement or pavers and typically consists of crushed aggregate smaller in size than the underlying storage reservoir. Course thickness will vary with permeable pavement type.

Leveling course material and thickness must be included as required per manufacturer or designer recommendations. Leveling course material must be compatible with underlying storage reservoir material (with low potential to migrate into underlying storage reservoir) and must not limit the infiltration rate through the system. An example leveling course aggregate recommended by some manufacturers is ASTM No. 8 clean, open-graded, 1/4” or 3/8” chip stone. Fractured jointing sand must not be used.

Storage Reservoir

Stormwater passes through the wearing and leveling courses to an underlying aggregate storage reservoir, also referred to as base material, where it is filtered and stored prior to infiltration into the underlying soil. This aggregate also serves as the pavement's support base and must be sufficiently thick to support the expected loads. Design of the subgrade for loading is outside of the scope of this manual. A licensed engineer is needed to determine subsoil load bearing, minimum aggregate base thickness, and aggregate compaction for loading.

Minimum requirements associated with the storage reservoir design include the following:

- A 6-inch minimum depth of storage reservoir aggregate is required. Note that more depth may be needed for structural design support. A shallower depth may be approved around trees where necessary to protect roots.
- The storage reservoir must be laid partially or completely below the elevation of the surrounding grade.
- The storage reservoir must have a minimum total void volume of 25 percent after compacted in place. Percent voids (porosity) must be determined in accordance with ASTM C29/C29M. Use the jigging procedure to densify the sample (do not use the shoveling procedure). These requirements are met if the aggregate materials recommended below are used.
- Aggregate material must have 0 to 2 percent passing #200 wet sieve.
- For walkways, the following aggregate materials are recommended and meet the requirements listed above:
    - City of Seattle Mineral Aggregate Type 22 or 24
    - Modified AASHTO #57 per *Washington State Department of Transportation Standard Specifications for Road, Bridge, and Municipal Construction*, 2020 (WSDOT 2020) Section 903.1(4)C, with 0 to 2 percent passing #200 wet sieve; percent fracture must be in accordance with requirements per WSDOT 2020 903.9(2)
- For vehicular applications, the following aggregate materials are recommended and meet the requirements listed above:
    - City of Seattle Mineral Aggregate Type 13
    - Modified AASHTO #57 per WSDOT 2020 Section 903.1(4)C with 0 to 2 percent passing #200 wet sieve; percent fracture must be in accordance with requirements per WSDOT 2020 903.9(2)
    - Permeable ballast per WSDOT 2020 Section 9-03.9(2)

Subgrade

The minimum measured subgrade infiltration rate for permeable pavement facilities is 0.3 inch per hour when used only for the on-site stormwater management list approach or when any pre-sized factor is used. A lower infiltration rate may be used for flow control, water quality treatment and the on-site stormwater management performance standard if the facility is modeled using an approved continuous runoff model and the minimum 48-hr

drawdown time is demonstrated. If permeable pavement facilities are to be used to meet the water quality treatment requirement, underlying soil must meet the treatment soil requirements outlined in *Section 4.5.2* or a water quality treatment course must be included.

During construction the subgrade soil surface can become smeared and sealed by excavation equipment. The design must require scarification or raking of the side walls and bottom of the facility excavation to a minimum depth of 4 inches after excavation to restore infiltration rate.

Subsurface Check Dam

Sloped facilities have an increased potential for lateral flows through the storage reservoir aggregate along the top of relatively impermeable subgrade soil. This poses a risk of subsurface erosion (which may undermine pavement) and reduces the storage and infiltration capacity of the pavement facility. If required depending upon slope, the subgrade must be designed to create subsurface ponding to detain subsurface flow, increase infiltration, and reduce structural problems associated with subgrade erosion (refer to Figure 5.20). In such cases, ponding must be provided using periodic lateral subsurface barriers (e.g., check dams) oriented perpendicular to the subgrade slope. While the frequency of the check dams is calculated based on the required subsurface ponding depth and the subgrade slope, typical designs include barriers every 6 to 12 inches of grade loss.

Subsurface check dams are required unless:

- The subgrade slope is less than 1 percent and the storage reservoir aggregate is laid below surrounding subgrade or
- A licensed professional makes a determination based on soil type and permeability that check dams are not required to address subgrade erosion or ensure performance of system.

Minimum requirements associated with check dams include the following:

- Check dams must restrict lateral flow along the top of the subgrade soil. Examples of material to use for subsurface check dams include concrete, controlled-density fill (CDF), or similar material.
- Check dams must be installed at regular intervals perpendicular to the subgrade slope to provide the required average subsurface ponding depth in the storage reservoir.
- The check dams must not extend to the elevation of the surrounding ground.
- Each check dam must have an overflow, as described below, or allow overtopping to the next downslope storage reservoir section without causing water to flow out of the pavement surface or out the sides of the base materials that are above grade.

Note that the subgrade on sloped sites may be terraced to reduce the frequency of check dams. Even with terracing, a minimum of one downstream check dam is required to provide subsurface ponding.

Overflow

Unless designed to provide full infiltration (*Section 4.5.1*), permeable pavement facilities must have an overflow (*Section 4.3.3*). Minimum requirements associated with the overflow design include the following:

- Overflow must be designed to convey any flow exceeding the capacity of the facility unless designed to fully infiltrate all flows for the full, required simulation period. Plans must indicate surface flow paths in case of failure of the BMP (refer to *Section 4.3.3*). Options include:
  - Subsurface slotted drain pipe(s) set at the design ponding elevation to route flow to a conveyance system
  - Lateral flow through the storage reservoir to a daylighted conveyance system
- In the right-of-way, slotted pipe per City of Seattle Standard Plan No. 291 must be used. On private property, perforated pipe must meet Side Sewer Directors' Rule requirements.
- For facilities installed on a sloped subgrade, at least one overflow must be sited at the downslope extent of the facility.
- If a slotted overflow pipe is used to collect water in the pavement section, the pipe diameter and spacing must be designed based on the hydraulic capacity required. In permeable pavement facilities that are 8 feet wide or wider, the perforated overflow pipe must be spaced at 6 feet on-center. A non-perforated cleanout (sized to match underdrain diameter) must be connected to the underdrain every 100 feet at a minimum. Projects in the right-of-way must use City of Seattle Standard Plan No. 281. Projects on private properties must use requirements in the Side Sewer Directors' Rule.
- A minimum wearing course surface slope of 1 percent is required (2 percent recommended) to ensure positive surface drainage should the surface become clogged.
- The designer must consider the flow path of water when the permeable pavement section is fully saturated to the maximum design depth or when the wearing course is clogged to confirm there are no unanticipated discharge locations (e.g., impact to intersecting utility trenches, sheet flow to adjacent properties). The flow path must be described on the plan submittal.
- If a permeable pavement facility is used in the public roadway section, the roadway conveyance system must be designed as if the road surface were impermeable unless otherwise approved by the Director.

Note that the slotted pipe discussed in this section is set at the design ponding depth in the storage reservoir and is considered an overflow, not an underdrain. Underdrains are addressed in a separate subsection below.

Geotextile

Generally, geotextiles and geogrids are used for the following purposes:

- As a filter layer to prevent clogging of infiltration surfaces
- To prevent fines from migrating to more open-graded material and causing associated structural instability
- To prevent downward movement of the aggregate base into the subgrade for soil types with poor structural stability

Geotextiles between the permeable pavement subgrade and aggregate base in a traditional permeable pavement facility design are not required or necessary for many soil types and, if incorrectly applied, can clog and reduce infiltration capability at the subgrade or other material interface. Therefore, the use of geotextiles is discouraged unless it is deemed necessary. As part of the pavement section design, the designer must review the existing subgrade soil characteristics and treatment layer if any, and determine if geotextile is needed. If a combination permeable pavement facility and infiltration chamber facility is being used, geotextile must be placed between the wearing course and the stackable, modular plastic cells. Additional guidance on geotextile design is provided in *Appendix E*.

Minimum requirements associated with the geotextile design, if used, include the following:

- Use geotextile recommended by the manufacturer's specifications and by a geotechnical engineer for the given subgrade soil type or treatment layer and base aggregate.
- Extend the fabric up the sides of the excavation. This is especially important if the base is adjacent to conventional paving surfaces to prevent migration of fines from dense-graded base material and soil subgrade to the open graded base. Geotextile is not required on the sides if concrete curbs extend the full depth of the base/sub-base.
- Overlap adjacent strips of fabric at least 24 inches.
- Use geotextile that passes water at a greater rate than the design infiltration rate for the existing subgrade soils.

Water Quality Treatment Course (If Required)

If the permeable pavement is being designed to provide water quality treatment or if the permeable pavement will be PGHS exceeding 2,000 square feet, underlying soils must meet the requirements for treatment soil provided in *Section 4.5.2*. If the existing subgrade does not meet these requirements, a 6-inch water quality treatment course must be included between the subbase and the storage reservoir. The course must be composed of a media meeting the treatment soil criteria (*Section 4.5.2*) or the sand media material specification for sand filters in *Section 5.8.5*.

Observation/Maintenance Port

If a permeable pavement facility is designed to meet flow control and/or water quality treatment requirements and the permeable pavement area plus the run-on area (if any) is 5,000 square feet or greater, it must be equipped with an observation/maintenance port to allow for monitoring of the drawdown time following a storm. The observation/maintenance port must consist of an 8-inch minimum diameter perforated or slotted pipe with a locking lid that extends to the bottom of the pavement section and keyed into the subbase.

Observation/maintenance ports are required:

- At the downslope area of the pavement system and
- One for every additional 5,000 square feet of contributing area (permeable pavement area plus run-on area)

Underdrain (Optional)

Underdrain systems must be installed if the subgrade soils have a measured infiltration rate of less than 0.3 inch per hour. Designs utilizing underdrains provide less infiltration and flow control benefits. To improve performance, the underdrain may be elevated to maximize infiltration and/or outlet controls (e.g., orifice control) may be used to attenuate underdrain flows prior to release.

The underdrain pipe diameter will depend on hydraulic capacity required. The minimum requirements associated with the underdrain design include:

- In the right-of-way, slotted pipe per City of Seattle Standard Plan No. 291 must be used. On private property, perforated pipe must meet Side Sewer Directors' Rule requirements.
- Underdrain pipe slope must be no less than 0.5 percent.
- A non-perforated cleanout (sized to match underdrain diameter) must be connected to the underdrain every 100 feet minimum. Projects in the right-of-way must use City of Seattle Standard Plan No. 281. Projects on private properties must use requirements in the Side Sewer Directors' Rule.

Note that the slotted pipe discussed in this section is set below the design ponding depth in the storage reservoir and is considered an underdrain, not an overflow. Overflows are addressed in a separate subsection above.

Edge Treatment

Edge treatment is required around the perimeter of permeable pavers to prevent it from unraveling over time. Edge treatments can also be used to protect the subgrade of adjacent conventional pavement. Refer to Figures 5.21 and 5.22 for examples of concrete and geomembrane edge treatments, respectively. Concrete edge treatments may be used for either of those purposes while geomembrane may only be used to protect adjacent pavement. A manufactured paver restraint may also be used at edges, but it must be suitable for the pavement use (e.g., vehicular use vs. pedestrian only).

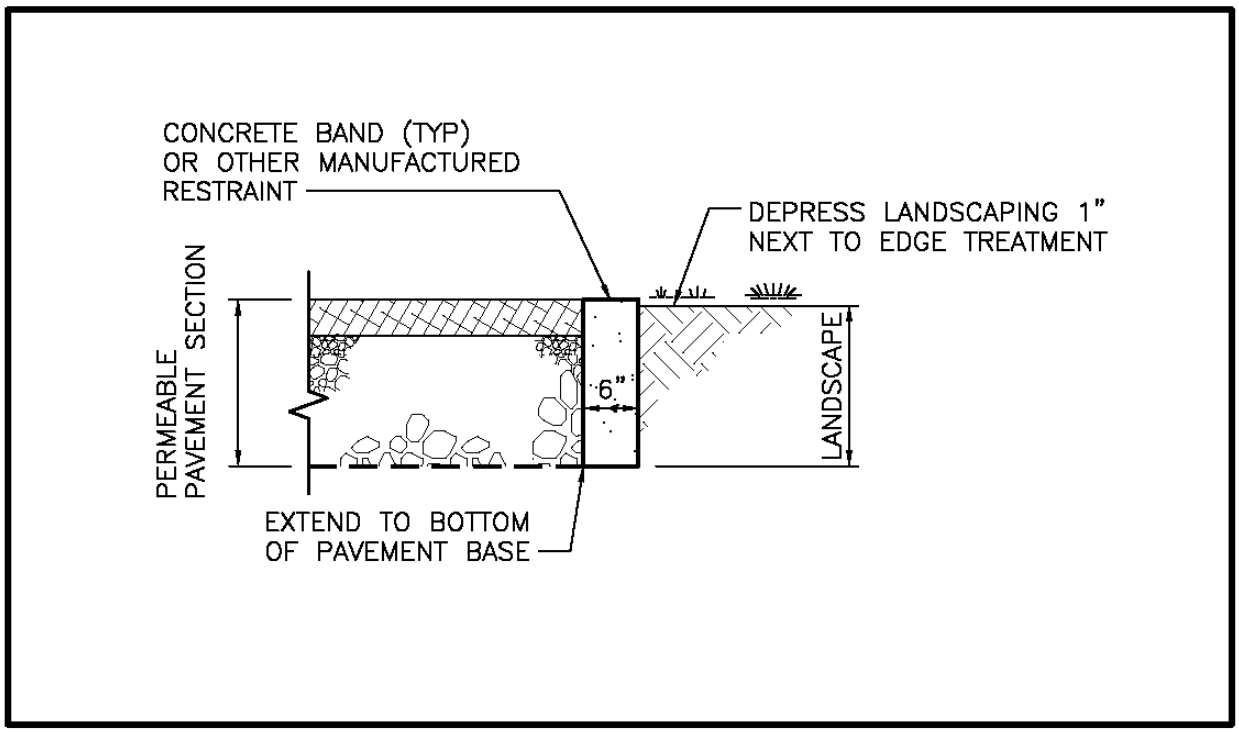


Figure 5.21. Example Permeable Pavement Concrete Edge Treatment.

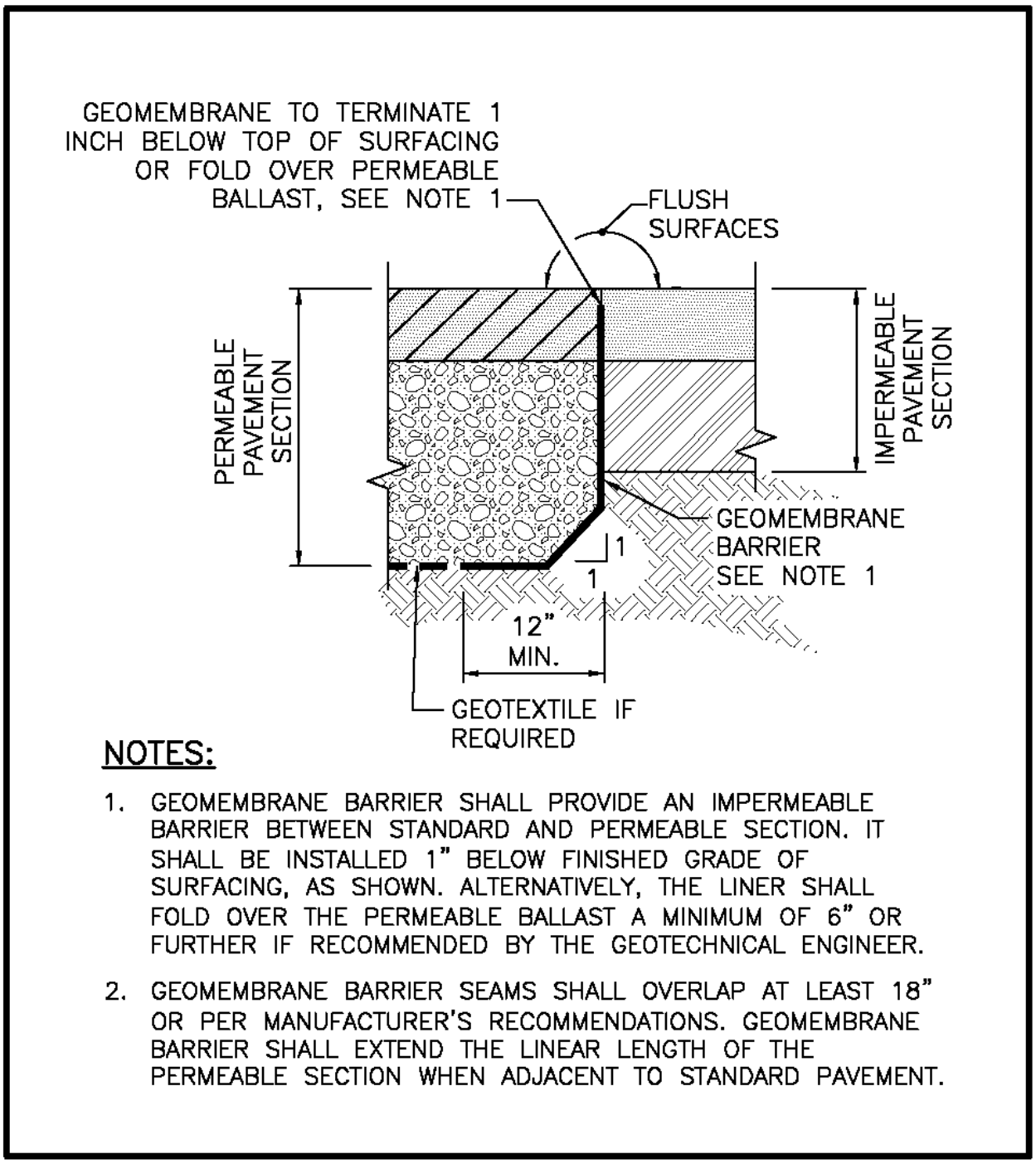


Figure 5.22. Example Permeable Pavement Geomembrane Edge Treatment.

BMPs Equivalent to Permeable Pavement Facilities

As an option, infiltration BMPs that do not include permeable pavement could be designed to be equivalent to a permeable pavement facility. If all design criteria and sizing criteria for permeable pavement facilities are met, except for the Wearing Course, Leveling Course, and Edge Treatment requirements applicable to a permeable pavement, then the BMP is considered equivalent to permeable pavement facilities and may be used in its place in the

on-site stormwater management list approach or to meet the on-site performance standard, flow control or water quality requirements. For example, an equivalent infiltration facility such as a shallow, spread out, infiltration trench could be constructed under standard pavement or landscaping if the area of the facility is sized to meet the run-on ratios from Section 5.4.6.5 – Contributing Area (i.e., 2:1 for non-pollution generating hard surface run-on areas and 5:1 for pollution-generating hard surface run-on areas).

Note: if constructed under landscaping, non-woven geotextile fabric, according to the specifications presented in Appendix E, must be placed around the top and side walls of the facility.

5.4.6.6. BMP Sizing

Sizing for On-site List Approach

Permeable pavement facilities without underdrains may be selected to meet the On-site List Requirement (refer to *Section 3.3.1* and *Appendix C* for infeasibility criteria). The area of the permeable pavement facility meets the requirement. In addition, hard surface area contributing run-on to a permeable pavement facility also meets the requirement if it does not exceed the thresholds listed below:

- For pollution-generating hard surfaces (e.g., roadways, parking lots) the run-on ratio must be no more than 2:1 (sizing factor 50 percent or greater)
- For non-pollution generating hard surfaces (e.g., roofs, sidewalks) and stabilized pervious surfaces the run-on ratio must be no more than 5:1 (sizing factor 20 percent or greater)
- For a mix of surface areas, the maximum run-on ratio must be area-weighted (e.g., a contributing area composed of half parking lot and half roof would be subject to a maximum run-on ratio of 3.5:1).

For permeable pavement facilities receiving run-on, the minimum required permeable pavement facility area is calculated as 50 and 20 percent of the hard surface area routed to it for pollution-generating and non-pollution generating hard surfaces, respectively.

Pre-sized Approach for Flow Control and Water Quality Treatment

The Pre-sized Approach may be used for projects with new and replaced hard surface areas up to 10,000 square feet. Under the Pre-sized Approach (refer to *Section 4.1.2*), pre-sized permeable pavement facilities without underdrains may be used to achieve Pre-developed Pasture, Peak Control and Water Quality Treatment Standards. Sizing factors and equations for permeable pavement facilities receiving runoff from a hard surface are provided in Table 5.26. Factors are organized by performance standard, subgrade soil design infiltration rate, and contributing area. The design rate for the subgrade soil must be rounded down to the nearest infiltration rate in the pre-sized table (i.e., 0.15, 0.3, 0.6, 1.0, or 2.5 inches per hour).

To use these sizing factors or equations to meet performance standards, the facility must meet the general requirements for permeable pavement facilities outlined in this section plus the following specific requirements:

- To size the permeable pavement facility area, compare the calculated size determined by applicable sizing factor or equation in Table 5.26 to the size based on the applicable run-on ratio from Section 5.4.6.5 – Contributing Area Select the larger of the two sizes (see the example after the table).
- The selected subsurface ponding depth (i.e., 6 or 12 inches) must be provided in the storage reservoir. For intermediate ponding depths (between 6 and 12 inches), the sizing factor may be linearly interpolated. For subgrade slopes of 1.0 percent or greater, check dams are required to provide this subsurface ponding depth, on average, across the facility.
- To meet water quality treatment, the underlying soil must meet the soil requirements outlined in *Section 4.5.2* or a water quality treatment course must be used.
- No underdrain or low-permeability liner or impermeable liner may be used.

Table 5.26. Pre-sized Sizing Factors and Equations for Permeable Pavement Facilities without Underdrains.

Ponding Depth in Storage Reservoir	Subgrade Soil Design Infiltration Rate	Contributing (Run-on) Area (sf)	Sizing Factor/Equation for Permeable Pavement Facility Area[a]: Pre-developed Pasture Standard	Sizing Factor/Equation for Permeable Pavement Facility Area[a]: Peak Control Standard	Sizing Factor/Equation for Permeable Pavement Facility Area[a]: Water Quality Treatment Standard[b]
6 inches	0.15 inch/hour	≤2,000	132.6%	342.1%	26.9%
		2,001 – 10,000	[0.4842 x A] + 1651.1	342.1%	26.9%
	0.3 inch/hour	≤2,000	99.8%	247.4%	24.6%
		2,001 – 10,000	[0.375 x A] + 1223.9	247.4%	24.6%
	0.6 inch/hour	≤2,000	34.1%	58.0%	20.0%[c]
		2,001 – 10,000	[0.1568 x A] + 369.4	58.0%	20.0%[c]
	1.0 inch/hour	≤2,000	29.2%	50.6%	20.0%[c]
		2,001 – 10,000	[0.1349 x A] + 314.9	50.6%	20.0%[c]
	2.5 inch/hour	≤2,000	20.0%[c]	22.7%	20.0%[c]
		2,001 – 10,000	[0.053 x A] + 110.7	22.7%	20.0%[c]
12 inches	0.15 inch/hour	≤2,000	71.4%	113.9%	20.0%[c]
		2,001 – 10,000	[0.3236 x A] + 785.9	113.9%	20.0%[c]
	0.3 inch/hour	≤2,000	55.5%	88.1%	20.0%[c]
		2,001 – 10,000	[0.2573 x A] + 600.3	88.1%	20.0%[c]
	0.6 inch/hour	≤2,000	23.8%	36.6%	20.0%[c]
		2,001 – 10,000	[0.1247 x A] + 229.2	36.6%	20.0%[c]

Table 5.26 (continued). Pre-sized Sizing Factors and Equations for Permeable Pavement Facilities without Underdrains.

Ponding Depth in Storage Reservoir	Subgrade Soil Design Infiltration Rate	Contributing (Run-on) Area (sf)	Sizing Factor/Equation for Permeable Pavement Facility Area[a]: Pre-developed Pasture Standard	Sizing Factor/Equation for Permeable Pavement Facility Area[a]: Peak Control Standard	Sizing Factor/Equation for Permeable Pavement Facility Area[a]: Water Quality Treatment Standard[b]
12 inches	1.0 inch/hour	≤2,000	20.5%	33.1%	20.0%[c]
		2,001 – 10,000	[0.1076 x A] + 198.2	33.1%	20.0%[c]
	2.5 inch/hour	≤2,000	20.0%[c]	20.0%[c]	20.0%[c]
		2,001 – 10,000	[0.0435 x A] + 81.7	20.0%[c]	20.0%[c]

A –hard surface area contributing run-on; sf – square feet.

For Sizing Factors: Permeable Pavement Facility Area = Contributing Hard Surface Area x Factor (%)/100.
Hard Surface Area Managed = Permeable Pavement Area ÷ Factor (%)/100.

For Sizing Equations: Permeable Pavement Area (sf) = [Factor x A (sf)] + Integer.
Hard Surface Area Managed (sf) = [Permeable Pavement Area (sf) – Integer]÷ Factor.

[a] Maximum run-on ratios apply which may require larger permeable pavement facilities than those sized using the Pre-sized Approach.

[b] Pre-sized Approach may be used to meet basic water quality treatment. Metals water quality treatment may be achieved if soil suitability criteria are met (refer to *Section 4.5.2*).

[c] The minimum sizing factor is 20 percent because the contributing area to a facility is limited to 5 times the permeable pavement facility area.

The required permeable pavement facility area is calculated as a function of the hard surface area routed to it. As an example, to meet the Pre-developed Pasture Standard using a permeable pavement facility with an average water depth in the storage reservoir of 6 inches for a contributing area less than 2,000 square feet, the permeable pavement area would be equal to 34.1 percent of the hard surface area routed to it when the subgrade infiltration rate is between 0.6 and 0.99 inch per hour (Table 5.24). If the contributing area is a non-pollution generating surface (e.g., roof, sidewalk), a sizing factor of 34.1 percent is acceptable because it is greater than 20 percent (corresponding to a run-on ratio less than 5:1). However, if the contributing area is pollution generating (e.g., driveway, parking lot), a minimum sizing factor of 50 percent is required (corresponding to a run-on ratio less than 2:1). If the contributing area is a mix of surface types, the minimum sizing factor and maximum run-on ratio must be calculated as a weighted average:

> Minimum Sizing Factor = (% area non-pollution generating x 20% + % area pollution generating x 50%)/100%
>
> Maximum Run-on Ratio (X:1) = (% area non-pollution generating x 5 + % area pollution generating x 2)/100%

For example, a site with 70 percent roof and 30 percent driveway would have a minimum sizing factor of 29 percent [(70% x 20% + 30% x 50% / 100] and a maximum run-on ratio of 4:1 [(70% x 5 + 30% x 2) / 100%].

Alternatively, permeable pavement facilities can be sized using a continuous simulation hydrologic model as described below.

Modeling Approach for On-site Performance Standard, Flow Control, and Water Quality Treatment

When using continuous simulation hydrologic modeling to size permeable pavement, the assumptions listed in Table 5.27 must be applied. It is recommended that permeable pavement be modeled as an impervious area with runoff routed to a gravel-filled infiltration trench (with the same area as the contributing impervious area). Runoff from other areas draining to the permeable pavement surface can also be routed to the trench. The contributing area, pavement area, and average subsurface ponding depth in the aggregate storage reservoir should be iteratively sized until the Minimum Requirements for On-site Stormwater Management, Flow Control and/or Treatment are met (refer to *Volume 1, Project Minimum Requirements*) or where it has been determined by the Director that there is no off-site point of discharge for the project, the requirements of *Section 4.3.2* are met. General sizing procedures for infiltration facilities are presented in *Section 4.5.1*. Specific modeling guidelines are outlined below:

- Model only the average depth of the storage reservoir occupied by ponded water before check dam overtopping or overflow. The storage reservoir aggregate above this depth, and the overlying leveling and wearing course are not modeled.
- Because the infiltration rates of the wearing course and leveling course are typically high and will not restrict flow entering the facility section, the infiltration through these layers may be neglected (i.e., not modeled).
- The area of subgrade covered by check dams must be excluded from gravel trench bottom area.
- Only the volume in the reservoir course may be used as storage volume in the model. The BMP must not rely on void space in the wearing course to function.
- The area of the permeable pavement facility must not be less than the area determined by the maximum run-on ratios from Section 5.4.6.5 – Contributing Area.

Table 5.27. Continuous Modeling Assumptions for Permeable Pavement Facility.

Variable	Assumption
Precipitation Series	SEPTS-99 unless otherwise adopted by the Director
Computational Time Step	5 minutes
HSPF Parameters	LSUR, SLSUR, NSUR must be adjusted per *Appendix F*
Permeable Pavement Facility and Contributing Area	Set the length and width of the modeling element used for the permeable pavement facility so the area is not less than the area determined by the maximum run-on ratios from Section 5.4.6.5 – Contributing Area (i.e., 5:1 for non-pollution generating hard surface run-on areas and 2:1 for pollution-generating hard surface run-on areas). Option 1: WWHM and MGSFlood have a modeling element specifically developed for permeable pavement that simulates run-on from other contributing drainage areas, precipitation falling on the pavement, infiltration through the pavement section, storage in the aggregate beneath the pavement, and infiltration into the underlying soil. Option 2: If a permeable pavement modeling element is not available in the selected model, represent the permeable pavement area as an impervious basin with runoff routed to a gravel-filled trench (of the same size as the permeable pavement area) with infiltration to underlying soil. Other drainage areas contributing runoff to the pavement (surface flow and interflow), if any, are also routed to the gravel trench.
Precipitation Applied to Facility	If using Option 1, precipitation is applied to the pavement area. If using Option 2, do not apply precipitation to the trench bed because precipitation is already applied to basin before routing to trench.
Evaporation Applied to Facility	If using Option 1, evaporation is applied to the pavement area. If using Option 2, evaporation is applied to the impervious basin before routing to the trench.
Storage Reservoir Depth	Average subsurface water ponding depth in the pavement aggregate courses (average across the facility) before check dam overtopping or overflow.
Storage Reservoir Porosity	Assume maximum 25 percent unless test is provided showing higher porosity (up to 35 percent) for aggregate compacted and in place.
Subgrade Soil Design Infiltration Rate	Design infiltration rate (*Section 4.5.2*, *Appendix D*).
Infiltration Across Wetted Surface Area	No, if subgrade sidewalls are steeper than 2H:1V (infiltration on bottom area only).
Outlet Structure	Unless the selected model represents surface sheet flow when pavement section is saturated, the overflow can be simulated as overtopping an overflow riser. Overflow riser elevation is set at average maximum subsurface ponding depth. Flow may be modeled as weir flow over riser edge. Freeboard modeled within the storage reservoir must be sufficient to allow the water surface elevation to rise above the weir or overflow pipe elevation to provide head for discharge.

5.4.6.7. Minimum Construction Requirements

Proper construction methods and pre-planning are essential for the successful application of any permeable paving facility. Over compaction of the underlying soil or fine sediment contamination onto the existing subgrade and pavement section during construction will significantly degrade or effectively eliminate the infiltration capability of the facility.

Minimum requirements associated with construction of a permeable pavement facility include the following:

- Conduct field infiltration and compaction testing of the water quality treatment course (if included) prior to placement of overlying courses.
- Prevent intermixing of the various base course materials with fines and sediment. Remove and replace all contaminated material.
- Complete final subgrade excavation during dry weather on the same day bottom aggregate course is placed, when practicable.
- Use traffic control measures to protect permeable pavement subgrade areas from heavy equipment operation or truck/vehicular traffic.
- Select excavation, grading, and compaction equipment to minimize the potential for over-compaction.
- Follow a back-dumping approach to prevent compaction when installing the aggregate base. Back-dumping includes the following steps:
    1. The aggregate base is dumped onto the subgrade from the edge of the installation and the aggregate is then pushed out onto the subgrade.
    2. Trucks then dump subsequent loads from on top of the aggregate base as the installation progresses.
- Isolate the permeable pavement site from sedimentation during construction, either by use of effective erosion and sediment control measures upstream. Alternatively, delay the excavation of the lowest 1 foot of material above the final subgrade elevation for the entire pavement area until after all sediment-producing construction activities have been completed and upstream areas have been permanently stabilized. Once the site is stabilized, the lowest 1 foot of material may be removed. For more information on site stabilization, refer to *Volume 2, Construction Stormwater Control*.
- Conduct field infiltration test of the permeable surface after the complete pavement section is installed to verify that it meets the minimum initial uncorrected infiltration rate of 100 inches per hour (refer to testing methods in the *Wearing Course* subsection in *Section 5.4.6.5*).

5.4.6.8. Operations and Maintenance Requirements

Permeable pavement O&M requirements are provided in *Appendix G* (*BMP No. 26*). For permeable pavement facilities, see also BMP No. 2 – Infiltration Facilities.

5.4.7. Perforated Stub-Out Connections

5.4.7.1. Description

A perforated stubout connection is a length of perforated pipe within a gravel-filled trench that is placed between roof downspouts and a stubout connection to the public drainage system.

5.4.7.2. Performance Mechanisms

Perforated stub-out connections are intended to provide some flow control via infiltration during drier months. During the wet winter months, they may provide little or no flow control.

5.4.7.3. Applicability

As shown in the table below, perforated stub-out connections can only be applied to meet the on-site stormwater management requirement using the On-site List Approach.

BMP	On-site: List	On-site: Standard	Flow Control: Forest	Flow Control: Pasture	Flow Control: Peak	Water Quality: Basic	Water Quality: Enhanced Metals	Water Quality: Oil Control	Water Quality: Phosphorus	Conveyance
Perforated Stub-out Connections	x									

5.4.7.4. Site Considerations

The stub-out connection should be sited to allow a maximum amount of runoff to infiltrate into the ground (ideally a dry, relatively well drained, location). Site considerations for the applicability of perforated stub-out connections include:

- **Setbacks and restrictions**: The perforated portion of the system must meet the siting and infiltration rate requirements for infiltration facilities presented in *Section 3.2 and Section 4.5*.
- **Site prohibitions**: The perforated pipe portion of the system must not be located under hard or heavily compacted (e.g., driveways and parking areas) surfaces.
- Refer to *Appendix C* for additional infeasibility criteria for the On-site List Approach.

5.4.7.5. Design Criteria

This section provides a description and requirements for the components of perforated stub-out connections. A typical stub-out connection is shown in Figure 5.23. Design criteria are provided in this section for the following elements:

- Presettling
- Perforated pipe and trench
- Overflow

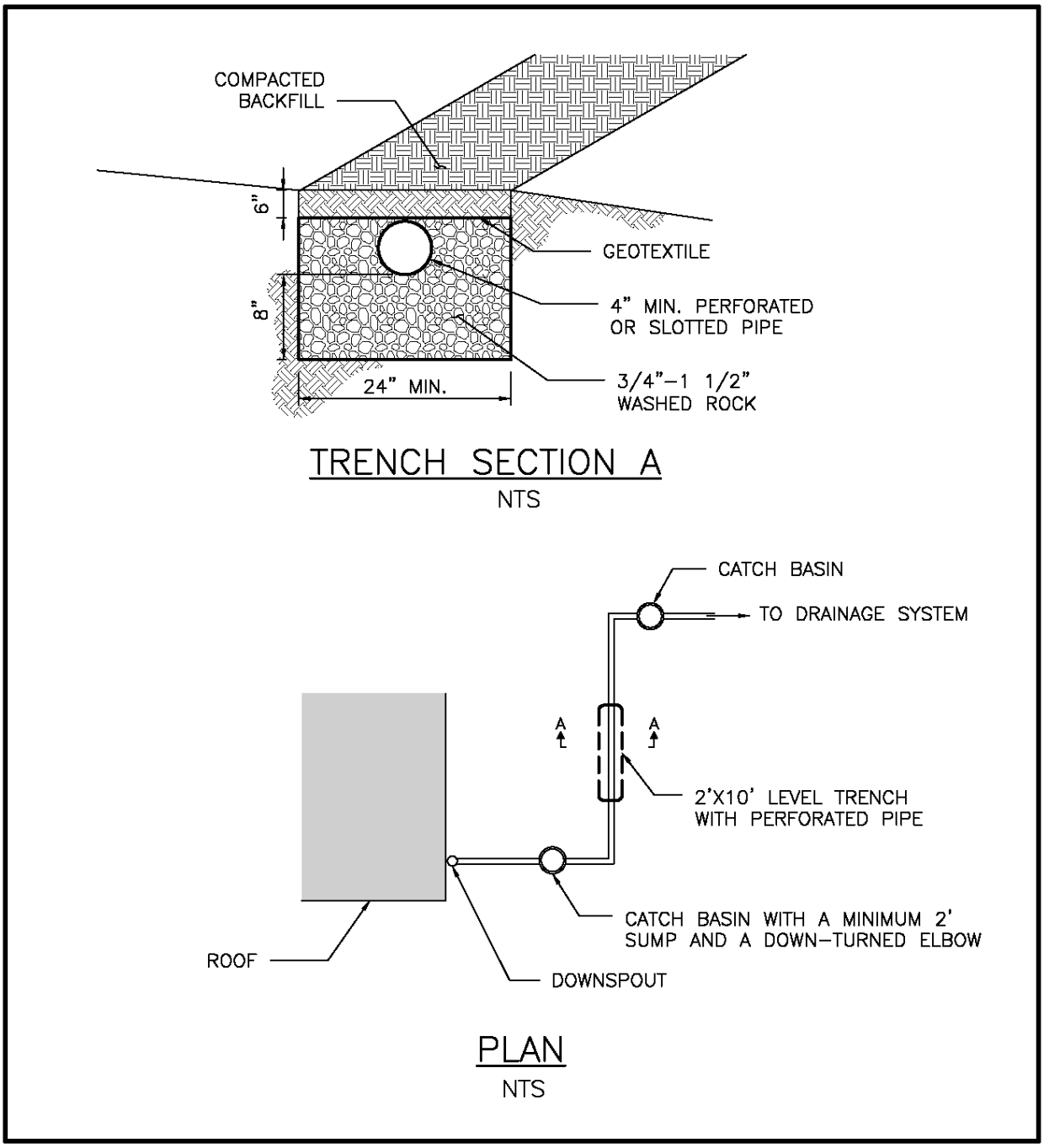


Figure 5.23. Perforated Stub-out Connection.

Presettling

- Stormwater inflows must be routed through a catch basin with a downturned elbow (trap). Presettling requirements are provided in *Section 4.4.5*.

Perforated Pipe and Trench

The minimum requirements associated with the pipe and trench include the following:

- Perforated stub-out connections must be at least 10 feet of perforated pipe per 5,000 square feet of roof area.
- The trench must be a minimum of 2 feet wide and 18 inches deep. The bottom of the trench must be level.
- The trench must be filled with uniformly graded, washed gravel with a nominal size from 0.75- to 1.5-inch diameter. The minimum void volume must be 30 percent. These requirements can be met with City of Seattle Mineral Aggregate Type 4.
- The pipe length that extends through the trench must be a perforated or slotted pipe with a minimum diameter of 4 inches. The pipe must be placed level with the pipe invert a minimum of 8 inches above the bottom of the trench.
- The trench must be wrapped with non-woven geotextile fabric, according to specifications in Appendix E, and covered with 6 inches of compacted backfill.

Subgrade

The minimum measured subgrade infiltration rate for perforated stub-out connections is 0.3 inch per hour.

During construction the subgrade soil surface can become smeared and sealed by excavation equipment. The design must require scarification or raking of the side walls and bottom of the facility excavation to a minimum depth of 4 inches after excavation to restore infiltration rate.

Overflow

Perforated stub-out connections must have an overflow designed to convey any flow exceeding the capacity of the facility unless designed to fully infiltrate all flows for the full, required simulation period. Plans must indicate surface flow paths in case of failure of the BMP (refer to *Section 4.3.3*).

If overflow is connected to the public drainage system, a catch basin must be installed prior to the connection to the public drainage system to prevent root intrusion into public drainage main lines.

5.4.7.6. BMP Credits

Credit for On-site List Approach

Perforated stub-outs may be selected to meet the On-site List Requirement (refer to *Section 3.3.1* and *Appendix C* for infeasibility criteria). The area of hard surface conveyed using a perforated stub-out meets the requirement.

Pre-sized Approach

Perforated stub-out connections are not included in the Pre-sized Approach because this BMP is not eligible for flow control credits.

Modeling Approach

Any flow reduction is variable and unpredictable. No computer modeling techniques are allowed that would predict any reduction in flow rates and volumes from the connected area.

5.4.7.7. Minimum Construction Requirements

During construction, it is critical to prevent clogging and over-compaction of the subgrade. The minimum construction requirements for infiltration trenches in *Section 5.4.2.7* apply.

5.4.7.8. Operations and Maintenance Requirements

General O&M requirements for infiltration facilities apply to perforated stub-out connections. Perforated stub-out connection O&M requirements are provided in *Appendix G* (*BMP No. 2*).

5.4.8. Infiltration Ponds

5.4.8.1. Description

Infiltration ponds are large earthen impoundments used for the collection, temporary storage, and infiltration of stormwater runoff.

5.4.8.2. Performance Mechanisms

Pollutant removal and flow control occur through infiltration of stormwater into the underlying soils. Secondary pollutant removal mechanisms include filtration, adsorption, and biological uptake.

5.4.8.3. Applicability

An infiltration pond can be designed to provide treatment and/or flow control. This BMP can be applied to meet the requirements listed below.

BMP	On-site: List	On-site: Standard	Flow Control: Forest	Flow Control: Pasture	Flow Control: Peak	Water Quality: Basic	Water Quality: Enhanced Metals	Water Quality: Oil Control	Water Quality: Phosphorus	Conveyance
Infiltration Pond		x	x	x	x	x[a]	x[a]		x[b]	

[a] Soil suitability criteria (*Section 4.5.2*) and applicable drawdown requirements (*Section 4.5.1*) also apply.

[b] Refer to treatment train options for infiltration BMPs included in *Section 4.4.3.2*.

5.4.8.4. Site Considerations

Refer to Infiltration Ponds in Volume V of the SWMMWW for site considerations related to infiltration ponds. Additional site considerations may apply depending on site conditions and other factors.

5.4.8.5. Design Criteria

Refer to Infiltration Ponds in Volume V of the SWMMWW for infiltration pond design criteria.

5.4.8.6. BMP Sizing

Refer to Infiltration Ponds in Volume V of the SWMMWW for infiltration pond sizing requirements.

5.4.8.7. Minimum Construction Requirements

Refer to Infiltration Ponds in Volume V of the SWMMWW for infiltration pond minimum construction requirements. The following minimum construction requirements also apply to infiltration ponds installed in Seattle:

- The development plan sheets must list the proper construction sequence so that the infiltration pond is protected during construction.
- The floor of an infiltration pond must be raked or deep tilled after final grading to restore infiltration rates.

5.4.8.8. Operations and Maintenance Requirements

Infiltration pond O&M requirements are provided in *Appendix G* (*BMP No. 2*).

5.4.9. Infiltration Chambers/Vaults

5.4.9.1. Description

Infiltration chambers/vaults are buried structures within which collected stormwater is temporarily stored and then infiltrated into the underlying soil. Infiltration chambers/vaults create an underground cavity that can provide a greater void volume than infiltration trenches and often require a smaller footprint.

Infiltration chambers are subject to state UIC regulations. Provided that the design and O&M criteria in this section are met, only the registration requirement applies.

Ecology SWMMWW Language	References
All UIC wells must be registered except: UIC wells at single-family homes (or duplexes) receiving only residential roof runoff used to collect stormwater runoff from roof surfaces on an individual home (or duplex) or for basement flooding control.	• *Volume 1 Section 1-4.3 of the SWMMWW*

5.4.9.2. Performance Mechanisms

Infiltration chambers/vaults can be used on their own or in combination with other BMPs to provide temporary storage of stormwater runoff and subsequent infiltration into the underlying soils. Pollutant removal mechanisms include infiltration, filtration, and soil adsorption.

5.4.9.3. Applicability

Infiltration chambers/vaults can be designed to provide on-site stormwater management, flow control and/or treatment. This BMP can be applied to meet the requirements listed below.

BMP	On-site: List	On-site: Standard	Flow Control: Forest	Flow Control: Pasture	Flow Control: Peak	Water Quality: Basic	Water Quality: Enhanced Metals	Water Quality: Oil Control	Water Quality: Phosphorus	Conveyance
Infiltration Chambers/ Vaults		x	x	x	x	x[a]	x[a]		x[b]	

[a] Soil suitability criteria for subgrade soils (*Section 4.5.2*) and applicable drawdown requirements (*Section 5.4.1*) also apply.

[b] Refer to treatment train options for infiltration BMPs included in *Section 4.4.3.2*.

5.4.9.4. Site Considerations

Site considerations for the applicability of infiltration chambers/vaults are provided in *Section 3.2* and *Section 4.5*.

5.4.9.5. Design Criteria

The following provides a description and requirements for the components of infiltration chambers/vaults. Some or all of the components may be used for a given application depending on the site characteristics and restrictions and design objectives. Refer to

Figure 5.24 for a schematic of a typical infiltration chamber/vault. Design criteria are provided in this section for the following elements:

- Flow entrance and presettling
- Chamber/vault materials and layout
- Chamber/vault bedding
- Subgrade
- Liner
- Overflow
- Observation/maintenance port

Flow Entrance and Presettling

Inflow pipe or a manifold system must be connected to each infiltration chamber/vault. Stormwater inflows must be routed through a catch basin with downturned elbow (trap). Presettling requirements are provided in *Section 4.4.5*.

Chamber/Vault Materials and Layout

Infiltration chambers/vaults can be constructed of a variety of different materials (i.e., plastic, concrete, aluminum, steel) and shapes (i.e., arch, box, cylindrical). Chamber/vault spacing and depth of cover must be per the manufacturer's requirements.

Chamber/Vault Bedding

Infiltration chamber/vault bedding is specified by the manufacturer. Minimum bedding must be from 6 inches below the infiltration chamber/vault to an elevation one-half the height of the chamber/vault on the outside of the chamber/vault. Chambers/vaults must be bedded with uniformly graded, washed gravel with a nominal size from 0.75 to 1.5inch diameter. The minimum void volume must be 30 percent. These requirements can be met with City of Seattle Mineral Aggregate Type 4.

Subgrade

The minimum measured subgrade infiltration rate for infiltration chambers/vaults is 0.6 inch per hour.

During construction the subgrade soil surface can become smeared and sealed by excavation equipment. The design must require scarification or raking of the side walls and bottom of the facility excavation to a minimum depth of 4 inches after excavation to restore infiltration rate.

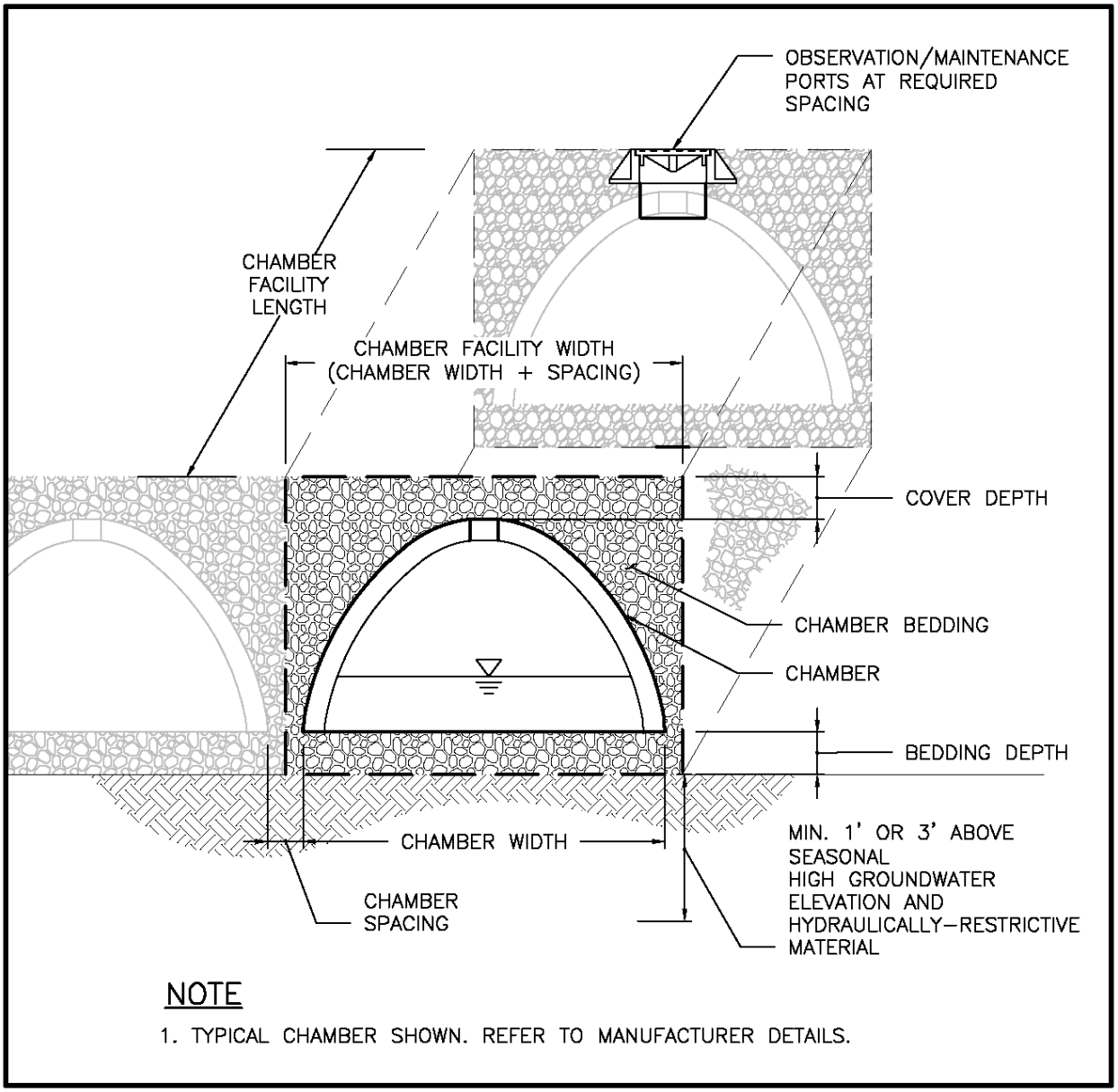


Figure 5.24. Typical Infiltration Chamber/Vault.

Liner

Non-woven geotextile fabric, a low permeability liner, or an impermeable liner must be placed at the sides of a stackable, modular infiltration chamber where the chamber abuts soil or other in situ material. Refer to the specifications presented in *Appendix E*.

Overflow

Infiltration chambers/vaults must have an overflow designed to convey any flow exceeding the capacity of the facility unless designed to fully infiltrate all flows for the full, required simulation period. Plans must indicate surface flow paths in case of failure of the BMP (refer to *Section 4.3.3*). If overflow is connected to the public drainage system, a catch basin must

be installed prior to the connection to the public drainage system to prevent root intrusion into public drainage main lines.

Observation/Maintenance Port

Infiltration chambers/vaults must be equipped with observation/maintenance ports to measure the drawdown time following a storm, to monitor sedimentation, to determine maintenance needs, and to provide access for sediment removal. Observation/maintenance ports at a 50-foot minimum spacing are required at:

- All inlets
- All outlets
- Any sediment forebay/trap

The observation/maintenance ports must consist of a 24inch minimum- diameter opening for maintenance access with unobstructed view down to the gravel bedding. The ports must have locking lids. The ports for stackable, modular infiltration chamber products must have an open, unobstructed view to the bottom of the chambers. If the port uses pipe that extends to the bottom of the chamber, it must be perforated or slotted pipe and must have openings at the bottom to allow for sediment removal. If 24-inch-diameter ports are not available from the manufacturer of the modular chamber product, a 12-inch-diameter port can be used for stackable, modular infiltration chambers. Refer to the Operations and Maintenance Requirements (*Section 5.4.9.*8) for personnel access requirements.

If personnel will be entering the facility, a 24-inch-diameter ring and cover and a 36-inch-diameter vertical pipe is required.

5.4.9.6. BMP Sizing

Pre-sized Approach for Flow Control and Water Quality Treatment

The Pre-sized Approach may be used for projects with new and replaced hard surface areas up to 10,000 square feet. Under the Pre-sized Approach (refer to *Section 4.1.2*), pre-sized arched infiltration chambers may be used to achieve Pre-developed Pasture, Peak Control and Water Quality Treatment Standards. Sizing factors were not developed for other infiltration vault shapes other than arched infiltration chambers. Sizing factors and equations for infiltration chambers receiving runoff from a hard surface are provided in Table 5.28 Factors are organized by flow control standard, subgrade soil design infiltration rate, and contributing area. The design rate for the subgrade soils must be rounded down to the nearest infiltration rate in the Table 5.28 (i.e., 0.15, 0.3, 0.6, 1.0, or 2.5 inch per hour).

To use these sizing factors or equations to meet flow control standards, the facility must meet the general requirements for infiltration chambers outlined in this section, plus the following specific requirements:

- The chamber area must be sized using the applicable sizing factor or equation.
- The aggregate storage reservoir must be composed of Mineral Aggregate Type 4 or approved equal.

- The effective chamber storage depth (as calculated in the Modeling Approach below) must be at least 2 feet.
- To use a pre-sized infiltration chamber to meet water quality treatment, the underlying soil must meet soil requirements specified in *Section 4.5.2*.
- Invert of overflow must be set at top of the storage reservoir to provide the required storage reservoir depth used in the manufacturer's calculation of chamber storage volume.

Infiltration chambers that do not meet the above requirements must use the Modeling Approach.

Table 5.28. Pre-sized Sizing Factors and Equations for Infiltration Chambers.

Subgrade Soil Design Infiltration Rate	Contributing Area (sf)	Sizing Factor/Equation for Infiltration Chamber Area: Pre-developed Pasture Standard	Sizing Factor/Equation for Infiltration Chamber Area: Peak Control Standard	Sizing Factor/Equation for Infiltration Chamber Area: Water Quality Treatment Standard[a]
0.15 inch/hour	≤2,000	13.1%	12.6%	3.0%
	2,001 – 10,000	[0.0879 x A] + 91.4	12.6%	3.0%
0.3 inch/hour	≤2,000	11.1%	6.2%	7.2%
	2,001 – 10,000	[0.0733 x A] + 79.9	6.2%	7.2%
0.6 inch/hour	≤2,000	7.2%	11.1%	2.6%
	2,001 – 10,000	[0.0441 x A] + 56.8	11.1%	2.6%
1.0 inch/hour	≤2,000	6.4%	5.1%	4.3%
	2,001 – 10,000	[0.0392 x A] + 50.7	5.1%	4.3%
2.5 inch/hour	≤2,000	3.4%	8.0%	1.4%
	2,001 – 10,000	[0.021 x A] + 28	8.0%	1.4%

A – contributing hard surface area; sf – square feet.

For Sizing Factors: Infiltration Chamber Area (sf) = Contributing Hard Surface Area (sf) x Factor (%)/100.
Hard Surface Area Managed (sf) = Chamber Area (sf) ÷ Factor (%)/100.

For Sizing Equations: Infiltration Chamber Area (sf) = [Factor x A (sf)] + Integer.
Hard Surface Area Managed (sf) = [Chamber Area (sf) – Integer]÷ Factor.

[a] Pre-sized Approach may be used to meet basic water quality treatment. Metals water quality treatment may be achieved if soil suitability criteria are met (refer to *Section 4.5.2*).

The infiltration chamber area is calculated as a function of the area contributing runoff to the chamber. As an example, to meet the Pre-developed Pasture Standard for a contributing area between 2,000 and 10, 000 square feet where the subgrade infiltration rate is between 0.3 and 0.59 inch per hour, the chamber area would be calculated as: 0.0733 x contributing hard surface area + 79.9. All area values must be in square feet.

Alternatively, infiltration chambers and other shapes of infiltration vaults can be sized using a continuous hydrologic simulation model as described in the subsequent section.

Modeling Approach for On-site Performance Standard, Flow Control, and Water Quality Treatment

When using continuous hydrologic modeling to size infiltration chambers/vaults, the assumptions listed in Table 5.29 must be applied. It is recommended that infiltration chambers/vaults be modeled as a pond with vertical side walls and a depth (controlled in the model by the height of the outlet structure) set equal to the effective depth of the chamber/vault. For a given chamber/vault type and size, the effective depth (i.e., the equivalent chamber/vault storage depth assuming 100 percent voids) can be estimated based on the chamber/vault storage volume (chamber/vault plus aggregate storage — typically obtained from the chamber/vault manufacturer) and chamber/vault footprint area (including aggregate spacing between chambers/vaults). Storage volume provided by the manufacturer should assume 30 percent aggregate porosity unless test showing higher porosity is provided. For example, for a 4-foot-wide by 7-foot-long chamber/vault with 6-inch chamber/vault spacing and a manufacturer provided storage volume of 70 cubic feet (assuming 30 percent aggregate porosity), the effective depth would be calculated as follows:

> Effective Storage Depth = Storage Volume (70 cubic feet — per manufacturer) ÷ Chamber/Vault Area where,
>
> Chamber/Vault Area = Chamber/Vault Width including Spacing (4 feet + 3 inches + 3 inches) x Chamber/Vault Length (7 feet).

Once the effective depth for a given chamber/vault system is established, the chamber/vault area or length should be iteratively sized until the Minimum Requirements for Flow Control and/or Water Quality Treatment are met (refer to *Volume 1*) or where it has been determined by the Director that there is no offsite point of discharge for the project, the requirements of *Section 4.3.2* are met. General sizing procedures for infiltration BMPs are presented in *Section 4.5.1*.

Table 5.29. Continuous Modeling Assumptions for Infiltration Chambers/Vaults.

Variable	Assumption
Precipitation Series	SEPTS-99 unless otherwise adopted by the Director
Computational Time Step	5 minutes
HSPF Parameters	LSUR, SLSUR, NSUR must be adjusted per *Appendix F*
Inflows to Facility	Surface flow and interflow from total drainage area (including impervious and pervious contributing areas) routed to facility
Precipitation and Evaporation Applied to Facility	No
Total Depth	Effective storage depth plus freeboard
Subgrade Soil Design Infiltration Rate	Design infiltration rate (*Section 4.5.2*, *Appendix D*)
Infiltration Across Wetted Surface Area	No (bottom area only)
Outlet Structure	Specify riser diameter and riser height (set equal to the effective storage depth)

5.4.9.7. Minimum Construction Requirements

During construction, it is critical to prevent clogging and over-compaction of the subgrade. Refer to the minimum construction requirements for infiltration trenches in *Section 5.4.2.7*.

5.4.9.8. Operations and Maintenance Requirements

General O&M requirements for infiltration facilities provided in *Appendix G* (*BMP No. 2*) apply to infiltration chambers/vaults. Manufacturers of specific infiltration chambers/vaults may have additional O&M recommendations.

Document a plan for cleaning and maintenance access for any equipment and personnel required for chambers and for vaults that are not as shown in Figure 5.24. If personnel will be entering the facility, a 24-inch-diameter ring and cover and 36-inch-diameter vertical pipe is required.

5.4.10. Infiltrating Soil Cell Bioretention

5.4.10.1. Description

Infiltrating soil cell bioretention is a modular proprietary pavement suspension system originally designed to support growth of urban trees by increasing soil volume and reducing soil compaction adjacent to trees. This BMP is commonly used in two applications:

1. Constrained sites, where there is limited space to site bioretention
2. Sites with additional hardscape needs, such as sidewalks or trails

The standard design of this BMP is modified to act similarly to an infiltrating bioretention facility using a minimum 12-inch depth of designed soil mix (bioretention cell) within soil cell modules to facilitate stormwater runoff management. Stormwater runoff is conveyed to soil cell modules that support overlying hardscape. The runoff is detained within the soil cell modules, ponding above the bioretention cell (and below the overlying hardscape), until it filters through the designed soil mix layer. Runoff that exceeds the ponding storage and filtration capacities overflows to an adjacent drainage system. Infiltrating soil cell bioretention can be stacked soil cell modules and/or multiple soil cell modules connected to one another. Infiltrating soil cell bioretention may require one or more trees to be planted within the facility footprint outside of the soil cell modules unless determined to be infeasible (refer to *Section 3.3.1* and *Appendix C* for infeasibility criteria).

Two variations of infiltrating soil cell bioretention facilities are included in this section:

- **Infiltrating Soil Cell Bioretention without Underdrain:** Stormwater is filtered through the BSM then is infiltrated into the underlying subgrade soils. Excess flows would exit through the overflow device.
- **Infiltrating Soil Cell Bioretention with Underdrain:** Stormwater filters through the BSM, then enter a filter gravel section where it is infiltrated into the underlying subgrade soils. Excess flows that are not infiltrated are collected by an underdrain and discharged to the downstream drainage system.

All variations of the infiltrating soil cell bioretention may be connected in series, with the overflows of upstream bioretention cells directed to downstream bioretention cells to provide additional flow control and/or treatment capacity and conveyance. Individual infiltrating soil cell bioretention facilities are defined as separate ponding areas delineated by a distinct overflow to a downstream BMP or point of discharge.

5.4.10.2. Performance Mechanisms

The infiltrating soil cell bioretention without underdrain provides flow control via detention, attenuation, and losses due to infiltration, interception, evaporation, and transpiration. Water quality treatment is accomplished through sedimentation, filtration, adsorption, uptake, or biodegradation and transformation of pollutants by soil organisms, soil media, and the tree (if required or used).

5.4.10.3. Applicability

Infiltrating soil cell bioretention can be designed to provide on-site stormwater management, flow control and/or water quality treatment. This BMP can be applied to meet or partially meet the requirements listed below.

BMP	On-site: List	On-site: Standard	Flow Control: Forest	Flow Control: Pasture	Flow Control: Peak	Water Quality: Basic	Water Quality: Enhanced Metals	Water Quality: Oil Control	Water Quality: Phosphorus	Conveyance
Infiltrating soil cell bioretention BMP without underdrain	x	x	x	x	x	x	x		x[b]	
Infiltrating soil cell bioretention BMP with underdrain	x	x[a]	x[a]	x[a]	x[a]	x	x		x[b]	

[a] Standard may be partially or completely achieved depending upon ponding depth, degree of underdrain elevation, infiltration rate, and contributing area.

[b] Refer to Soil Suitability Criteria in *Section 4.5.2*.

Infiltrating bioretention may be constructed in conjunction with other stormwater BMPs to achieve other performance standards.

5.4.10.4. Site Considerations

All variations of the infiltrating soil cell bioretention have minimum requirements similar to those associated with infiltrating bioretention and tree planting and retention. In addition, infiltrating soil cell bioretention in the ROW must meet the minimum clearances and planting strip widths for the tree(s), which can be found in Seattle Streets Illustrated, the Right-of-Way Improvements Manual (refer to SDOT/SDCI Director's Rules 04 2017/31 2017).

5.4.10.5. Design Criteria

This section provides a description, recommendations, and requirements for the components of infiltrating soil cell bioretention. Typical components of infiltrating soil cell bioretention without an underdrain are shown in Figures 5.25 and 5.26. Typical components of infiltrating soil cell bioretention with an underdrain are shown in Figures 5.27 and 5.28. Refer to *Appendix C* for additional infeasibility criteria for the On-site List Approach. Further guidance can be found in SPU's Green Stormwater Infrastructure Manual for Capital Improvement Projects.

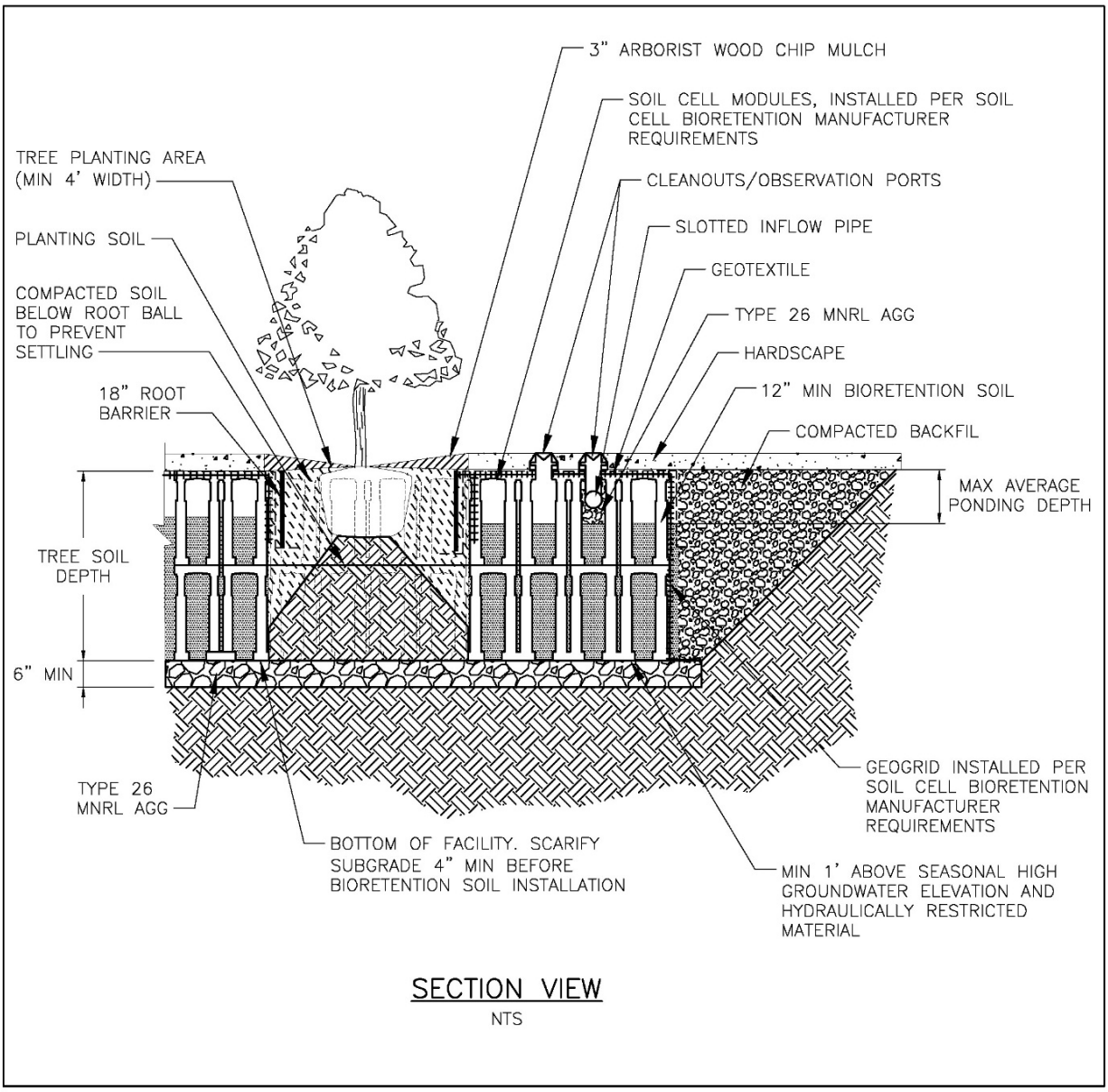


Figure 5.25. Infiltrating Soil Cell Bioretention (without Underdrain) Profile.

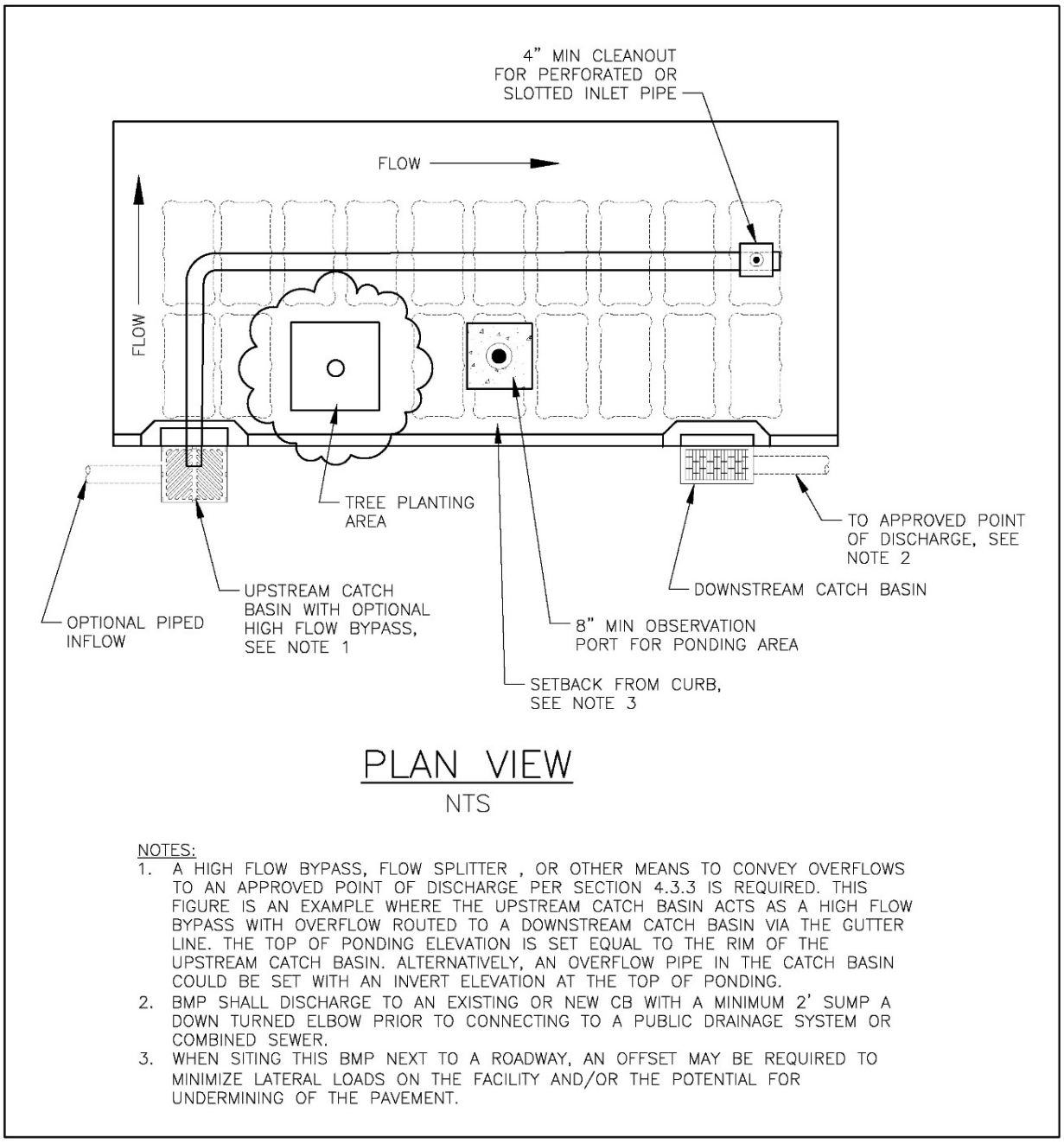


Figure 5.26. Infiltrating Soil Cell Bioretention (without Underdrain) Plan.

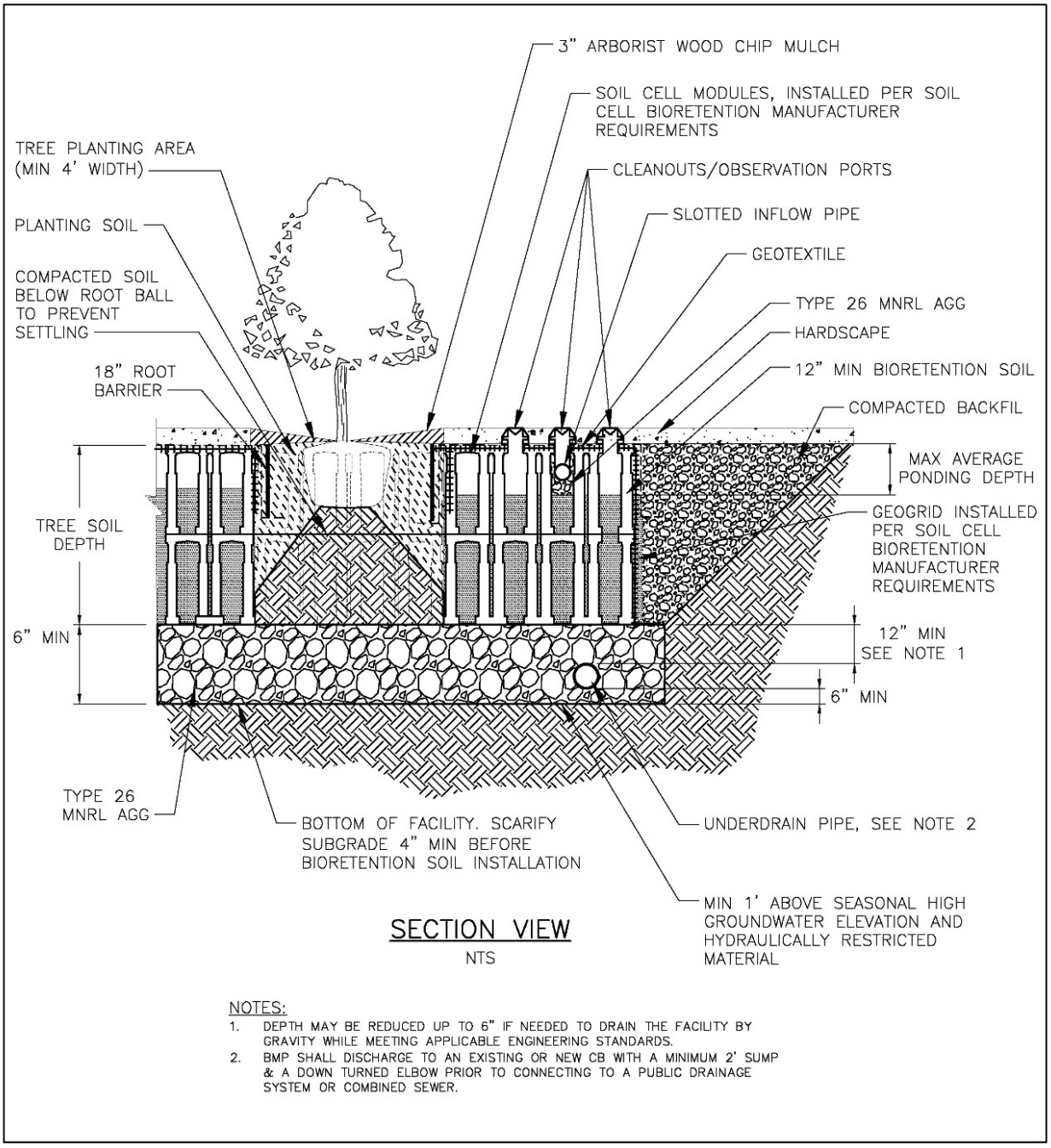


Figure 5.27. Infiltrating Soil Cell Bioretention (with Underdrain) Profile.

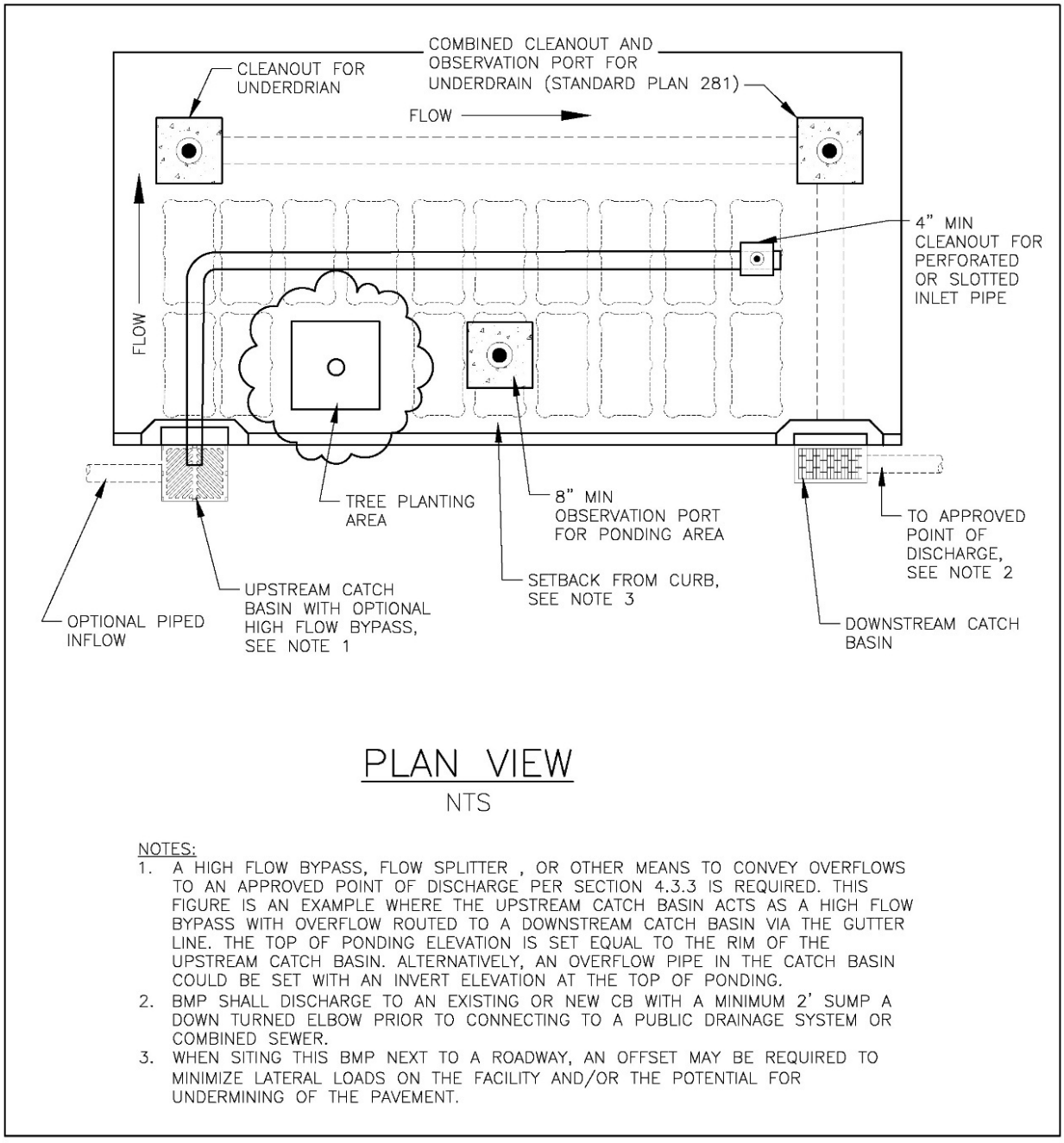


Figure 5.28. Infiltrating Soil Cell Bioretention (with Underdrain) Plan.

The design criteria for the infiltrating soil cell bioretention is the same as for infiltrating bioretention in *Section 5.4.4* for the following elements:

1. Contributing area
2. Flow entrance
3. Bioretention soil
4. Flow restrictor (optional)

The following elements are different from infiltrating bioretention and are discussed in detail below:

1. Presettling
2. Ponding area
3. Subgrade
4. Underdrain (if required)
5. Cleanouts and observation/maintenance ports
6. Overflow
7. Geotextile
8. Liners
9. Plants
10. Tree (if required)
11. Mulch layer
12. Hardscapes
13. Manufacturer design requirements

Presettling

Presettling for infiltrating soil cell bioretention is required. Stormwater inflows must be routed through a catch basin or another device that provides presettling equal or better to a catch basin when compared to City of Seattle Standard Plan No. 240 or 241. If using a catch basin for presettling, a 2-foot-deep minimum sump and a downturned elbow (trap) before entering the BMP is required. The volume of the sump must be equal to the volume of a catch basin required by the current Director's Rules for side sewers.

Ponding Area

The ponding area provides surface storage for storm flows and the first stages of pollutant treatment within infiltrating soil cell bioretention. The minimum requirements for ponding area design for BMPs with and without underdrains include:

1. The bottom area of soil cell bioretention must be no larger than 800 square feet (limitation is to ensure that these facilities are small-scale and distributed). The bottom of a soil cell bioretention may be larger than 800 square feet if the BMP serves a regional area and with the permission of the Director. If approved, the Director may require a more robust presettling approach for the larger facility
2. The average ponding depth must be no less than 2 inches.
3. The ponding depth must be no more than 12 inches unless it meets the maximum drawdown time criteria and is approved by the Director. In right-of-way areas with high pedestrian traffic, the ponding depth may be restricted to 6 inches or less.
4. The surface pool drawdown time must be a maximum of 24 hours (drain time is calculated as the maximum ponding depth divided by the subgrade soil design

infiltration rate). Note that BMPs sized using the Pre-sized Approach meet this requirement.

5. The longitudinal slope must be no more than 5 percent.
6. The bottom slope must be no more than 3 percent.
7. The minimum ponding area width on either side of the tree planting area is 18-inches and the total facility width will vary depending on the required width required for the tree planting area and configuration of ponding areas (e.g. small to medium tree vs. large tree, tree centered in the facility vs. tree set to one side of the facility). In no case must the total facility width be less than 5 feet.

To address traffic and pedestrian safety concerns, the following additional minimum requirements also apply to infiltrating soil cell bioretention BMPs in the right-of-way:

- Infiltrating soil cell bioretention must not impact driveway/alley access. A 2-foot minimum setback must be provided from the pavement edge of the driveway curb cut wing to the edge of the BMP.
- A 2-foot minimum setback must be provided from the edge of paving for the public sidewalk/curb ramp at the intersection to the top of slope of the infiltrating bioretention. Curb ramp improvements are required whenever the construction of infiltrating soil cell bioretention and associated street improvements remove pavement within the crosswalk area of the street or sidewalk, impact curbs, sidewalks, curb ramps, curb returns or landings within the intersection area, or affect access to or use of a public facility.

Subgrade

The minimum measured subgrade infiltration rate for infiltrating soil cell bioretention facilities without underdrains is 0.6 inch per hour. For infiltrating soil cell bioretention facilities with underdrains, the minimum measured subgrade infiltration rate is 0.3 inch per hour where used to meet the On-site List Approach (there is no minimum rate where used to meet other standards).

During construction the subgrade soil surface can become smeared and sealed by excavation equipment. The design of infiltrating soil cell bioretention without underdrain must require the following:

- 6 inches of City of Seattle Mineral Aggregate Type 26 (gravel backfill for drains, City of Seattle Standard Specifications).
- Scarification or raking of the bottom of the facility excavation to a minimum depth of 4 inches after excavation to restore infiltration rate

The design of infiltrating soil cell bioretention with underdrain must also require scarification or raking of the bottom of the facility excavation to a minimum depth of 4 inches after excavation to restore infiltration rate. More information about underdrain requirements can be found in the following section. Refer to the Manufacturer Design Requirements below for additional subgrade preparation requirements.

Underdrain (if required)

Underdrain systems (refer to Figures 5.27 and 5.28) must be installed if the subgrade soils have a measured infiltration rate of less than 0.6 inch per hour. Designs utilizing underdrains provide less infiltration and flow control benefits. To improve performance, the underdrain may be further elevated (beyond the 6 inches shown in Figure 5.27); the subsurface gravel reservoir under the pipe is required to extend across the entire facility bottom; and/or a flow restrictor may be used.

The underdrain pipe diameter will depend on hydraulic capacity required. The underdrain can be connected to a downstream BMP, such as another soil cell bioretention as part of a connected system, or to an approved point of discharge.

The minimum requirements associated with the underdrain design include:

- Slotted pipe per City of Seattle Standard Plan No. 291.
- Underdrain pipe must have a minimum diameter of 6 inches in the ROW and 4 inches outside of the ROW.
- Underdrain pipe slope must be no less than 0.5 percent.
- Pipe must be placed in filter material and have a minimum cover depth of 12 inches and bedding depth of 6 inches. Refer to Figure 5.27 for required pipe bedding dimensions. Cover depth may be reduced up to 6 inches in order to discharge stormwater from the facility under gravity flow conditions while meeting the applicable engineering standards.
- Filter material must meet the specifications of City of Seattle Mineral Aggregate Type 26 (gravel backfill for drains, City of Seattle Standard Specifications).
- Underdrains must be equipped with cleanouts and observation ports as follows:
    - For right-of-way projects, underdrains must have a cleanout per City of Seattle Standard Plans at the upstream end and a combined cleanout and observation ports per City of Seattle Standard Plan No. 281 a minimum of every 100 feet along the pipe. No cleanouts are required within a run from underdrain maintenance hole to underdrain maintenance hole except at bends.
    - For non-right-of-way projects, underdrains must have a cleanout at the upstream end (Figure 5.28) and a combined cleanout and observation ports (City of Seattle Standard Plan No. 281) a minimum of every 100 feet along the pipe. Cleanouts and observation ports must be non-perforated pipe (sized to match underdrain diameter) and must meet the requirements in the Side Sewer Directors' Rule.
- The subsurface gravel reservoir beneath the underdrain pipe must extend across the entire facility bottom for infiltrating bioretention.

Cleanouts and Observation/Maintenance Ports

A cleanout is required at the end of the perforated or slotted inlet pipe. The cleanout must consist of a 4-inch minimum, non-perforated PVC pipe that extends to the end of the perforated or slotted inlet pipe and is equipped with a secure cleanout cover. For infiltrating soil cell bioretention with underdrains, the underdrain must be equipped with cleanouts and

observation ports as described the section above. In addition to the cleanouts, an 8-inch or larger observation port is required to observe the ponding area.

Overflow

Infiltrating soil cell bioretention must have an overflow. The infiltrating soil cell bioretention overflow can be provided by an offline design (where flows above the water quality design flows or volume are bypassed around the facility). The overflow must be connected to a downstream BMP or an approved point of discharge.

The minimum requirements associated with the overflow design include the following:

- Flow exceeding the capacity of the infiltrating soil cell bioretention must overflow the BMP and directed into the downstream system. Alternatively, the BMP could be designed to fully infiltrate all flows for the full, required simulation period. In this case, no overflow would be required. Plans must indicate surface flow paths in case of failure of the BMP (refer to *Section 4.3.3*).
- If the infiltrating soil cell bioretention will receive flows from areas beyond the area for which the facility is sized, the overflow must be design with sufficient conveyance capacity to safely convey runoff from the entire area draining to the facility.

Geotextile

For infiltrating soil cell bioretention with and without underdrain, a geotextile is not required. However, a geogrid is required to keep the design soil mix contained with the soil cell modules. Minimum requirements associated with the geogrid design include:

- Use a geogrid recommended by the manufacturer's specifications and by a geotechnical engineer for the given subgrade soil type or aggregate.
- Use a geogrid that passes water at a greater rate than the design infiltration rate for the existing subgrade soils.

Liners

Liners are not required for infiltrating soil cell bioretention with or without underdrain.

Plants

Unlike infiltrating bioretention facilities, infiltrating soil cell bioretention do not contain plants other than the tree(s) noted below. Therefore, there are no design criteria for plants.

Tree (If Required)

For infiltrating soil cell bioretention, a tree may be required to meet on-site stormwater management, flow control, or water quality treatment requirements (refer to *Section 3.3.1* and *Appendix C* for infeasibility criteria). In cases where a tree is determined to be infeasible, infiltrating soil cell bioretention without tree may be used.

If a tree is required, the tree must meet the following requirements:

- Species:
  - Select tree species from the bioretention BMP plant list in Appendix J that are suitable for bioretention Zone 1.

- Location:
  - Locate trees according to sun, soil, and moisture requirements.
  - Select planting locations to ensure that sight distances and appropriate setbacks are maintained given mature height, size, and rooting depths.
- Setbacks:
  - Setbacks from trees to structures, underground utility lines and paved surfaces must be per *Section 5.2.5.2*, Tree Setbacks.
- Size:
  - The size of the tree at the time of planting (i.e. trunk caliper diameter, height, etc.) must be per *Section 5.2.5.2*, Tree Size.
- Spacing:
  - Spacing requirements must be per *Section 5.2.5.2*, Tree Spacing.
- Tree Planting Area:
  - Provide a minimum tree planting width of four feet.
  - Soil depths and volumes must meet the requirements in *Section 5.2.5.2*, Table 5.1.
  - To calculate the volume needed for the tree beneath the tree planting area in infiltrating soil cell bioretention, refer to the Sizing for the On-site List Approach in *Section 5.4.10.6*.

Mulch Layer

Ponding Area

Mulch is not required for the ponding area. If mulch is used, it must be compost mulch as indicated in the mulch layer design criteria in *Section 5.4.4*.

Tree Planting Area

Properly selected organic mulch material, including arborist wood chip mulch, reduces weed establishment, regulates soil temperatures and moisture, and adds organic matter to the soil. Arborist wood chip mulch (per City of Seattle Standard Specification 9 14.4(4)) is required for infiltrating soil cell bioretention. Benefits of arborist wood chip mulch are described in *Section 5.4.4*.

The arborist wood chip mulch must be located within the tree planting area, be 3 inches deep, and meet the criteria below:

- Arborist wood chip mulch must be coarse ground wood chips (approximately 0.5 inch to 6 inches along the longest dimension) derived from the mechanical grinding or shredding of the aboveground portions of trees. It may contain wood, wood fiber, bark, branches, and leaves; but may not contain visible amounts of soil. It must be free of weeds and weed seeds Including but not limited to plants on the King County Noxious Weed list available at: www.kingcounty.gov/weeds, and must be free of invasive plant portions capable of resprouting, including but not limited to horsetail, ivy, clematis, knotweed, etc. It may not contain more than 0.5 percent by weight of manufactured inert material (plastic, concrete, ceramics, metal, etc.).

- Arborist wood chip mulch, when tested, must meet the following loose volume gradation:

Sieve Size	Percent Passing: Minimum	Percent Passing: Maximum
2″	95%	100%
1″	70%	100%
5/8″	0%	50%
1/4″	0%	40%

No particles may be longer than 8 inches.

Hardscapes

Hardscape is required to be located above infiltrating soil cell bioretention. This requirement only applies to the soil cell modules and not the tree planting area. Hardscapes may include asphalt flexible, rigid concrete, or permeable pavement surfaces (refer to *Section 5.6.2*). If permeable pavement surfaces are selected, all associated design criteria specific to the BMP must be met. Note: permeable pavement over soil cell bioretention is included as hard surface for determining thresholds for requirements in this manual but can be excluded from stormwater calculations if the pre-sized equations are used or if the stormwater model used applies precipitation to the soil cell bioretention facility. Also, when using the On-site Stormwater Management Calculator, do not include the permeable pavement surface over the soil cells as contributary area for sizing the soil cell bioretention.

For hardscapes in the ROW, SDOT may have additional setback requirements if located adjacent to vehicular traffic.

Manufacturer Design Requirements

Infiltrating soil cell bioretention must meet all manufacturer design requirements including the following:

1. Subgrade preparation
2. Underdrain location for optimal performance (if required)
3. Lateral and dynamic (live) loading requirements
4. Geotextile and geogrid type, use, and installation
5. Impermeable liners installation
6. Compatible hardscape types
7. Backfill requirements adjacent to soil cells

Design review with the manufacturer is required to confirm these design criteria have been met.

5.4.10.6. BMP Sizing

Sizing for On-site List Approach

Infiltrating soil cell bioretention may be selected to meet the On-site List Requirement (refer to *Section 3.3.1* and *Appendix C* for infeasibility criteria). To meet the requirement,

infiltrating soil cell bioretention must be sized according to the sizing factors provided in Table 5.30.

Factors are organized by cell ponding depth and subgrade design infiltration rate. To select the appropriate sizing factor:

- The subgrade design infiltration rate must be rounded down to the nearest rate in the sizing table.
- The design ponding depth must be rounded down to the nearest depth in the sizing table, or sizing factors may be linearly interpolated for intermediate ponding depths (e.g., between 2 and 6 inches ponding).

The BMP must meet the general requirements for infiltrating soil cell bioretention outlined in this section plus the following specific requirements:

1. The bottom area must be sized using the applicable sizing factor.
2. It is preferred that the bottom area is flat, but up to 3 percent slope is permitted.
3. The bioretention soil depth must be a minimum of 18 inches.
4. The average ponding depth for the bioretention cell must be no less than the selected ponding depth.
5. If the soil cell bioretention includes a tree, additional tree planting area is required. Refer to *Sections 5.2.5.2*, 5.*4.4.5*, and *5.4.10.5* for more information about tree planting area, depth, and volume sizing. Equations to calculate the facility size is included after Table 5.30 below.

Table 5.30. On-site List Sizing for Infiltrating Soil Cell Bioretention with and without Underdrains.

Average Ponding Depth	Subgrade Soil Design Infiltration Rate	Sizing Factor for Soil Cell Bioretention Bottom Area: Without Underdrain[a,b]	Sizing Factor for Soil Cell Bioretention Bottom Area: With Underdrain[c]
2 inches	0.15 inch/hour	NA[d,g]	10.2%[e]
	0.3 inch/hour	6.8%[f]	7.6%[e]
	0.6 inch/hour	5.5%[h]	6.1%[h]
	1.0 inch/hour	5.5%[h]	6.1%[h]
	2.5 inch/hour	5.5%[h]	6.1%[h]
6 inches	0.15 inch/hour	NA[d,g]	7.9%[e]
	0.3 inch/hour	5.5%	6.1%
	0.6 inch/hour	5.5%	6.1%
	1.0 inch/hour	5.5%	6.1%
	2.5 inch/hour	5.5%	6.1%

Table 5.30 (continued). On-site List Sizing for Infiltrating Soil Cell Bioretention with and without Underdrains.

Average Ponding Depth	Subgrade Soil Design Infiltration Rate	Sizing Factor for Soil Cell Bioretention Bottom Area: Without Underdrain[a,b]	Sizing Factor for Soil Cell Bioretention Bottom Area: With Underdrain[c]
12 inches	0.15 inch/hour	NA[d,g]	6.3%[e]
	0.3 inch/hour	NA[g]	6.1%
	0.6 inch/hour	5.5%	6.1%
	1.0 inch/hour	5.5%	6.1%
	2.5 inch/hour	5.5%	6.1%

NA – not applicable.

[a] Soil cell bioretention cell bottom area is 10% larger than bioretention cell bottom area to account for the soil cells modules, but it does not include the tree planting area. If the soil cell bioretention includes a tree, additional tree planting area is required. Refer to *Sections 5.2.4.2 and 5.4.10.5* for more information about sizing tree planting area, depth, and volume sizing. Equations needed to calculate the soil cell bioretention with tree volume are included below this table.

[b] Sizing factors are based on achieving a minimum wetted surface area of 5 percent, as per Ecology requirements, unless otherwise noted.

[c] Sizing factors are based on a minimum wetted surface area of 5 percent multiplied by a factor of 1.11, as per Ecology requirements, unless otherwise noted.

[d] Underdrain systems must be installed if the subgrade soils have a measured infiltration rate of less than 0.6 inch per hour (note that the infiltration rates listed in the table are design rates).

[e] Sizing factor increased to the sized required to meet the On-site Performance Standard for a pre-developed condition of forest on till and multiplied by a factor of 1.11.

[f] Sizing factor increased beyond the minimum wetted surface area of 5 percent to meet the On-site Performance Standard for a pre-developed condition of forest on till.

[g] Ponding depth and infiltration rate combination do not achieve drawdown requirements.

Bioretention Cell Bottom Area = Contributing Hard Surface Area x Factor (%)/100.

Hard Surface Area Managed = Bioretention Cell Bottom Area ÷ Factor (%)/100.

The infiltrating soil cell bioretention area is calculated as a function of the hard surface area routed to it. Depending on the configuration, the infiltrating soil cell bioretention area may consist of bioretention cell area and the tree planting area. To meet the On-site List Sizing for an infiltrating soil cell bioretention without a tree, only the bioretention cell area is required. To meet the On-site List Sizing for an infiltrating soil cell bioretention with tree, the bioretention cell and tree planting areas are required. The bioretention cell and tree planting areas are used to calculate the volume of the soil cell bioretention with tree.

The following equations can be used to calculate the volume for soil cell bioretention with tree:

Soil cell bioretention with tree volume = bioretention cell volume + tree soil volume

Where:

Bioretention cell volume = bioretention cell bottom area (refer to Table 5.30) x bioretention soil depth (minimum of 12 inches)

Tree soil volume = tree planting area x depth of soil for tree planting area extending to undisturbed native soil (no underdrain) or Type 26 aggregate (with underdrain)

If the calculated soil cell bioretention with tree volume using the equations above is less than the minimum soil volume required for the tree (refer to *Section 5.4.10.5*), the following options are available to meet the minimum soil volume requirements:

- Stacking additional soil cell modules,
- Reducing the ponding depth (to be able to increase the bioretention soil depth),
- Expanding the tree planting area, and/or
- Expanding the soil cell bioretention area by adding additional soil cell modules.

Constraining factors such as available space should be considered when selecting an option above to meet the soil volume requirements. Other soil cell bioretention designs are allowed with the permission of the Director.

The City has prepared a spreadsheet tool (On-site Stormwater Management — List Approach Calculator) to help users select and size BMPs (including infiltrating soil cell bioretention with tree) using the On-Site List Approach. Refer to SDCI's Stormwater Code web page to download the latest version of the spreadsheet tool: www.seattle.gov/sdci/codes/codes-we-enforce-(a-z)/stormwater-code.

Pre-sized Approach for Flow Control and Water Quality Treatment

The Pre-sized Approach may be used for projects with new and replaced hard surface areas up to 10,000 square feet. Under the Pre-sized Approach (refer to *Section 4.1.2*), simple equations are used to calculate the size of "pre-designed" bioretention cell portion of infiltrating soil cell bioretention subject to specific design requirements (e.g., ponding depth). Sizing factors and equations for the bioretention cell portion of infiltrating soil cell bioretention without underdrains and with underdrains are provided in Tables 5.31 and 5.32, respectively.

Pre-sized infiltrating soil cell bioretention without underdrains may be used to achieve the Pre-developed Pasture, Peak Control, and Water Quality Treatment Standards. Pre-sized infiltrating soil cell bioretention with underdrains may be used to achieve the Peak Control and Water Quality Treatment Standards. Sizing factors are organized by ponding depth, subgrade soil design infiltration rate (for infiltrating soil cell bioretention without underdrains), contributing area, and performance standard. To select the appropriate sizing factor or equation:

- The design ponding depth must be rounded down to the nearest depth in the sizing table, or sizing factors may be linearly interpolated for intermediate ponding depths (e.g., between 2 and 6 inches ponding).
- For facilities without underdrains, the subgrade design infiltration rate must be rounded down to the nearest infiltration rate in the pre-sized table (i.e., 0.15, 0.3, 0.6, 1.0, or 2.5 inches per hour).

Table 5.31. Pre-sized Sizing Factors and Equations for Infiltrating Soil Cell Bioretention without Underdrains.

Average Ponding Depth	Subgrade Soil Design Infiltration Rate	Contributing Area (sf)	Sizing Factor/Equation for Bioretention Cell Bottom Area[a] Pre-developed Pasture Standard	Sizing Factor/Equation for Bioretention Cell Bottom Area[a] Peak Control Standard	Sizing Factor/Equation for Bioretention Cell Bottom Area[a] Water Quality Treatment Standard
2 inches	0.15 inch/hour	≤2,000	138.2%	NP	29.1%
		2,001 – 10,000	[1.3898 x A] + 34.3	NP	29.1%
	0.3 inch/hour	≤2,000	103.5%	NP	23.2%
		2,001 – 10,000	[1.0474 x A] + 21.8	NP	23.2%
	0.6 inch/hour	≤2,000	34.0%	NP	11.5%
		2,001 – 10,000	[0.3444 x A] - 3	NP	11.5%
	1.0 inch/hour	≤2,000	24.1%	NP	9.9%
		2,001 – 10,000	[0.2445 x A] - 2.7	NP	9.9%
	2.5 inch/hour	≤2,000	11.03%	NP	3.8%
		2,001 – 10,000	[0.113 x A] - 2.2	NP	3.8%
6 inches	0.15 inch/hour	≤2,000	NA[b]	NA[b]	NA[b]
		2,001 – 10,000	NA[b]	NA[b]	NA[b]
	0.3 inch/hour	≤2,000	17.4%	17.6%	7.2%
		2,001 – 10,000	[0.1052 x A] + 138.6	17.6%	7.2%
	0.6 inch/hour	≤2,000	11.7%	14.4%	4.9%
		2,001 – 10,000	[0.0738 x A] + 89.3	14.4%	4.9%
	1.0 inch/hour	≤2,000	10.2%	12.9%	4.4%
		2,001 – 10,000	[0.0648 x A] + 76.2	12.9%	4.4%
	2.5 inch/hour	≤2,000	4.6%	7.5%	2.2%
		2,001 – 10,000	[0.0308 x A] + 27	7.5%	2.2%
12 inches	0.15 inch/hour	≤ 2,000	NA[b]	NA[b]	NA[b]
		2,001 – 10,000	NA[b]	NA[b]	NA[b]
	0.3 inch/hour	≤2,000	NA[b]	NA[b]	NA[b]
		2,001 – 10,000	NA[b]	NA[b]	NA[b]
	0.6 inch/hour	≤2,000	8.9%	10.6%	4.0%
		2,001 – 10,000	[0.0570 x A] + 63.4	10.6%	4.0%
	1.0 inch/hour	≤2,000	7.7%	9.5%	3.5%
		2,001 – 10,000	[0.0505 x A] + 52.6	9.5%	3.5%
	2.5 inch/hour	≤2,000	3.3%	5.1%	1.8%
		2,001 – 10,000	[0.0261 x A] + 11.9	5.1%	1.8%

NP – not provided; NA – not applicable; A – contributing hard surface area; sf – square feet.

For Sizing Factors: Bioretention Cell Bottom Area = Contributing Hard Surface Area x Factor (%)/100.
Hard Surface Area Managed = Bioretention Cell Bottom Area ÷ Factor (%)/100.

For Sizing Equations: Bioretention Cell Bottom Area (sf) = [Factor x A (sf)] + Integer.
Hard Surface Area Managed (sf) = [Bioretention Cell Bottom Area (sf) - Integer] ÷ Factor.

[a] Soil cell bioretention cell bottom area is 10% larger than bioretention cell bottom area to account for the soil cell modules, but it does not include the tree planting area. If the soil cell bioretention includes a tree, additional tree planting area is required. Refer to *Sections 5.2.4.2 and 5.4.10.5* for more information about sizing tree planting area, depth, and volume sizing. Equations needed to calculate the soil cell bioretention with tree volume are included in the Sizing for On-site List Approach above.

[b] Ponding depth and infiltration rate combination do not achieve drawdown requirements.

Table 5.32. Pre-sized Sizing Factors and Equations for Infiltrating Soil Cell Bioretention with Underdrains.

Average Ponding Depth	Contributing Area (sf)	Sizing Factor/Equation for BMP Bottom Area: Pre-developed Pasture Standard	Sizing Factor/Equation for BMP Bottom Area: Peak Control Standard	Sizing Factor/Equation for BMP Bottom Area: Water Quality Treatment Standard[a]
2 inches	0 – 10,000	NA[b]	NA[b]	1.8%
6 inches	0 – 10,000	NA[b]	NA[b]	1.4%
12 inches	0 – 10,000	NA[b]	NA[b]	1.1%

NA – not applicable; sf – square feet.

For Sizing Factors: Bioretention Cell Bottom Area = Contributing Hard Surface Area x Factor (%)/100.
Hard Surface Area Managed = Bioretention Cell Bottom Area ÷ Factor (%)/100.

[a] Soil cell bioretention cell bottom area is 10% larger than bioretention cell bottom area to account for the soil cell modules, but it does not include the tree planting area. If the soil cell bioretention includes a tree, additional tree planting area is required. Refer to *Sections 5.2.4.2 and 5.4.10.5* for more information about sizing tree planting area, depth, and volume sizing. Equations needed to calculate the soil cell bioretention with tree volume are included in the Sizing for On-site List Approach above.

[b] Ponding depth and infiltration rate combination do not achieve drawdown requirements.

To use these pre-sized BMPs to meet performance standards, infiltrating soil cell bioretention must meet the general requirements outlined in this section plus the following specific requirements:

- The bioretention cell bottom area must be sized using the applicable sizing factor or equation.
- It is preferred that the bottom area is flat, but up to 3 percent slope is permitted.
- For BMPs without underdrains, the bioretention soil depth must be a minimum of 12 inches for flow control and 18 inches for water quality treatment. For BMPs with underdrains, the amended soil must have a minimum depth of 18 inches.
- The average ponding depth for the bioretention cell must be no less than the selected ponding depth.
- If the soil cell bioretention includes a tree, additional tree planting area is required. Refer to Sections 5.2.4.2 and 5.4.10.5 for more information about sizing tree planting area, depth, and volume sizing. Equations needed to calculate the soil cell bioretention with tree volume are included in the Sizing for On-site List Approach above.

The bottom area for the bioretention cell portion of the soil cell bioretention is calculated as a function of the hard surface area routed to it. All area values must be in square feet.

Modeling Approach for On-site Performance Standard, Flow Control, and Water Quality Treatment

When using continuous simulation hydrologic modeling to size infiltrating structural soil cell BMPs, the assumptions listed in Table 5.33 must be applied. Refer to the *Approval Status of Continuous Simulation Models* section of the SWMMWW for a list of currently approved models. If MGSFlood is used, the "Ecology Bioretention" element must be used to represent infiltrating soil cell bioretention. The contributing area, cell bottom area, and ponding depth should be iteratively sized until the Minimum Requirements for On-site Stormwater

Management, Flow Control and/or Treatment are met (refer to *Volume 1, Project Minimum Requirements*) or where it has been determined by the Director that there is no off-site point of discharge for the project, the requirements of *Section 4.3.2* are met. General sizing procedures for infiltration facilities are presented in *Section 4.5.1*.

Table 5.33. Continuous Modeling Assumptions for Infiltrating Structural Soil Cell BMPs.

Variable	Assumption
Precipitation Series	SEPTS-99 unless otherwise adopted by the Director
Computational Time Step	5 minutes
HSPF Parameters	LSUR, SLSUR, NSUR must be adjusted per *Appendix F*
Inflows to Facility	Surface flow and interflow from total drainage area (including impervious and pervious contributing areas) routed to facility
Precipitation and Evaporation Applied to Facility	Yes. WWHM and MGSFlood both apply precipitation and evaporation to the facility automatically. If model does not apply precipitation and evaporation to facility automatically, then modelers must add the facility area to the post developed impervious contributing area to account for this additional precipitation and evaporation (note that this will underestimate the evaporation of ponded water).
Bioretention Soil Type	SWMMWW 6in/hr or SMMWW 12 in/hr (see below for safety factor)
Bioretention Soil Infiltration Rate	The design infiltration rate must be 6 inches per hour. Apply a saturated hydraulic conductivity safety factor (KSat) of 2 when using the SMMWW 12 in/hr bioretention soil type.
Bioretention Soil Porosity	Use the default Bioretention Soil Porosity included in WWHM and MGSFlood for the SMMWW 12in/hr soil type.
Bioretention Soil Depth	For facilities without underdrains, the soil must have a minimum of 12 inches for flow control and minimum of 18 inches for water quality treatment. For facilities with underdrains, the soil must have a minimum depth of 18 inches.
Subgrade (Native) Soil Design Infiltration Rate	Design infiltration rate (*Section 4.5.2*, *Appendix D*)
Underdrain (if required)	If an underdrain is simulated, a gravel aggregate layer must be included for the underdrain layer media. The default underdrain invert elevation is located at the bottom of the lowest soil layer unless a height or offset is specified. If the underdrain is elevated above the bottom extent of the aggregate layer, water stored in the aggregate below the underdrain invert may be modeled to provide storage and infiltrate to subsurface soil. For the purposes of this manual, underdrains meeting the bedding requirements shown in Figure 5.27 are considered “elevated” by 6 inches. In order to model the underdrain with underlying storage and infiltration, the aggregate gravel reservoir must extend across the bottom of the facility. The underdrain pipe could be further elevated for improved flow control performance.
Underdrain Layer Media Type	Gravel
Overflow Structure	The overflow elevation must be set at the maximum ponding elevation (excluding freeboard). It may be modeled as weir flow over a riser edge. Note that the total facility depth (including freeboard) must be sufficient to allow water surface elevation to rise above the overflow elevation to provide head for discharge.

5.4.10.7. Minimum Construction Requirements

Infiltrating soil cell bioretention must meet the following minimum construction requirements.

Bioretention Soil

During construction, it is critical to prevent clogging and over-compaction of the subgrade and bioretention soils. Minimum requirements associated with infiltrating soil cell bioretention construction include the following:

1. Place bioretention soil per the requirements of City of Seattle Standard Specifications.
2. Do not excavate or place soil during wet or saturated conditions.

Tree Planting Requirements

Refer to *Section 5.2.5.2* for tree planting requirements.

Manufacturer Construction Requirements

Follow the recommended construction procedures and installation instructions from manufacturers as well as any applicable City requirements.

5.4.10.8. Operations and Maintenance Requirements

In addition to the bioretention O&M requirements provided in *Appendix G (BMP No. 23)*, the soil cell bioretention BMP must meet the following O&M requirements.

Tree O&M Requirements

Refer to *Section 5.2.7* for O&M requirements for newly planted trees.

Manufacturer O&M Requirements

Refer to manufacturer websites for product-specific maintenance requirements.

5.5. Rainwater Harvesting BMPs

Rainwater harvesting BMPs capture and store rainwater for beneficial use. The BMPs in this section include:

- Rainwater harvesting (*Section 5.5.1*)
- Residential cisterns (*Section 5.5.2*)

5.5.1. Rainwater Harvesting

5.5.1.1. Description

Rainwater harvesting is the capture and storage of rainwater for subsequent use. Runoff from roofs may be routed to cisterns for storage and beneficial non-potable uses, such as irrigation, mechanical equipment, industrial process uses, toilet flushing, and the cold water supply for laundry. The potable use of collected rainwater may be used for single-family residences with proper design and approval from Public Health — Seattle & King County.

Rainwater harvesting functions can be combined with detention pipes, vaults, and cisterns (refer to *Sections 5.7.2*, *5.7.3*, and *5.7.4*).

5.5.1.2. Performance Mechanisms

Rainwater harvesting can be used to achieve reductions in peak flows, flow durations and runoff volumes. The flow control performance of rainwater harvesting is a function of contributing area, storage volume and rainwater use rate.

5.5.1.3. Applicability

Rainwater harvesting systems can be designed to provide on-site stormwater management and flow control, and can be an effective volume reduction practice for projects where infiltration is not permitted or desired. Rainwater harvesting has higher stormwater management benefits when designed for uses that occur regularly through the wet season (e.g., toilet flushing and cold water laundry). The use of harvested rainwater for irrigation during the dry months provides less benefit.

This BMP can be applied to meet the requirements listed below.

BMP	On-site: List	On-site: Standard	Flow Control: Forest	Flow Control: Pasture	Flow Control: Peak	Water Quality: Basic	Water Quality: Enhanced Metals	Water Quality: Oil Control	Water Quality: Phosphorus	Conveyance
Rainwater Harvesting	x	x	x	x	x					

[a] Rainwater harvesting is not approved for pollution-generating surfaces, so the water quality treatment standard is not applicable.

5.5.1.4. Site Considerations

Rainwater harvesting can be used for new or retrofit projects. Depending upon site constraints, cisterns may be installed at grade, underground, under a deck, or in a basement or crawl space. Cisterns may be used individually or connected to each other in a series for increased storage capacity. Refer to *Appendix C* for additional infeasibility criteria for the On-site List Approach.

Rainwater harvesting cisterns are allowed in the side, front, and rear yard/setbacks that are required by the Land Use Code (SMC Title 23) in certain land use zones. However, if the cistern extends above grade or sits above grade, then the amount of the yard/setback that it can cover may be restricted if the cistern is over a certain height, width, or total storage capacity. Height is measured from the lowest adjacent grade. Width is the outside width and

is measured perpendicular to the setback line. Storage capacity is the total volume of water that can be stored in the cistern.

Refer to the Land Use Code (SMC Title 23) for the specific height, width, and storage capacity that trigger yard/setback coverage limitations for GSI features. Note: The requirements vary based on zoning and are not required in all zones.

5.5.1.5. Design Criteria

This section provides descriptions, recommendations, and requirements for the common components of rainwater harvesting systems. Design criteria are provided in this section for the following elements:

- Contributing area
- Collection system
- Prefilter
- Cistern/storage system
- Distribution system
- Water treatment system
- Overflow
- Backflow prevention device

The City accepts rainwater harvesting systems with indoor and/or outdoor water use for compliance with flow control standards. The indoor use of harvested water is regulated by Public Health — Seattle & King County.

In addition to the requirements presented in this section, all components of a rainwater harvesting system must be designed and constructed in accordance with the manufacturer's recommendations and the City of Seattle Building and Residential Code, City of Seattle Plumbing Code, and Public Health — Seattle & King County requirements, and all other applicable laws.

Refer to the Puget Sound LID Manual and ARCSA/ASPE/ANSI 63-2013: Rainwater Catchment Systems for general guidance for design of rainwater harvesting systems. Refer to *Rainwater Harvesting and Connection to Plumbing Fixtures* (Public Health — Seattle & King County 2011) and the Puget Sound LID Manual for design requirements specific to indoor use of harvested rainwater.

Links to resources on rainwater harvesting, including permit requirements, are available at the SDCI website (www.seattle.gov/sdci/codes/codes-we-enforce-(a-z)/stormwater-code).

Contributing Area

The area contributing runoff to a rainwater harvesting system must be a roof. Any rainwater collected from a vegetated roof underdrain may require additional treatment to remove tannins and suspended solids. Additionally vegetated roofs will naturally reduce the amount of water available for collection through the evapotranspiration of the plants and soil media.

Collection System

The collection system includes gutters and downspouts, as well as the piping and any other conveyance needed to route rainwater to the prefilter and on to the cistern.

Prefilter

A prefilter must be provided with a debris screen that protects the cistern from the intrusion of debris, insects, vermin, or other organisms. The debris screen must be corrosion resistant and must have openings no larger than a nominal 0.15 cm (1,500 microns) (1/16 inch) or have been certified by a government regulatory agency to remove particles greater than 500 µm. A self-cleaning prefilter is recommended.

Cistern/Storage System

Cisterns can be constructed from a variety of materials (e.g., plastic, concrete, corrugated steel with liner, fiberglass) and placed in various locations. They can include tanks, pipes, and enclosed portions of buildings—above or underground. The minimum requirements for all cistern systems include the following:

- Cisterns must be installed in accordance with manufacturer's installation instructions, the City of Seattle Building Code, and all applicable laws, including foundation and other structural requirements.
- Cistern/storage systems must have access points and drains to allow inspection and cleaning.
- Cistern openings must be designed to restrict entry from unauthorized personnel and appropriate signage must be provided. Any cistern/storage system opening that could allow the entry of personnel must be marked: "danger — confined space."
- Cleaning of any accumulated sediment on the bottom of the cistern must be possible by flushing through a drain or vacuuming.
- Cisterns must be designed to prevent mosquitoes and other nuisance insects and animals from entering the cistern system. This must be done with 1/16-inch stainless steel mesh screening at all vents and other openings to the cistern.
- Opaque containers must be used for aboveground cisterns to minimize algal growth.

Minimum requirements specific to underground cistern design include the following:

- Cistern/storage systems that are buried underground must have a maintenance hole riser that protrudes a minimum of 8 inches above the surrounding ground. Maintenance hole covers must be secured and locked to prevent tampering.
- Cistern/storage systems must meet buoyancy resistance requirements per manufacturer's specifications, the City of Seattle Building Code, and the City of Seattle Plumbing Code.

Distribution System

Distribution of collected rainwater may be accomplished by gravity or by pumps and pipes to move water from the storage system to the end use area. For gravity fed irrigation use, an outlet spigot can be installed near the bottom of the tank. Water must be drawn from at least

4 inches above the bottom of the tank or by use of a floating screened inlet in the tank. Any piping and/or fixtures containing collected rainwater must be appropriately labeled per code.

Water Treatment System

Water quality treatment is typically required to protect the delivery and distribution system and to improve the quality of the collected water for the intended use. The pre-filter may be sufficient for a gravity fed irrigation system, while a pumped system for toilet flushing may require sediment filtration to 20µ to 50µ.

Additional discussion of treatment for indoor use is outside of the scope of this manual. Refer to the Puget Sound LID Manual and/or ARCSA/ASPE/ANSI 63-2013: Rainwater Catchment Systems for additional guidance on indoor use of harvested rainwater. Approval is required by Public Health — Seattle & King County for any project routing harvesting water to an indoor plumbing system.

Overflow

Minimum requirements associated with overflow design include the following:

- Overflows must be designed to convey excess flow to the approved point of discharge per *Section 4.3.3*.
- The overflow pipe must have a conveyance capacity that is equal to or greater than all of the conveyance inlets delivering rainwater to the cistern. The minimum overflow pipe diameter must be 4 inches.

Backflow Prevention Device

Refer to Public Health — Seattle & King County and the City of Seattle Plumbing Code for backflow prevention and cross-connection control requirements for back-up water supply.

5.5.1.6. BMP Sizing

Sizing for On-site List Approach

Rainwater harvesting may be selected to meet the On-site List Requirement in Category 2 or Category 4 (refer to *Section 3.3.1* and *Appendix C* for infeasibility criteria). To meet the requirement for Category 2 of the On-site List, the rainwater harvesting system must be designed to meet the On-site Performance Standard appropriate to the project (refer to Modeling Approach for On-site Performance Standard and Flow Control).

If rainwater harvesting is selected for Category 4 of the On-site List, the rainwater harvesting system must reduce discharged rooftop runoff volume by 25 percent on an average annual basis, as determined by an approved continuous simulation model. This reduction in runoff volume can be determined by comparing the total runoff from the roof and the average annual rainwater demand outlined in the following steps.

Step 1: Determine the average annual runoff volume from the tributary roof area

The roof area contributing to the rainwater harvesting system can be determined using the total runoff volume divided by the number of simulation years (e.g., 158 years).

Step 2: Determine the average annual runoff volume discharging as overflow from the rainwater harvesting system

This can be determined using the total discharged runoff volume divided by the number of simulation years (e.g., 158 years).

Step 3: Determine the ratio of the overflow discharge volume compared to the average annual runoff volume

Calculate the ratio of the numbers determined in Steps 1 and 2 (divide the average annual rainwater harvesting system overflow volume from Step 2 by the average annual roof runoff volume from Step 1). If the ratio is at least 0.75, the rainwater harvesting system meets the requirements for Category 4 of the On-site List.

Modeling Approach for On-site Performance Standard and Flow Control

If rainwater harvesting is selected for Category 2 of the On-site List, the on-site performance standard appropriate to the project must be used to size the rainwater harvesting system. Rainwater harvesting systems can also be sized to meet flow control standards. The process for sizing a rainwater harvesting system to meet the on-site performance standard or a flow control standard is the same and is outlined in the following steps.

Step 1: Determine rainwater demand

When estimating rainwater demand for the purposes of modeling the on-site performance standard or a flow control standard, only year-round indoor uses may be included (e.g., seasonal irrigation may not be considered). Typical assumptions for non-potable and potable uses are provided in Table 5.34 and 5.35 below.

Table 5.34. Typical Assumptions for Non-potable Rainwater Demand Calculations.

Use	Assumptions	Source
Commercial Building Uses for Employees		
Number of employees	Actual[a]	
Employees that are male	50%	Assumed
Water closet (toilet) uses per male employee	1 use/day	LEED Reference Guide
Urinal uses per male employee	2 uses/day	LEED Reference Guide
Water closet uses per female employee	3 uses/day	LEED Reference Guide
Toilet and urinal fixture flow rates	Actual (gallons per use)	Manufacturer's data
Commercial Building Uses for Visitors		
Number of visitors	Actual[b]	
Water closet (toilet) uses per male visitor	0.2 use/day	LEED Reference Guide
Urinal uses per male visitor	0.1 use/day	LEED Reference Guide
Water closet (toilet) uses per female visitor	0.1 uses/day	LEED Reference Guide
Toilet and urinal fixture flow rates	Actual (gallons per use)	Manufacturer's data

Table 5.34 (continued). Typical Assumptions for Non-potable Rainwater Demand Calculations.

Use	Assumptions	Source
Residential Building		
Water closet (toilet) uses per resident	5.1 uses per day per person	Rainwater Catchment Systems (ARCSA/ASPE/ANSI 63-2013)
Toilet and urinal fixture flow rates	Actual (gallons per use)	Manufacturer's data
Cold water leg of laundry	80%	DeOreo and Mayer (2012)
Laundry usage	0.31 loads/day/capita[c]	Residential End Uses of Water Executive Report, Version 2 (WRF 2016)
Residents per bedroom	2 for the first bedroom and 1 for each other bedroom per unit	Assumed

[a] Typically not more than 1 employee per 2,000 sf of retail or 1 employee per 150 sf of office.

[b] Typically not more than 150 visitors per day for commercial uses.

[c] Derived from 31 gallons/load and 9.6 gallons per day per person from the Residential End Uses of Water Executive Report (WRF 2016).

Table 5.35. Typical Assumptions for Potable Rainwater Demand Calculations.

Use	Usage	Duration	Source
Commercial Building Uses for Employees			
Lavatory faucet	3 uses/day	30 seconds/use	LEED Reference Guide
Shower	0.1 uses/day	300 seconds/use	LEED Reference Guide
Kitchen sink	1 use/day	15 seconds/use	LEED Reference Guide
Faucet, shower and sink fixture flow rates	Actual (gallons/minute)	–	Manufacturer's data
Commercial Building Uses for Visitors			
Lavatory faucet	0.5 use/day	30 seconds/use	LEED Reference Guide
Faucet fixture flow rates	Actual (gallons/minute)	–	Manufacturer's data
Residential Building Uses[a]			
Faucets	11.1 gallons/day/capita	–	Residential End Uses of Water Executive Report, Version 2 (WRF 2016)
Shower	11.1 gallons/day/capita	–	Residential End Uses of Water Executive Report, Version 2 (WRF 2016)
Bath	1.5 gallons/day/capita	–	Residential End Uses of Water Executive Report, Version 2 (WRF 2016)
Dishwasher	0.7 gallons/day/capita	–	Residential End Uses of Water Executive Report, Version 2 (WRF 2016)
Faucet and shower fixture flow rates	Actual (gallons/minute)	–	Manufacturer's data

[a] Additional residential potable water use rates can be obtained from the Water Research Foundation (WRF 2016) executive report: www.allianceforwaterefficiency.org/resources/residential.

Daily demand is calculated for each use as shown in the examples below:

- Water closet demand for female employees in commercial building (gallons/day) = total number of employees x 50 percent x 3 uses/day x toilet flow rate (gallons/use)
- Lavatory faucet demand for visitors in commercial building (gallons/day) = [number of visitors per day x 0.5 uses/day x 30 seconds/use x faucet flow rate (gallons/minute)] ÷ 60 seconds/minute

The rainwater uses are summed to calculate a total daily demand in gallons per day. For commercial buildings that do not operate daily, a multiplier is applied to the total demand (i.e., a multiplier of 5/7 is applied if business is open 5 days per week).

The average demand (D) in cubic feet per hour is then calculated by dividing the demand in gallons per day by 179.5. The rainwater demand is then reduced by a factor of 10 percent (multiplied by a factor of 0.9) to account for lower than anticipated water use (e.g., periods of vacancy).

Step 2: Calculate the "Infiltration Rate" Equivalent to the Rainwater Demand

In order to represent the daily rainwater demand in the continuous simulation model, the equivalent cistern "infiltration rate" is calculated as follows:

Equivalent Cistern "Infiltration Rate" (inch/hour) = D x (12 inches/foot)/A, where:

D = Average Daily Rainwater Demand (cubic feet per hour)
A = Cistern Footprint Area (square feet)

Step 3: Determine Contributing Roof Area

The actual roof area draining to the cistern is the contributing roof area.

Step 4: Integrate Rainwater Harvesting into Development Site Model

In an approved continuous hydrologic model, runoff from the contributing roof area is directed to a storage element (e.g., vault, cistern) with an infiltration routine to represent the cistern with rainwater use (refer to Table 5.36). The equivalent "infiltration rate," calculated as shown above, is applied to the bottom area of the storage element. The size of the storage element and/or the equivalent "infiltration rate" (rainwater use rate) are adjusted to achieve the desired level of performance. Note that when the storage element size is modified, the equivalent "infiltration area" must be updated based on the new cistern footprint area (refer to the equation in Step 2).

If rainwater harvesting does not achieve the applicable stormwater performance standard(s), overflow from the storage element can be routed to a downstream stormwater management practice (e.g., detention, bioretention) that can be sized to meet the standard(s).

Table 5.36. Continuous Modeling Assumptions for Rainwater Harvesting.

Variable	Assumption
Precipitation Series	SEPTS-99 unless otherwise adopted by the Director
Computational Time Step	5 minutes
HSPF Parameters	LSUR, SLSUR, NSUR must be adjusted per *Appendix F*
Inflows to Cistern	Surface flow from drainage area (roof area) routed to facility
Storage in Cistern	Storage element (e.g., vault, cistern)
Rainwater Demand	Represent rainwater demand as an equivalent "infiltration rate" applied to the bottom of the storage element
Outlet Structure	Overflow elevation set at live storage depth. May be modeled as weir flow over riser edge. Note that freeboard must be sufficient to allow water surface elevation to rise above the overflow elevation to provide head for discharge.

5.5.1.7. Minimum Construction Requirements

Rainwater harvesting systems must be constructed according to the manufacturer's recommendations, the City of Seattle Building Code, the City of Seattle Plumbing Code, and all applicable laws.

5.5.1.8. Operations and Maintenance Requirements

Rainwater harvesting O&M requirements are provided in *Appendix G* (*BMP No. 24*).

Additional O&M guidance can be found in ARCSA/ASPE/ANSI 63-2013: Rainwater Catchment Systems.

5.5.2. Residential Cisterns

5.5.2.1. Description

Detention cisterns (*Section 5.7.4*) can be designed to allow rainwater harvesting of roof runoff for outdoor irrigation use. For residential projects, these are combined harvesting and detention cisterns.

The residential cistern requires seasonal operation of a valve to detain water through the winter months.

5.5.2.2. Performance Mechanisms

Residential cisterns provide flow attenuation by slowly releasing low flows through an orifice.

5.5.2.3. Applicability

Residential cisterns can be applied to meet the requirements listed below.

BMP	On-site: List	On-site: Standard	Flow Control: Forest	Flow Control: Pasture	Flow Control: Peak	Water Quality: Basic	Water Quality: Enhanced Metals	Water Quality: Oil Control	Water Quality: Phosphorus	Conveyance
Residential Cisterns	x									

5.5.2.4. Site Considerations

Residential cisterns can be used on any new or retrofit residential project in Neighborhood Residential (NR), Residential Small Lot (RSL) and Lowrise (LR1, LR2, or LR3) zones. Refer to *Appendix C* for additional infeasibility criteria for the On-site List Approach.

Residential cisterns are allowed in the side, front and rear yard/setbacks that are required by the Land Use Code (SMC Title 23) in certain land use zones. However, the amount of the yard/setback that it can cover may be restricted if the cistern is over a certain height, width, or total storage capacity. Height is measured from the lowest adjacent grade. Width is the outside width and is measured perpendicular to the setback line. Storage capacity is the total volume of water that can be stored in the cistern.

Refer to the Land Use Code (SMC Title 23) for the specific height, width, and storage capacity that trigger yard/setback coverage limitations for GSI features. Note: The requirements vary based on zoning and are not required in all zones.

5.5.2.5. Design Criteria

The following provides descriptions, recommendations, and requirements for the common components of cistern detention systems. A schematic for a typical residential cistern is shown in Figure 5.29. Design criteria are provided in this section for the following elements:

- Contributing area
- Collection system
- Screen/debris excluder
- Cistern
- Flow control orifice
- Overflow

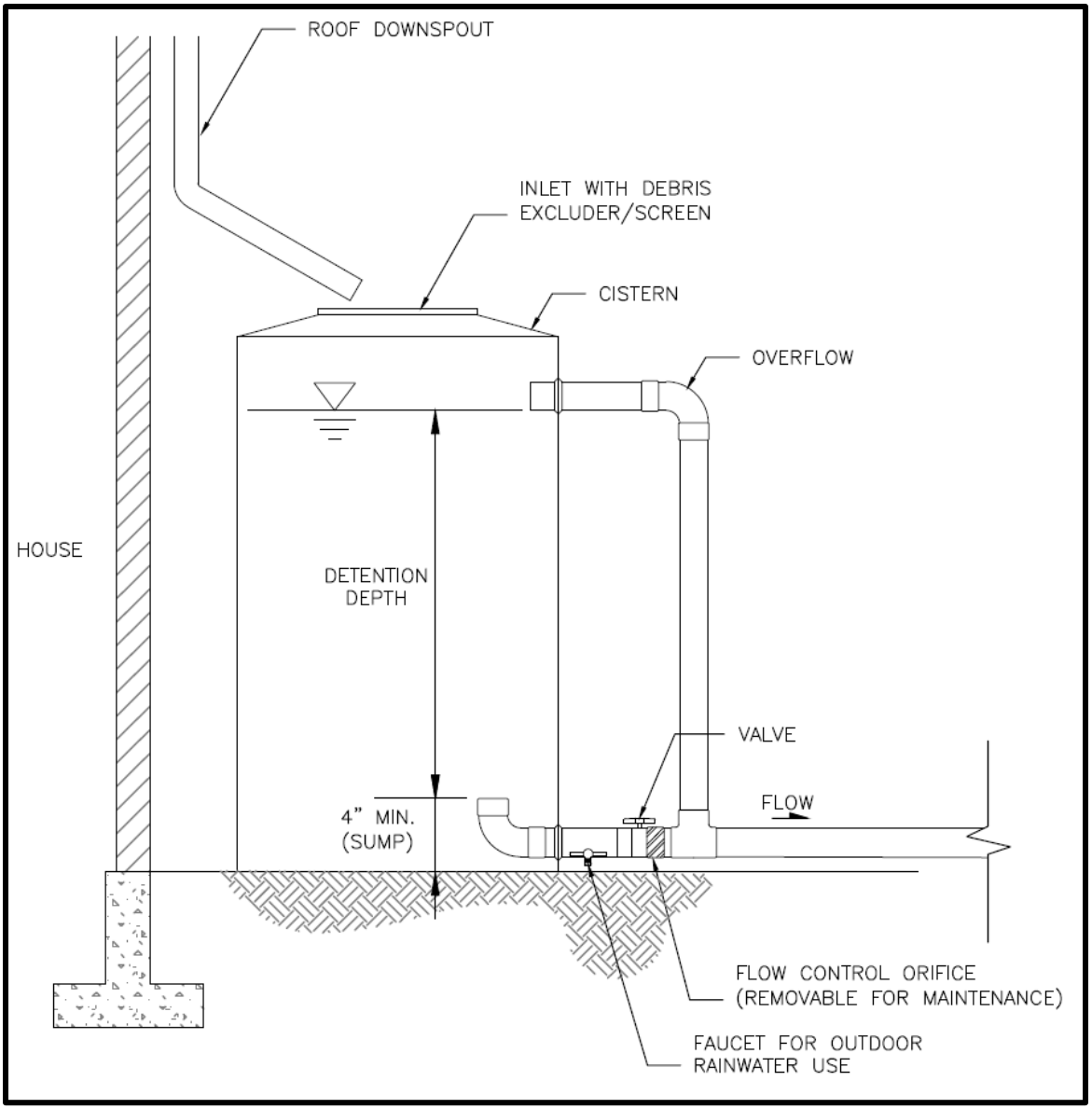


Figure 5.29. Detention Cistern with Harvesting Capacity for Residential Projects Only.

Contributing Area

The area contributing runoff to a residential cistern must not be pollution generating (e.g., surfaces subject to vehicular traffic are not acceptable).

To protect the water quality of the rainwater harvested, avoid collecting runoff from roof surfaces composed of materials such as copper or zinc that may release contaminants into your system. Also avoid collecting runoff from roof materials treated with fungicides or herbicides.

Collection System

Collection systems include gutters and downspouts, as well as piping and any other conveyance needed to route runoff from the roof to the cistern.

Rainwater use must be for outdoor irrigation uses only.

Screens/Debris Excluder

A filter screen or other debris barrier is required to prevent insects, leaves, and other larger debris from entering the system. A self-cleaning inlet filter is recommended.

Cistern

Cisterns are commonly constructed of fiberglass, polyethylene, concrete, metal, or wood. Tanks can be installed at or below grade, and individually or in series.

Minimum requirements associated with cistern design include the following:

- If cistern height exceeds 4.5 feet (excluding piping), width exceeds 4 feet, or storage volume exceeds 600 gallons, the cistern may be subject to stricter Land Use Code (SMC Title 23) setback requirements.
- All cisterns must be installed in accordance with manufacturer's installation instructions.
- Cisterns must be designed to prevent mosquitoes and other nuisance insects and animals from entering the cistern system. This can be done with tight-fitting covers and appropriate screening at all openings to the cistern.
- Opaque containers must be used for aboveground cisterns to prevent penetration of sunlight to minimize algal growth.
- Minimum cistern size must be that of a rain barrel (typically 55 gallons).

Flow Control Orifice

Minimum requirements associated with flow control orifice design include the following:

- Cisterns must be aboveground and have an orifice diameter of 0.25 inch.
- Minimum 4-inch sump must be provided to protect the orifice from sediment.

Overflow

Cisterns must have an overflow to convey water exceeding the detention capacity of the system to an approved point of discharge or another BMP (e.g., bioretention area, vegetated cell, or infiltration trench) per *Section 4.3.3*. Conveyance may be provided by gravity flow or by pumps, but gravity flow is preferred.

5.5.2.6. BMP Sizing

Sizing for On-site List Approach

Residential cisterns may be selected to meet the On-site List Requirement (refer to *Section 3.3.1* and *Appendix C* for infeasibility criteria). The area draining to a properly sized cistern meets the requirement. The cistern area sizing factors and minimum live storage depths are provided in Table 5.37. Three to five feet of live storage between the low flow

orifice and the overflow must be provided, and the low flow orifice must have a diameter of 0.25 inch.

Table 5.37. On-site List Sizing for Residential Cisterns.

Contributing Area (square feet)	Sizing Factor Cistern Bottom Area[a]: On-site Performance Standard	Minimum Live Storage Depth[b] (ft)
400–799	3.6%	3.0
800–899	2.8%	4.0
900–999	2.4%	4.0
1,000–1,099	2.0%	4.0
1,100–1,199	1.7%	4.0
1,200–1,299	1.4%	4.0
1,300–1,399	1.4%	5.0
1,400–1,899	1.3%	5.0
1,900–1,999	1.2%	5.0
2,000–2,999	1.6%	5.0
3,000–4,200	1.9%	5.0

sf – square feet.

Cistern Area = Contributing Hard Surface Area x Factor (%)/100.

Hard Surface Area Managed = Cistern Area ÷ Factor (%)/100.

[a] Sizing factors based on achieving an 85% reduction in the 1-year recurrence interval flow.

[b] Detention depth refers to live storage depth (i.e., does not include freeboard or sediment storage requirements).

5.5.2.7. Minimum Construction Requirements

Refer to the construction-related issues outlined above as part of the design criteria. An additional construction requirement is as follows:

- Submit field changes to the flow control device assembly, including elevation changes, to the Engineer of Record for confirmation that the device still meets the design requirements.

5.5.2.8. Operations and Maintenance Requirements

Residential cistern O&M requirements are provided in *Appendix G* (*BMP No. 24*).

The homeowner must open the valve to engage the flow control orifice during the non-growing season (approximately October through April or May). If the valve is not opened during this time, the cistern will fill and overflow, eliminating the detention benefits of the system. A plan must be submitted demonstrating how the O&M requirements will be met.

5.6. Alternative Surface BMPs

Alternative surface BMPs convert a conventional impervious surface to a surface that reduces the amount of stormwater runoff and also provides flow control. The BMPs in this section include:

- Vegetated roof systems
- Permeable pavement surfaces

5.6.1. Vegetated Roof Systems

5.6.1.1. Description

Vegetated roofs are areas of living vegetation installed on top of buildings, or other above-grade impervious surfaces (e.g., at least 10 feet above grade). Vegetated roofs are also known as ecoroofs, green roofs, and roof gardens.

A vegetated roof consists of a system in which several materials are layered to achieve the desired vegetative cover and stormwater management function (refer to Figure 5.30). Design components vary depending on the vegetated roof type and site constraints, but may include a waterproofing material, a root barrier, a drainage layer, a separation fabric, a growth media (soil), and vegetation. Vegetated roof systems are categorized by the depth and the types of courses used in their construction.

- **Intensive roofs**: Intensive roofs are deeper installations, composed of at least 6 inches of growth media and planted with ground covers, grasses, shrubs and sometimes trees.
- **Extensive roofs***:* Extensive roofs are shallower installations, composed of less than 6 inches of growth media and planted with a palette of drought-tolerant, low maintenance ground covers. Extensive vegetated roofs have the lowest weight and are typically the most suitable for placement on existing structures. Extensive systems are further divided into two types:
  - Single-course systems consist of a single growth media designed to be freely draining and support plant growth.
  - Multi-course systems include both a growth media layer and a separate, underlying drainage layer.

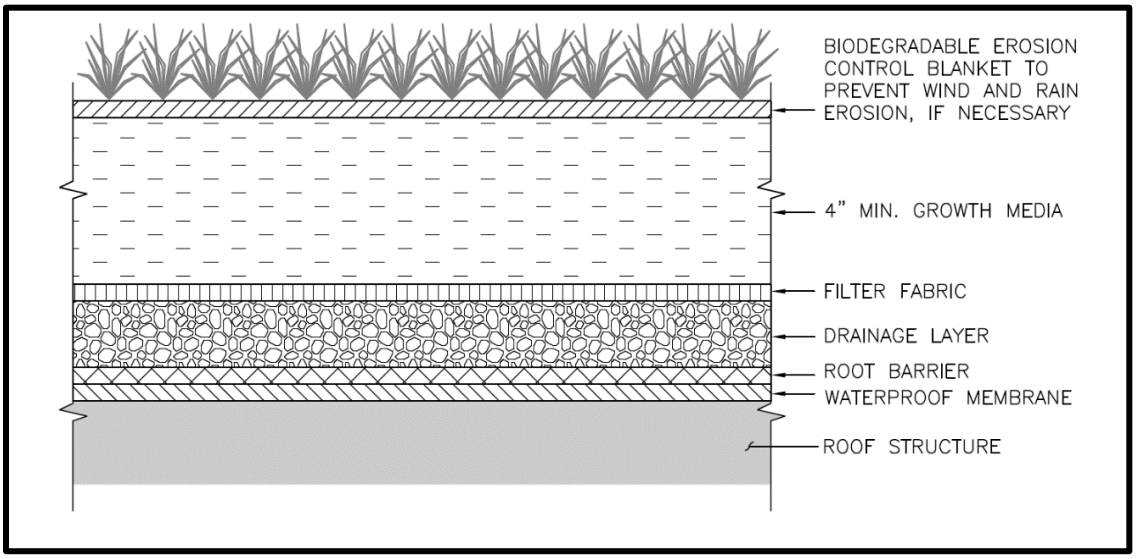


Figure 5.30. Vegetated Roof System.

The following types of vegetated roof systems are acceptable for flow control compliance:

- Intensive systems
- Extensive multi-course systems (and commercially available modular systems) with at least 4 inches of growth media
- Extensive single-course systems with at least 4 inches of growth media

5.6.1.2. Performance Mechanisms

Vegetated roof systems can provide flow control via attenuation, soil storage, and losses to interception, evaporation, and transpiration.

5.6.1.3. Applicability

Vegetated roof systems can be designed to provide on-site stormwater management and flow control. The degree of flow control provided by vegetated roofs varies depending on the growth media (soil) depth, growth media composition, drainage layer characteristics, vegetation type, roof slope, and other design considerations. This BMP can be applied to meet or partially meet the requirements listed below.

BMP	On-site: List	On-site: Standard	Flow Control: Forest	Flow Control: Pasture	Flow Control: Peak	Water Quality: Basic	Water Quality: Enhanced Metals	Water Quality: Oil Control	Water Quality: Phosphorus	Conveyance
Vegetated Roof System	x	x[a]	x[a]	x[a]	x[a]					

[a] Standard may be partially achieved and additional BMPs may be needed to meet the on-site standard or flow control standard.

5.6.1.4. Site Considerations

Vegetated roof systems for stormwater management are accepted for roof slopes between 1 and 22 degrees (0.2:12 and 5:12) but require additional analysis at slopes exceeding 10 degrees (2:12).

A primary consideration for the feasibility of vegetated roofs is the structural capability of the roof and building structure. Related factors, including design load, slipping and shear issues, and wind load, are outside the scope of this manual. Refer to the City of Seattle Building Code for structural requirements. Refer to *Appendix C* for additional infeasibility criteria for the On-site List.

5.6.1.5. Design Criteria

The following sections provide a description, recommendations, and requirements for the common components of vegetated roof systems. Typical components of a vegetated roof are shown in Figure 5.30. Design criteria are provided in this section for the following elements:

- Roof slope
- Vegetation
- Growth media

- Drainage layer
- Drain system and overflow

While vegetated roofs will include additional system components (e.g., waterproof membrane, root barrier, separation fabric for multi-course systems), the design and construction requirements for these components are outside of the scope of this manual.

Refer to the Puget Sound LID Manual for a more detailed description of the components of and design criteria for vegetated roofs, as well as additional references and design guidance.

Roof Slope

Vegetated roofs can be applied to a range of rooftop slopes; however, steeper slopes may result in reduced flow control performance and may warrant a more complicated design (e.g., lateral support measures). Roofs with slopes between 1 and 5 degrees (0.2:12 and 1:12) are the easiest to install, are the least complex, and generally provide the greatest stormwater storage capacity per inch of growth media.

For on-site or flow control compliance, the roof slope must be between 1 and 22 degrees (0.2:12 and 5:12). Roofs with slopes greater than 10 degrees (2:12) require an analysis of engineered slope stability.

Vegetation

Vegetation used on extensive vegetated roofs must be drought tolerant, self-sustaining, low maintenance, and perennial or self-sowing. Appropriate plants should also be able to withstand heat, cold, periodic inundation and high winds. Vegetation with these attributes typically includes succulents, grasses, herbs, and wildflowers that are adapted to harsh conditions. Refer to the Green Factor plant list posted on SDCI's website. Refer to the Puget Sound LID Manual for additional vegetation guidance for vegetated roofs.

Minimum requirements associated with vegetation design include the following:

- The design plans must specify that vegetation coverage of selected plants will achieve 80 percent coverage within 2 years.
- For non-single family residential projects, plant spacing and plant size must be designed to achieve specified coverage by a licensed landscape architect.
- Vegetation must be suitable for rooftop conditions (e.g., hot, cold, dry, and windy).
- Application of fertilizer, pesticides or herbicides must be minimized after a 3-year establishment period.

  Note: Vegetated roofs may require fertilizer for establishment and long-term health. The goal of fertilization is to support plant health and vigor while also minimizing the amount of nutrient runoff within stormwater. During the first 3 years of establishment, a granular, slow-release fertilizer with a target N-P-K ratio of 18-6-12 or a generic 10-10-10 is recommended. Application should occur during the spring growing season. After initial plant establishment, vegetation should be monitored and soil should be tested annually or every other year to determine whether additional fertilizer applications are necessary. Fertilizer should not be applied during the

hottest and driest parts of the year when plants are dormant or not actively growing. Fertilizer should not be over-applied. Vegetated roofs have excellent drainage and are intended to help reduce pollutants that result from stormwater runoff. Fertilizing should be conducted carefully and strategically to avoid water quality impacts.

Growth Media

Vegetated roof systems use a light-weight growth media with adequate fertility and drainage capacity to support plants and allow filtration and storage of water. Growth media composition (fines content and water holding capacity) is key to flow control performance. Refer to the Puget Sound LID Manual for additional guidance on growth media design.

Minimum requirements associated with the growth media design include the following:

- The growth media must be a minimum of 4 inches deep. Refer to the SDCI website (www.seattle.gov/sdci/codes/codes-we-enforce-(a-z)/stormwater-code) for a growth media specification. Approved media testing labs and approved media products are also provided on the website.
- For non-single family residential projects, growth media depth and characteristics must support growth for selected plant species and must be approved by a licensed landscape architect.
- Vegetated roofs must not be subject to any use that will significantly compact the growth media.
- Unless designed for foot traffic, vegetated roof areas that are accessible to the public must be protected (e.g., signs, railing, fencing) from foot traffic and other loads.
- Biodegradable erosion control blanket or other measures to control erosion of growth media must be maintained until 90 percent vegetation coverage is achieved.

Drainage Layer

Intensive and extensive multi-course vegetated roof systems must include a drainage layer below the growth media. The drainage layer is a multipurpose layer designed to provide void spaces to hold a portion of the water that passes through the growth media and to channel the water to the roof drain system. The drainage layer can consist of a layer of aggregate or a manufactured mat or board that provides an open free draining area. Many manufactured products include egg carton shaped depressions that retain a portion of the water for eventual evapotranspiration.

Drain System and Overflow

Vegetated roof systems must be equipped with a roof drainage system capable of collecting subsurface and surface drainage and conveying it safely to a downstream BMP or an approved point of discharge. To facilitate subsurface drainage, interceptor drains (i.e., underdrains) are often installed at a regular spacing to prevent excessive moisture build up in the media and convey water to the roof drain. Roof outlets must be protected from encroaching plant growth and loose gravel, and must be constructed and located so that they are permanently accessible.

5.6.1.6. BMP Credits

Credit for On-site List Approach

A vegetated roof system may be selected to meet the On-site List Requirement (refer to *Section 3.3.1* and *Appendix C* for infeasibility criteria). The hard surface area covered by a vegetated roof system meets the requirement. To account for roof areas that cannot feasibly be covered by a vegetated roof system (e.g., access ways, roof vents), the entire roof area meets the On-site List Requirement if 80 percent of the roof is covered by a vegetated roof. If a smaller portion of the roof is covered by a vegetated roof, only the covered portion of the roof meets the On-site List Requirement and an additional BMP is required for the remaining area.

Pre-sized Approach for Flow Control

The Pre-sized Approach may be used for projects with new and replaced hard surface areas up to 10,000 square feet. Under the Pre-sized Approach (refer to *Section 4.1.2*), flow control credits toward meeting the Pre-developed Pasture and Peak Control Standards may be partially achieved by vegetated roof systems. Credits for vegetated roofs are provided in Table 5.38, organized by performance standard and growth media depth. These credits can be applied to reduce the hard surface area requiring flow control. Because the credits for vegetated roofs are less than 100 percent, the standard is not completely achieved and additional flow control measures will be required. As an example, for a site subject to the Peak Control Standard, a vegetated roof would receive an 80 percent credit. Therefore, 86 percent of the impervious area covered by the vegetated roof can be excluded from drainage calculations. The impervious area used to size the downstream flow control facility would be calculated as 20 percent of the impervious area covered by the vegetated roof.

Table 5.38. Pre-sized Flow Control Credits for Vegetated Roofs.

Vegetated Roof Type	Credit (%) Pre-developed Pasture Standard	Credit (%): Peak Control Standard
Single or Multi-course/ 4 inch minimum media depth	16%	80%

Impervious Area Managed = Vegetated roof Area x Credit (%)/100.

The flow control credits outlined above are applicable only if the vegetated roof meets the minimum design requirements outlined in this section and the minimum media depth specified in Table 5.38.

Alternatively, vegetated roofs can be sized using a continuous model as described below.

Modeling Approach for On-site Performance Standard and Flow Control

When using continuous simulation hydrologic modeling to quantify the on-site stormwater management and/or flow control performance of vegetated roof systems, the assumptions listed in Table 5.39 must be applied. It is recommended that vegetated roofs be modeled as layers of aggregate with surface flows, interflow, and exfiltrating flow routed to an outlet.

Table 5.39. Continuous Modeling Assumptions for Vegetated Roof Systems.

Variable[a]	Assumption
Precipitation Series	SEPTS-99 unless otherwise adopted by the Director
Computational Time Step	5 minutes
HSPF Parameters	LSUR, SLSUR, NSUR must be adjusted per *Appendix F*
Inflows to Facility	None
Precipitation and Evaporation Applied to Facility	Yes
Depth of Material (inches)	Growth media/soil depth (minimum of 4 inches). Currently, MGSFlood and the Western Washington Hydrology Model (WWHM) are not capable of representing the flow control benefits of the drainage layer or other storage beneath the growth media.
Vegetative Cover	Ground cover or shrubs. Shrubs are appropriate only when growth media is 6 inches or greater.
Length of Rooftop (ft)	The average surface flow path length from the most upstream point to the roof drain
Slope of Rooftop (ft/ft)	The slope of the vegetated roof
Discharge from Facility	Surface flow, interflow and exfiltrated flow from vegetated roof module routed to downstream BMP or point of compliance. Note that the exfiltrated flow (flow infiltrated through the media and collected by the drainage layer) is tracked as groundwater in MGSFlood and WWHM.

[a] Depending upon the hydrologic model used, some inputs may not be requested.

The media depth can be modified to achieve various degrees of flow control. Because the on-site stormwater management and flow control standards cannot typically be achieved using a vegetated roof, additional downstream flow control measures may be required.

5.6.1.7. Minimum Construction Requirements

The growth media must be protected from over compaction during construction.

5.6.1.8. Operations and Maintenance Requirements

Vegetated roof system O&M requirements are provided in *Appendix G* (*BMP No. 28*). A Landscape Management Plan must be developed and implemented for vegetation O&M. Irrigation must be provided for a minimum of five growing seasons. An Irrigation Design and Operation Plan must be included in the Vegetated Roof Maintenance Plan.

5.6.2. Permeable Pavement Surfaces

5.6.2.1. Description

Permeable pavement is a paving system which allows rainfall to percolate into the underlying subgrade. Two categories of permeable pavement BMPs are included in this manual: permeable pavement surfaces and permeable pavement facilities. A comparison of these BMPs is provided in *Section 5.4.6*.

A permeable pavement surface consists of a pervious wearing course (e.g., porous asphalt, pervious concrete) and an aggregate subbase installed over subgrade soil. The aggregate subbase is designed to manage only the water that falls upon it. Because permeable pavement surfaces are designed to function as a permeable land surface and not intended to manage runoff from other surfaces, they are not considered infiltration facilities and have less onerous siting and design requirements.

5.6.2.2. Performance Mechanisms

Flow control occurs through temporary storage of stormwater runoff in the voids of the aggregate material and subsequent infiltration of stormwater into the underlying soils. Pollutant removal mechanisms include infiltration, filtration and sedimentation, biodegradation, and soil adsorption.

5.6.2.3. Applicability

Permeable pavement surfaces can be designed to provide on-site stormwater management, flow control and/or water quality treatment. This BMP can be applied to meet or partially meet the requirements listed below.

BMP	On-site: List	On-site: Standard	Flow Control: Forest	Flow Control: Pasture	Flow Control: Peak	Water Quality: Basic	Water Quality: Enhanced Metals	Water Quality: Oil Control	Water Quality: Phosphorus	Conveyance
Permeable Pavement Surface	x	x	x[a]	x[a]	x[a]	x[a, b]	x[a, b]			

[a] Standard may be partially or completely achieved depending upon subgrade slope, infiltration rate of subgrade soil, and whether aggregate subbase is laid above or below surrounding grade.

[b] Underlying soil must meet the treatment soil requirements outlined in *Section 4.5.2* or a water quality treatment course must be included per *Section 5.4.6.5*.

5.6.2.4. Site Considerations

Since permeable pavement surfaces are not designed to receive runoff from other surfaces and are designed to function as a permeable land surface, they are not considered infiltration facilities. Therefore, the restrictions related to infiltration facilities (e.g., restrictions, setbacks, separation from groundwater) are not applicable. An exception is that infiltration testing is required for permeable pavement surfaces when hydrologic modeling will be conducted to evaluate performance relative to the flow control, water quality treatment or

On-site Performance Standard. Site considerations for the applicability of permeable pavement surfaces include:

- **Site topography**: The recommended maximum surface (wearing course) slope for permeable pavement surfaces is 6 percent to allow efficient storage of water within the subbase. For vehicular traction, the maximum surface slope varies by wearing course type (refer to industry guidelines). Minimum wearing course slope must be 1 percent unless provision is made for positive drainage in event of surface clogging.

  The recommended maximum subgrade slope for permeable pavement applications is 6 percent. Subgrades with slopes exceeding 5 percent require subsurface check dams to promote storage in the subgrade. At steeper subgrades slopes, design and construction become more complex and the construction cost increases.

- **Land use**: Because permeable pavement can clog with sediment, permeable pavement surfaces are not recommended where sediment and pollutant loading is unavoidable, including the following conditions:
  - Excessive sediment contamination is likely on the pavement surface (e.g., construction areas, landscaping material yards).
  - It is infeasible to prevent stormwater run-on to the permeable pavement from unstabilized erodible areas without presettling.
  - Regular, heavy application of sand is anticipated for maintaining traction during winter, or the facility is in close proximity to areas that will be sanded. A minimum 7-foot clearance is required between a permeable pavement facility and the travel lane of sanded arterial roads.
  - Sites where the risk of concentrated pollutant spills are more likely (e.g., gas stations, truck stops, car washes, vehicle maintenance areas, industrial chemical storage sites).
- **Accessibility**: As for standard pavement design, ADA accessibility issues must be addressed when designing a permeable pavement surface, particularly when using pavers.
- **Subsurface contamination**: Permeable pavement surfaces must not be sited:
  - Within 10 feet of an underground storage tank (or connecting underground pipes) used to store petroleum products, chemicals, or liquid hazardous wastes
  - Where the site is a contaminated site or abandoned landfill

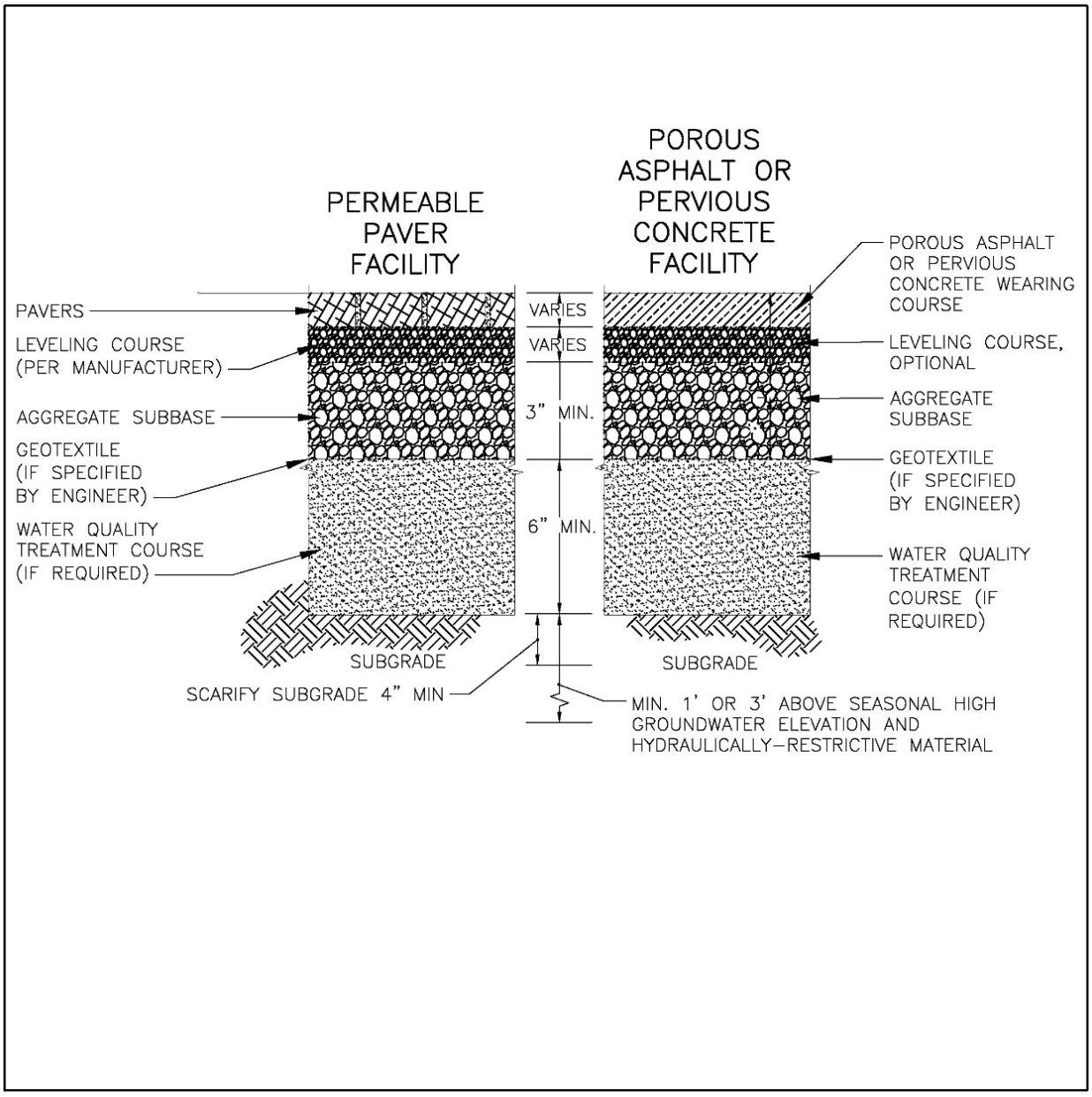
Refer to *Appendix C* for additional infeasibility criteria for the On-site List Approach.

5.6.2.5. Design Criteria

This section provides descriptions, recommendations, and requirements for the common components of permeable pavement surfaces. Some, or all, of the components may be used for a given application depending on the permeable pavement type (e.g., porous asphalt, pavers, etc.), site characteristics and restrictions, and design objectives. Typical components of a permeable pavement surface are shown in Figure 5.31. The design criteria for the

following components are the same as those presented for permeable pavement facilities (refer to *Section 5.4.6*):

- Wearing course
- Leveling course
- Subgrade
- Geotextile
- Water quality treatment course



[1] See Table C.3 of Appendix C to determine. Subsurface investigation is not required for permeable pavement surfaces, but subsurface investigation must be performed to demonstrate infeasibility due to lack of vertical separation.

Figure 5.31. Permeable Pavement Surface.

The requirements for the following components differ from permeable pavement facilities and the design criteria for these components are provided below.

- Contributing area
- Aggregate subbase
- Subgrade
- Subsurface check dams
- Overflow

Note that, unlike permeable pavement facilities, observation ports are not required, flow entrances, presettling, and underdrains are not applicable, and the aggregate is referred to as an aggregate subbase instead of storage reservoir.

The structural design of permeable pavement to support anticipated loads is outside the scope of this manual.

The Puget Sound LID Manual provides additional guidance on permeable pavement design.

Contributing Area

Permeable pavement surfaces must not be designed to receive significant runoff from other areas (run-on). In no case may the surface receive run-on from an impervious area greater than 10 percent of the permeable pavement area. Any run-on must be dispersed. To prevent sediment flowing onto the pavement, run-on must not occur from erodible/unstabilized areas or from impervious areas that receive run-on from unstabilized areas.

Aggregate Subbase

Stormwater passes through the wearing and leveling courses to an underlying aggregate subbase where it is filtered and stored prior to infiltration into the underlying soil. This aggregate also serves as the pavement's support base and must be sufficiently thick to support the expected loads. Design of the subgrade for loading is outside of the scope of this manual. A licensed engineer is needed to determine subsoil load bearing, minimum aggregate base thickness, and aggregate compaction for loading.

Minimum requirements associated with the aggregate subbase design include the following:

- A 3-inch minimum depth of aggregate subbase is required. Note that more depth may be needed for constructability and placement of the subbase material (due to size of rock in the subbase) and for structural design support.
- The aggregate base must have a minimum total void volume of 25 percent after compacted in place. Percent voids (porosity) must be determined in accordance with ASTM C29/C29M. Use the jigging procedure to densify the sample (do not use the shoveling procedure).
- Aggregate material must have 0 to 2 percent passing #200 wet sieve.

- For walkways, the following aggregate materials are recommended and meet the requirements listed above:
  - City of Seattle Mineral Aggregate Type 24
  - Modified AASHTO #57 per WSDOT 2020 Section 9-03.1(4)C with 0 to 2 percent passing #200 wet sieve; percent fracture must be in accordance with requirements per WSDOT 2020 9-03.9(2).
- For vehicular applications, the following aggregate materials are recommended and meet the requirements listed above:
  - City of Seattle Mineral Aggregate Type 13
  - Modified AASHTO #57 per WSDOT 2020 Section 9-03.1(4)C with 0 to 2 percent passing #200 wet sieve; percent fracture must be in accordance with requirements per WSDOT 2020 9-03.9(2).
  - Permeable ballast per WSDOT 2020 Section 9-03.9(2)

Subgrade

The minimum measured subgrade infiltration rate for permeable pavement surfaces is 0.3 inch per hour for meeting Flow Control, Water Quality Treatment, and the On-site Performance Standards unless the BMP is modeled using an approved continuous runoff model and the minimum 48-hr drawdown is demonstrated. There is no minimum subgrade infiltration rate for meeting the On-site List Approach. Infiltration testing is not required to use permeable pavement surfaces to meet the On-site List Approach, but may be used to demonstrate infeasibility (i.e., measured infiltration rates less than 0.3 inch per hour). If permeable pavement surfaces are to be used to meet the water quality treatment requirement, underlying soil must meet the treatment soil requirements outlined in *Section 4.5.2* or a water quality treatment course must be included.

During construction the subgrade soil surface can become smeared and sealed by excavation equipment. The design must require scarification or raking of the side walls and bottom of the facility excavation to a minimum depth of 4 inches after excavation to restore infiltration rate.

Subsurface Check Dams

Sloped facilities have an increased potential for lateral flows through the aggregate subbase along the top of the relatively impermeable subgrade soil. This poses a risk of subsurface erosion and reduces the storage and infiltration capacity of the pavement surface. If required depending upon slope, the subgrade must be designed to create subsurface ponding to detain subsurface flow, increase infiltration, and reduce structural problems associated with subgrade erosion on slopes (refer to Figure 5.20 in *Section 5.4.6*). In such cases, ponding must be provided using periodic lateral subsurface barriers (e.g., check dams) oriented perpendicular to the subgrade slope. While the frequency of the check dams is calculated based on the required subsurface ponding depth and the subgrade slope, typical designs include barriers at least every 3 inches of grade loss.

Minimum requirements associated with lateral subsurface barriers include the following:

- Permeable pavement surfaces with subgrade slopes greater than 5 percent must include subsurface check dams to reduce structural problems associated with subgrade

erosion on slopes, unless a geotechnical evaluation of subgrade soils shows that check dams are unnecessary for erosion control.

- Subsurface check dams must be impermeable and restrict lateral flow along the top of the subgrade soil.
- The check dams must not extend to the elevation of the surrounding ground.

Design of Underdrained Surfaces to be Equivalent to Permeable Pavement Surfaces

Areas with underdrains, such as athletic fields, play areas, synthetic turf yards, etc., are hard surfaces per the definitions of "impervious surface" and "hard surface" in Appendix A of this Stormwater Manual. However, they can be designed to act equivalently to a permeable pavement surface if they meet all of the design criteria for permeable pavement surfaces and the following criteria are met:

- The 3-inch minimum aggregate subbase for the entire underdrained area is located below the lowest underdrain or subsurface check dams are added to ensure at least 3 inches of subsurface ponding will occur across the entire underdrained area. Note that additional aggregate depth may be needed for constructability and placement of the subbase material (due to size of rock in the subbase), for structural design support, or for stormwater storage.
- The materials above and below the subbase aggregate are free-draining and no impermeable liners are used.

5.6.2.6. BMP Sizing

Sizing for On-site List Approach

Permeable pavement surfaces must be selected to meet the On-site List Requirement (refer to *Section 3.3.1* and *Appendix C* for infeasibility criteria). The area of permeable pavement surface meets the requirement.

Pre-sized Approach for Flow Control

The Pre-sized Approach may be used for projects with new and replaced hard surface areas up to 10,000 square feet. Under the Pre-sized Approach (refer to *Section 4.1.2*), pre-sized permeable pavement surfaces receive credits toward meeting the Pre-developed Pasture and Peak Control Standards. Credits for permeable pavement surfaces are provided in Table 5.40, organized by performance standard and subgrade slope. These credits can be applied to reduce the hard surface area requiring flow control. If partial credit (less than 100 percent) is received, the standard is not completely achieved and additional measures will be required. As an example, for a site subject to the Peak Control Standard, a permeable pavement surface on subgrade with a slope exceeding 2 percent would receive a 71 percent credit. Therefore, 71 percent of the permeable pavement surface can be excluded from drainage calculations. The impervious area (the area used to size the downstream flow control facility) would be calculated as 29 percent of the permeable pavement surface area.

Table 5.40. Pre-sized Flow Control Credits for Permeable Pavement Surfaces with and without Check Dams.

	Subgrade Slope	Credit (%): Pre-developed Pasture Standard	Credit (%): Peak Control Standard	Credit (%): Water Quality Treatment Standard[a]
Without Check Dams	Up to 2%	25%	7%	88%
	>2%	0%	0%	6%
With Check Dams	Up to 2%	100%	63%	100%
	>2%	99%	68%	100%

Impervious Area Managed = Permeable Pavement Surface Area x Credit (%)/100.

[a] Pre-sized Approach may be used to meet basic water quality treatment. Metals water quality treatment may be achieved if soil suitability criteria are met (refer to *Section 4.5.2*) or an appropriate water quality treatment course is used.

To use these flow control credits to meet flow control standards, the BMP must meet the general requirements for permeable pavement surfaces outlined in this section plus the following specific requirements:

- The aggregate subbase must be at least 3 inches in depth.
- Subgrade slope must be as specified in the table.
- The minimum measured infiltration rate must be at least 3 inches/hour.
- To meet water quality treatment, the underlying soil must meet the treatment soil requirements outlined in *Section 4.5.2* or a water quality treatment course must be used.
- No underdrain or low-permeability liner or impermeable liner may be used.

For subgrade slopes exceeding 2 percent, flow control performance is lower. For improved performance, the surface may be designed as a permeable pavement facility with subsurface ponding and/or increased aggregate subbase depth. In this case, the surface must be evaluated as a permeable pavement facility (refer to *Section 5.4.6*).

Alternatively, the performance of permeable pavement surfaces can be evaluated using a continuous simulation hydrologic model as described below.

Modeling Approach for On-site Performance Standard, Flow Control, and Water Quality Treatment

The approved continuous simulation hydrologic modeling methods for permeable pavement surfaces vary as shown in Table 5.41.

For flat and low slope permeable pavement surface installations (0 to 2 percent) with subgrade below the surrounding grade, the aggregate subbase depth may be iteratively sized until the performance standard(s) are met. For other scenarios, partial credit toward meeting standards can be achieved and runoff from the pavement area can be routed to a downstream BMP.

Table 5.41. Modeling Methods for Permeable Pavement Surfaces.

Subbase	Wearing Course	Subgrade Slope	Modeling Representation	Performance
Subbase below (or partially below) the surrounding grade without internal dams within the base materials	Any	0–2%	Model subbase storage and infiltration into underlying soil explicitly. The aggregate subbase depth should be set at the depth of the aggregate below the surrounding grade. Refer to Table 5.42.	The aggregate subbase depth may be sized to meet performance standards.
		>2%	Model subbase storage and infiltration into underlying soil explicitly with an infiltration rate and a total effective depth of 1 inch. The dimensions of the simulated permeable pavement must be equal to the below grade base materials. If required for simulation, an overflow riser must have a height of 0.5 inch and a diameter of 1,000 inches (to ensure there is minimal head on the riser). Refer to Table 5.42.	Partial credit toward performance standard may be achieved. To fully meet performance standards on sloped subgrade, use permeable pavement facility (refer to *Section 5.4.6*).
Subbase below (or partially below) the surrounding grade with internal check dams within the base material	Any	Any	Model subbase storage and infiltration into underlying soil explicitly. Model each cell of permeable pavement that is separated by internal dams separately as a gravel-filled trench. The dimensions of each simulated cell must be equal to the below grade base materials with a storage depth equal to the average depth of water behind the downstream check dam. If required for simulation, an overflow riser must have a height equal to the storage depth and a diameter of 1,000 inches (to ensure there is minimal head on the riser). Each cell should have an appropriate tributary drainage area equal to the permeable pavement area above. Refer to Table 5.42.	Partial credit toward performance standard may be achieved.

Table 5.42. Continuous Modeling Assumptions for Permeable Pavement Surface.

Variable	Assumption
Precipitation Series	SEPTS-99 unless otherwise adopted by the Director
Computational Time Step	5 minutes
HSPF Parameters	LSUR, SLSUR, NSUR must be adjusted per *Appendix F*
Permeable Pavement Surface	Option 1: WWHM and MGSFlood have an element specifically developed for permeable pavement that simulates precipitation falling on the pavement, infiltration through the pavement section, storage in the aggregate beneath the pavement, and infiltration into the underlying soil. Option 2: If a permeable pavement element is not available, represent the permeable pavement area as an impervious basin with runoff routed to a gravel-filled trench (of the same size as the permeable pavement area) with infiltration to underlying soil. The gravel-filled trench represents the pavement's underlying aggregate layer. Refer to Table 5.27 "Permeable Pavement Facility and Contributing Area" row for guidance on modeling run-on from other contributing drainage areas. Additional areas draining to permeable pavement surfaces are limited to 10% of the permeable pavement area.
Precipitation Applied to Surface	If using Option 1, precipitation is applied to the pavement area. If using Option 2, do not apply precipitation to the trench bed because precipitation is already applied to basin before routing to trench.
Evaporation Applied to Surface	If using Option 1, evaporation is applied to the pavement area. If using Option 2, evaporation is applied to the impervious basin before routing to the trench.
Aggregate Subbase Depth	When the subgrade slope is 0 to 2%, use the depth of the aggregate subbase below surrounding grade. When the subgrade slope exceeds 2%, use a total effective depth of 1 inch.
Aggregate Subbase Porosity	Assume maximum 25% unless test result is provided showing higher porosity (up to 35%) for aggregate compacted and in place.
Subgrade Soil Design Infiltration Rate	Design infiltration rate (*Section 4.5.2*, *Appendix D*)
Infiltration Across Wetted Surface Area	No (infiltration on bottom area only)
Outlet Structure	Unless the selected model represents surface sheet flow when pavement section is saturated, the overflow can be simulated as overtopping an overflow riser. Overflow riser elevation is set at average maximum subsurface ponding depth. Flow may be modeled as weir flow over riser edge. Freeboard modeled within the storage reservoir must be sufficient to allow the water surface elevation to rise above the weir or overflow pipe elevation to provide head for discharge.

5.6.2.7. Minimum Construction Requirements

The construction specifications and criteria for permeable pavement surfaces are the same as those presented for permeable pavement facilities (refer to *Section 5.4.6.7*).

5.6.2.8. Operations and Maintenance Requirements

Permeable pavement O&M requirements are provided in *Appendix G* (*BMP No. 26)*.

5.7. Detention BMPs

Detention facilities provide for the temporary storage of stormwater runoff. Stormwater is then released through a control structure at an attenuated rate to meet flow control performance standards. The BMPs in this section include:

- Detention ponds
- Detention pipes
- Detention vaults/chambers
- Detention cisterns
- Other detention options

5.7.1. Detention Ponds

5.7.1.1. Description

Detention ponds are basins that temporarily store runoff and control release rates. Detention ponds may be designed to drain completely between storm events or designed as a combination water quality treatment and flow control facility. The combination of water quality treatment and flow control functions is summarized in *Section 5.8.9*.

5.7.1.2. Performance Mechanisms

Detention ponds provide peak flow attenuation by slowly releasing low flows through an outlet control structure.

5.7.1.3. Applicability

Detention ponds can be applied to meet or partially meet the requirements listed below.

BMP	On-site: List	On-site: Standard	Flow Control: Forest	Flow Control: Pasture	Flow Control: Peak	Water Quality: Basic	Water Quality: Enhanced Metals	Water Quality: Oil Control	Water Quality: Phosphorus	Conveyance
Detention Pond		x[a]	x	x	x					x

[a] Standard may be partially achieved for smaller contributing areas.

5.7.1.4. Site Considerations

Detention ponds require a large amount of area. In addition to the area required for the pond, maintenance access must be provided, which can affect the footprint of the pond and in part determine whether they are feasible for a particular site. In a highly developed area like the City of Seattle, large open ponds are somewhat uncommon.

Setback requirements for detention ponds are intended to protect neighboring properties from flooding and protect receiving waters and critical areas from water quality impacts. Refer to Volume V of the SWMMWW for detention pond setback requirements. The following additional setback requirements also apply to detention ponds installed within the City limits:

- A minimum 5-foot setback is required from the toe of the exterior slope to the property line.
- A minimum 5-foot setback is required from the emergency overflow water surface to the property line.
- Geotechnical analysis is required for facilities within 20 feet of any structure or property line or within 50 feet up-slope of a structure when the slope between the top of the pond and the structure is greater than 15 percent.
- Detention ponds are not allowed within steep slopes, known landslide areas, and their 15foot buffers as defined by the regulations for ECAs (SMC, Section 25.09.012). For detention ponds within a setback equal to the height of the slope to a maximum of 50 feet from the top of steep slope and known landslide area, a slope stability assessment must be completed by a licensed geotechnical engineer or engineering

geologist considering the effects on slope stability due to a leaking or damaged detention BMP.

5.7.1.5. Design Criteria

The design criteria in this section are for detention ponds. However, many of the criteria also apply to infiltration ponds (*Section 5.4.8*), as well as wet ponds and combined detention/wet pools (*Section 5.8.9*).

The following provides a description and requirements for the components of detention ponds. Some or all of the components may be used for a given application depending on the site characteristics and restrictions, pollutant loading, and design objectives. Design criteria are provided in this section or in Volume V of the SWMMWW for the following elements:

Design Element	SWMMWW Design Criteria	Seattle-specific Design Criteria
Detention pond geometry	x	x
Access to cells for maintenance	x	x
Fencing	x	x
Embankments and failure analysis	x	x
Dam safety	x	x
Vegetation and landscaping	x	x
Design and construction of access roads	x	
Primary overflow	x	
Emergency overflow spillway	x	

Refer to Detention Ponds in Volume V of the SWMMWW for specific detention pond design criteria. The City's design criteria for specific design elements are summarized below.

Detention Pond Geometry

Refer to Detention Ponds in Volume V of the SWMMWW for detention pond design considerations. The following additional requirements must be followed for detention ponds installed in Seattle:

- Vertical retaining walls and fencing must be used for areas of the pond designed for sediment removal by Vactor.
- Any pond cell allowing or requiring entry for maintenance, including vegetation maintenance, must have a section of interior side slopes of 4H:1V for safe egress.

Flow Control Riser

Refer to City of Seattle Standard Plan No. 272 and *Appendix E, Section E-1,* for flow control riser details and design criteria. The minimum allowed orifice diameter is 0.5 inches, and the minimum allowed weir width is 0.25 inches. See Section 4.1.3.2 for modeling guidance when the minimum allowed orifice diameter does not allow the flow control standard to be met.

Access to Cells for Maintenance

Refer to Detention Ponds in Volume V of the SWMMWW for access design considerations. The following additional requirement must be followed for detention ponds installed in Seattle:

- An access plan is required for sediment removal from all cells.

Fencing

Refer to Detention Ponds in Volume V of the SWMMWW for fencing considerations. Fencing requirements will depend on the specific site and possibly on land use requirements. Fencing and gates will be evaluated as part of planning for access for maintenance in addition to public access or exclusion planning.

Embankments and Failure Analysis

Refer to Detention Ponds in Volume V of the SWMMWW for embankment design requirements. The following additional requirements must be followed for detention ponds installed in Seattle:

- If an embankment is proposed to impound water, early conversations with SPU and SDCI are encouraged. Impoundment of a water volume exceeding 10 acre-feet is considered a dam and is regulated by Ecology, and SPU must be notified. Materials provided to Ecology must be submitted to SPU upon request.
- A failure analysis describing impacts of embankment failure must be provided.

Dam Safety

Refer to Detention Ponds in Volume V of the SWMMWW for dam safety requirements. The following additional requirement must be followed for detention ponds installed in Seattle:

- Detention facilities that can impound 10 acre-feet or more with the water level at the embankment crest must meet the state's dam safety requirements, even if water storage is intermittent and infrequent (WAC 173-175-020(1)).

Ecology contact information and electronic versions of the guidance documents in PDF format are available on the Ecology website at (https://ecology.wa.gov/Water-Shorelines/Water-supply/Dams).

Vegetation and Landscaping

Refer to Detention Ponds in Volume V of the SWMMWW for vegetation and landscaping requirements. The following additional requirements must be followed for detention ponds installed in Seattle:

- A plan for landscape establishment is required. Consider installation of a hose bib and water service for watering.
- All planted slopes must be accessible for vegetation maintenance.
- Use of ornamental plantings in the vicinity of a detention pond are discouraged and may not be allowed to due concerns regarding seed transport.

5.7.1.6. BMP Sizing

Refer to Detention Ponds in Volume V of the SWMMWW for BMP Sizing considerations.

5.7.1.7. Minimum Construction Requirements

The following construction requirements should be considered during construction of a detention pond:

- Detention ponds may be used for sediment control during site construction, but sediment must be removed upon completion.
- Exposed earth on the pond bottom and interior side slopes must be vegetated or seeded with an appropriate seed mixture.

5.7.1.8. Operations and Maintenance Requirements

Detention pond O&M requirements are provided in *Appendix G* (*BMP No. 1*).

5.7.2. Detention Pipes

5.7.2.1. Description

Detention pipes are underground storage facilities for stormwater. Detention pipes can be combined with rainwater harvesting (refer to *Section 5.5.1*).

5.7.2.2. Performance Mechanisms

Detention pipes provide peak flow attenuation by slowly releasing low flows through an orifice.

5.7.2.3. Applicability

Detention pipes can be applied to meet or partially meet the requirements listed below.

BMP	On-site: List	On-site: Standard	Flow Control: Forest	Flow Control: Pasture	Flow Control: Peak	Water Quality: Basic	Water Quality: Enhanced Metals	Water Quality: Oil Control	Water Quality: Phosphorus	Conveyance
Detention Pipe		x[a]	x[b]	x[b]	x[b]					x

[a] Standard may be partially achieved for smaller contributing areas.

[b] Standard may be partially or completely achieved depending upon contributing area and minimum orifice size.

5.7.2.4. Site Considerations

The primary site considerations for detention pipes include conflicts with existing underground utilities, building foundation and steep slopes and landslide prone areas. While there are no specific setback requirements for detention pipes from buildings, detention pipe location and pipe material approval is required and may require geotechnical analysis.

Detention pipes are not allowed within steep slopes, known landslide areas, and their 15-foot buffers as defined by the regulations for ECAs (SMC, Section 25.09.012). For detention pipes within a setback equal to the height of the slope to a maximum of 50 feet from the top of steep slope and known landslide area, a slope stability assessment must be completed by a licensed geotechnical engineer or engineering geologist considering the effects on slope stability due to a leaking or damaged detention BMP. More stringent watertightness/ exfiltration field testing of detention pipes within a 50-foot setback from the top of the steep slope and known landslide area may be required.

Additionally, pipe systems that do not provide a watertight seal (e.g., CMP pipe) are not allowed within 200 feet from the top of an ECA steep slope, landslide prone area, or known landslide area or under buildings or other structures.

Grading and drainage collection on the site are important site considerations that can impact flow control effectiveness. Special care may be necessary, particularly with roadway projects, to match BMP sizing to actual runoff collected and conveyed to the facility.

5.7.2.5. Design Criteria

The following provides a description and requirements for the components of detention pipes. Components of a typical private property detention pipe are shown in Figure 5.32. Some or all

of the components may be used for a given application depending on the site characteristics and restrictions and design objectives. Design criteria are provided in this section for the following elements:

- Pipe Materials
- Flow Control Riser / Structure
- Bedding
- Structural stability
- Access
- Vents

Detention Pipe Materials

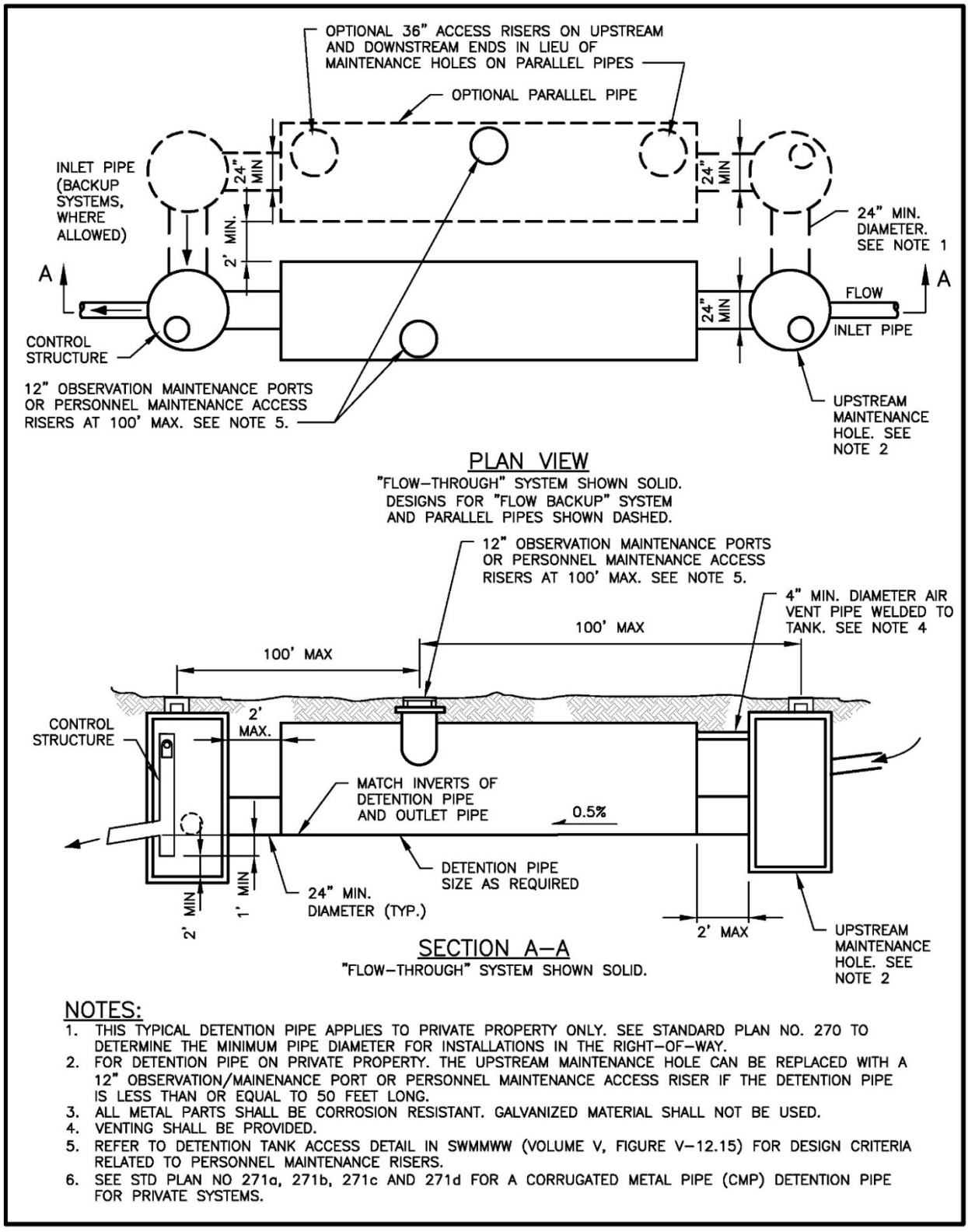
The material, diameter, and specification of the detention pipe must be indicated on the drainage plans required before installing the drainage facility. Typical design requirements for detention pipes are shown in City of Seattle Standard Plan No. 270 through 272 and provided in the SPU Director's Rule 2011-4 - *Requirements for Design and Construction of Side Sewers (Drainage and Wastewater Discharges)* (aka Side Sewer Directors' Rule), which can be found on the SPU Side Sewer Permit website (https://www.seattle.gov/utilities/construction-resources/sewer-and-drainage/side-sewer-permits) proposals for alternate materials, or alternate bulkhead designs must be submitted with loading calculations.

Flow Control Riser / Structure

Refer to City of Seattle Standard Plan No. 272 and *Appendix E, Section E-1,* for flow control riser and structure details and design criteria. The minimum allowed orifice diameter is 0.5 inches, and the minimum allowed weir width is 0.25 inches. See Section 4.1.3.2 for modeling guidance when the minimum allowed orifice diameter does not allow the flow control standard to be met.

Bedding

All detention pipe bedding installed on public property must be per the City of Seattle Standard Specifications for Road, Bridge and Municipal Construction.



NOTES:

1. THIS TYPICAL DETENTION PIPE APPLIES TO PRIVATE PROPERTY ONLY. SEE STANDARD PLAN NO. 270 TO DETERMINE THE MINIMUM PIPE DIAMETER FOR INSTALLATIONS IN THE RIGHT-OF-WAY.
2. FOR DETENTION PIPE ON PRIVATE PROPERTY. THE UPSTREAM MAINTENANCE HOLE CAN BE REPLACED WITH A 12" OBSERVATION/MAINENANCE PORT OR PERSONNEL MAINTENANCE ACCESS RISER IF THE DETENTION PIPE IS LESS THAN OR EQUAL TO 50 FEET LONG.
3. ALL METAL PARTS SHALL BE CORROSION RESISTANT. GALVANIZED MATERIAL SHALL NOT BE USED.
4. VENTING SHALL BE PROVIDED.
5. REFER TO DETENTION TANK ACCESS DETAIL IN SWMMWW (VOLUME V, FIGURE V-12.15) FOR DESIGN CRITERIA RELATED TO PERSONNEL MAINTENANCE RISERS.
6. SEE STD PLAN NO 271a, 271b, 271c AND 271d FOR A CORRUGATED METAL PIPE (CMP) DETENTION PIPE FOR PRIVATE SYSTEMS.

Figure 5.32. Typical Private Property Detention Pipe.

Structural Stability

The following structural requirements apply to detention pipes:

- Detention pipes must meet structural requirements for overburden support, buoyancy, and traffic loading as appropriate.
- Detention pipes and associated structures must be watertight and the finished detention pipe system must be field tested as described in *Section 5.7.2.7*.
- When a detention pipe is located under a building, provide a load analysis and show the detention pipe on the structural plans for the building for structural review in addition to the drainage plans. The pipe must not be located under the foundation or have pressure exerted on it by the foundation. In moderately pervious soils where seasonal groundwater may induce flotation, buoyancy tendencies must be balanced either by ballasting with backfill or concrete backfill, providing concrete anchors, or increasing the total weight.
- When corrugated metal pipe is selected, end plates must be designed for structural stability at maximum hydrostatic loading. Flat end plates generally require thicker gage material than the pipe and/or require reinforcing ribs. Corrugated metal pipe is not allowed for use in the right-of-way, critical areas, geologic hazard areas, or underneath buildings.
- When an alternate to the City of Seattle Standard Plans is proposed (including materials, end plates or combination Ttop maintenance hole and end plate, or end plate with a smaller pipe connecting to a standard maintenance hole), the alternate must be designed for structural stability at maximum hydrostatic loading and to be watertight. Alternates to City of Seattle Standard Plan No. 270 are not allowed for use in the right-of-way.
- Detention pipes must be placed on a stable, well consolidated foundation, have suitable bedding, and must follow City of Seattle Standard Specifications for Road, Bridge, and Municipal Construction.
- Detention pipes must not be placed in fill slopes, unless a geotechnical analysis is provided for stability and constructability.

Access

The following access requirements apply to detention pipes in the right-of-way:

- A maintenance hole structure is required at all access points as shown on City of Seattle Standard Plan No. 270.
- Truck access is required at each maintenance hole location.

The following access requirements apply to detention pipes on private property:

- A maintenance hole structure must be provided for the flow control riser per City of Seattle Standard Plan No. 270 or 271.
- A maintenance hole structure per City of Seattle Standard Plan 204 (or larger) must be provided at the upstream and downstream ends of each detention pipe run and at a maximum spacing of 350 feet, except as follows:
    - A 36-inch-diameter vertical pipe with ladder and a 24-inch-diameter locking manhole frame and cover per the Detention Tank Access Detail in the SWMMWW

(Volume V, Figure V-13.15) may be used in lieu of maintenance hole structures on the upstream and downstream ends of detention pipe systems with parallel pipe runs except for the flow control structure.

  - Detention pipes less than 50 feet long may substitute a 12-inch minimum observation/maintenance port with locking lid for the maintenance hole at the upstream end.

- In addition, either observation/maintenance ports or personnel maintenance access are required at a maximum spacing of 100 feet along pipe spans.
  - Observation/maintenance ports must consist of a 12-inch minimum diameter opening with unobstructed view down to the bottom of the pipe. The ports must have locking lids.
  - Personnel maintenance accesses must consist of either a maintenance hole per City of Seattle Standard Plan 204 (or larger depending on the detention pipe size), or a 36 inch-diameter vertical pipe with ladder and a 24 inch-diameter locking manhole frame and cover per the Detention Tank Access Detail in the SWMMWW (Volume V, Figure V 13.15).
- Alternate configurations may be approved only when a plan for cleaning and maintenance access for any equipment and personnel required and for visual inspection by City of Seattle inspection personnel has been prepared and submitted for review.

In addition, the following access requirements apply to both detention pipes in the right-of-way and on private property:

- All detention pipe openings and flow control structures must be readily accessible for maintenance personnel, maintenance vehicles, and City of Seattle inspection personnel.
- Multiple detention pipes that are connected to a single flow control structure must be connected between structures with pipe of a minimum 24-inch diameter. Larger diameter connecting pipe is preferred.
- Connector pipes for manifolded detention pipes or for the connection between a maintenance hole structures must be a minimum of 24-inch diameter.

Vents

A 4” diameter vent pipe is required on the upstream end of each detention pipe run where the detention pipe is a larger diameter than the pipe that connects to a maintenance hole. If an observation/maintenance port or access riser is placed at the upstream end of the detention pipe run, then the vent is not required.

5.7.2.6. BMP Sizing

Pre-sized Approach for Flow Control

The Pre-sized Approach may be used for projects with new and replaced hard surface areas up to 10,000 square feet. Under the Pre-sized Approach (refer to *Section 4.1.2*), pre-sized detention pipes may be used to achieve Pre-developed Pasture and Peak Control Standards. Sizing factors for detention pipe receiving runoff from a hard surface are provided in Table 5.43. Sizing factors are organized by pipe diameter, contributing area, and flow control standard. To use these sizing factors to meet flow control standards, the facility must meet

the general requirements for detention pipes outlined in this section, plus the following specific requirements:

- Sizing equations are applicable for contributing areas between 2,000 and 10,000 square feet.
- Pipe length must be sized using the applicable sizing equation.
- The low flow orifice diameter must be 0.5 inch.
- Detention pipe must be the designated diameter (24 or 36 inches). For intermediate diameters (between 24 and 36 inches), the pipe length may be linearly interpolated.
- The entire volume of the pipe must be available for storage (overflow riser must be set equal to the crown of the pipe).
- The pre-sized equations must not be used for detention pipes constructed within the public right-of-way because the equations do not account for the 2" difference from the invert of the detention pipe to the invert of the outlet pipe shown on City of Seattle Standard Plan 270.

The pipe length is calculated as a function of the hard surface area routed to it. As an example, for the Pre-developed Pasture Standard, the pipe length for a 24-inch-diameter pipe receiving runoff from between 2,000 to 10,000 square feet of hard surface would be calculated as:

0.0571 x contributing hard surface area (square feet) + 49.5 feet

All area values must be in square feet and length values must be in feet. Alternatively, detention pipes for small sites can be sized using a continuous model as described in the subsequent section.

Table 5.43. Pre-sized Sizing Equations for Detention Pipe.

Detention Pipe Diameter[a]	Contributing Area	Sizing Equation for Pipe Length: Pre-developed Pasture Standard	Sizing Equation for Pipe Length: Pre-Developed Pasture Standard Orifice Diameter for Construction	Sizing Equation for Pipe Length: Peak Control Standard	Sizing Equation for Pipe Length: Peak Control Standard Orifice Diameter for Construction
24 inches	2,000 – 5,000 sf	[0.0571 x A] + 49.5	0.5	[0.0475 x A] + 27	0.5
	5,001 – 6,000 sf	[0.0571 x A] + 49.5	0.5	[0.0475 x A] + 27	0.5
	6,001 – 8,500 sf	[0.0571 x A] + 49.5	0.5	[0.0475 x A] + 27	0.625
	8,501 – 10,000 sf	[0.0571 x A] + 49.5	0.5	[0.0475 x A] + 27	0.75

Table 5.43 (continued). Pre-sized Sizing Equations for Detention Pipe.

Detention Pipe Diameter[a]	Contributing Area	Sizing Equation for Pipe Length: Pre-developed Pasture Standard	Sizing Equation for Pipe Length: Pre-Developed Pasture Standard Orifice Diameter for Construction	Sizing Equation for Pipe Length: Peak Control Standard	Sizing Equation for Pipe Length: Peak Control Standard Orifice Diameter for Construction
36 inches	2,000 – 5,000 sf	[0.0257 x A] + 21.8	0.5	[0.0236 x A] + 6.75	0.5
	5,001 – 7,000 sf	[0.0257 x A] + 21.8	0.5	[0.0236 x A] + 6.75	0.5
	7,001 – 10,000 sf	[0.0257 x A] + 21.8	0.5	[0.0236 x A] + 6.75	0.625

A – contributing hard surface area; ft – feet; sf – square feet.

For Peak Control Standard: Pipe Length (ft) = Factor x [A (sf) ^ Integer].

Hard Surface Area Managed (sf) = [Pipe Length (ft) ÷ Factor] ^ (1 ÷ Integer).

For Pre-developed Pasture Standard: Pipe Length (ft) = [Factor x A (sf)] + Integer.

Hard Surface Area Managed (sf) = [Pipe Length (ft) - Integer] ÷ Factor.

[a] Detention pipe diameter refers to live storage depth (i.e., does not include freeboard or sediment storage requirements).

Modeling Approach for On-site Performance Standard and Flow Control

When using the continuous runoff model for pipe sizing, the assumptions listed in Table 5.44 must be applied. It is recommended that pipes be modeled as horizontal cylinders with an outlet structure that includes a low flow orifice. The contributing area, pipe diameter, pipe length and orifice configuration should be iteratively sized until the Minimum Requirements for Flow Control are met (refer to *Volume 1, Section 5.3*).

For smaller contributing areas, the minimum diameter for the low flow orifice (0.5 inch) will be too large to meet standard release rates, even with minimal head. Refer to *Section 4.1.3.2* for contributing area thresholds and an alternative modeling approach for smaller contributing areas. The designer is advised to evaluate other detention BMPs, including vaults, since the required pipe slope, minimum orifice size, and contributing area may make the detention pipe BMP impractical. Evaluation of a detention pipe diameter less than 18 inches is not advised. Refer to *Section 4.1.3.2* for additional flow control modeling guidance.

Table 5.44. Continuous Modeling Assumptions for Detention Pipe.

Variable	Assumption
Precipitation Series	SEPTS-99 unless otherwise adopted by the Director
Computational Time Step	5 minutes
HSPF Parameters	LSUR, SLSUR, NSUR must be adjusted per Appendix F
Inflows to Facility	Surface flow and interflow from total drainage area (including impervious and pervious contributing areas) be connected to the facility
Precipitation and Evaporation Applied to Facility	No
Infiltration	No
Total Depth	The total depth is the pipe diameter (i.e., live storage depth)
Outlet Structure	Low flow orifice, riser height and diameter
Low Flow Orifice	Minimum diameter of 0.5 inch, set 1 foot below the pipe invert

5.7.2.7. Minimum Construction Requirements

Construction requirements are as follows:

- Place at least 4 inches of bedding under the pipe. The bedding must fill the trench to a point half-way up the sides of the pipe (to the "spring line").
- Provide at least 2 feet of cover over a detention pipe. For single-family and duplex residences, 18 inches of cover is allowable. Before a side sewer permit is signed off as completed, a City inspector must approve the installed system, including the detention pipe and the flow control structure, after it is bedded but before it is covered with soil.
- The standard slope for detention pipes is 0.5 percent. The inlet pipe to the detention pipe and the outlet pipe from the flow control structure must have at least a 2 percent slope, the same as required for other service drain pipes.
- Detention pipe systems must be field tested for exfiltration (i.e., watertightness) as follows:
  - Plug the inlets and outlet and fill the system to one-half the distance from the outlet invert to the top of the riser on the outlet structure.
  - The maximum allowable leakage must not exceed 1 percent of the volume over a 24hour period
- Field changes to the flow control device assembly, including elevation changes, require submittal to the Engineer of Record for confirmation that the device still meets the design requirements.

5.7.2.8. Operations and Maintenance Requirements

Detention pipe O&M requirements are provided in *Appendix G* (*BMP No. 3*).

Alternate configuration of detention pipes must document a plan for cleaning and maintenance access for any equipment and personnel required.

5.7.3. Detention Vaults/Chambers

5.7.3.1. Description

Detention vaults/chambers are underground storage facilities for stormwater. Detention vaults/chambers can be combined with rainwater harvesting (refer to *Section 5.5.1*). Stackable, modular detention chambers can also be used.

5.7.3.2. Performance Mechanisms

Detention vaults/chambers provide peak flow attenuation by slowly releasing low flows through an orifice.

5.7.3.3. Applicability

Detention vaults/chambers can be applied to meet or partially meet the requirements listed below.

BMP	On-site: List	On-site: Standard	Flow Control: Forest	Flow Control: Pasture	Flow Control: Peak	Water Quality: Basic	Water Quality: Enhanced Metals	Water Quality: Oil Control	Water Quality: Phosphorus	Conveyance
Detention Vault/ Chamber		x[a]	x[b]	x[a, b]	x[b]					x

[a] Standard may be partially achieved for smaller contributing areas.

[b] Standard may be partially or completely achieved depending upon contributing area and minimum orifice size.

5.7.3.4. Site Considerations

Detention vaults/chambers are typically shallower than detention pipes, since they can utilize a greater area. Primary site considerations for a detention vault/chamber include providing sufficient access points for maintenance, incorporating the access requirements into a site, conflicts with existing underground utilities, and site setback requirements. While there are no specific setback requirements for detention vaults/chambers from buildings and utilities, detention vault/chamber location and vault/chamber material approval is required and may also require geotechnical analysis.

Detention vaults/chambers are not allowed within steep slopes, known landslide areas, and their 15-foot buffers as defined by the regulations for ECAs (SMC, Section 25.09.012).

An impermeable liner is required for detention chambers with open bottoms or sides when the facility is within the horizontal setbacks and site constraint areas that are required for infiltrating BMPs per Step 2 of *Section 3.2*. However, detention facilities that include chambers with open bottoms or sides (e.g., modular, stackable chambers, open-bottom arch pipe, etc.) are not allowed within 200 feet from the top of an ECA steep slope, landslide prone area, or known landslide area or under buildings or other structures even if an impermeable liner is provided.

For detention vaults/chambers within a setback equal to the height of the slope to a maximum of 50 feet from the top of steep slope and known landslide area, a slope stability assessment must be completed by a licensed geotechnical engineer or engineering geologist

considering the effects on slope stability due to a leaking or damaged detention BMP. More stringent exfiltration (i.e., watertightness) testing of detention vaults/chambers within a 50-foot setback from the top of the steep slope and known landslide area may be required.

Grading and drainage collection on site are important site considerations that can impact flow control effectiveness. Special care is necessary, particularly with roadway projects, to match BMP sizing to actual runoff collected and conveyed to the facility.

5.7.3.5. Design Criteria

The following provides a description and requirements for the components of standard detention vaults (Figure 5.33) and stackable, modular detention chambers. Flow control structure details are outlined in *Appendix E*. Some or all of the components may be used for a given application depending on the site characteristics and restrictions, pollutant loading, and design objectives.

Detention Vaults

Design criteria are provided in this section for the following elements of a detention vault:

- Materials
- Flow Control Riser
- Sediment storage
- Structural stability
- Access

Design criteria are summarized below for each of these design elements.

Materials

Minimum 3,000 psi structural reinforced concrete must be used for detention vaults. All construction joints must be provided with water stops.

Flow Control Riser

Refer to City of Seattle Standard Plan No. 272 and *Appendix E, Section E-1,* for flow control riser details and design criteria. The minimum allowed orifice diameter and the minimum allowed width of weir is 0.5-inches. See Section 4.1.3.2 for modeling guidance when the minimum allowed orifice diameter does not allow the flow control standard to be met.

Sediment/Oil Storage

Elevate the invert elevation of the outlet above the bottom of the vault to provide an average of 6 inches of sediment storage over the entire bottom. Also, elevate the outlet a minimum of 2 feet above the orifice to retain oil within the vault. The sediment storage requirement can also be addressed by deepening the forebay at the inlet with a dead storage volume equal to 10 percent of the live volume or an equivalent volume to the 6-inch-deep average sediment storage, whichever is greater.

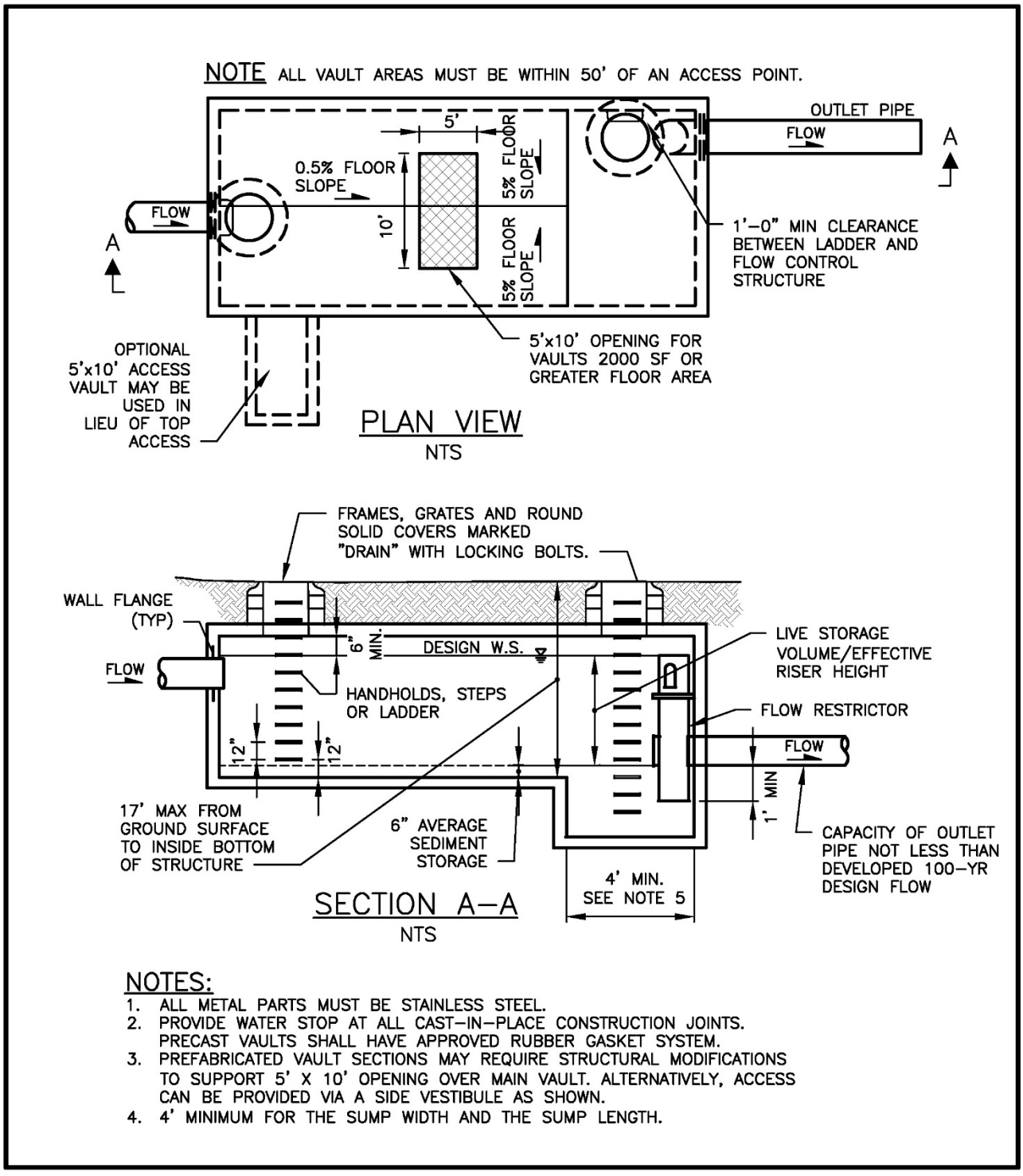


Figure 5.33. Typical Detention Vault.

Structural Stability

The following structural requirements apply to detention vaults:

- Detention vaults must meet structural requirements for overburden support, buoyancy, and traffic loading as appropriate. Provide a load analysis and submit structural plans for review.
- Detention vaults must be watertight and must be field tested as described in *Section 5.7.3.7*.
- When detention vaults are incorporated into or underneath a building, they must meet all structural requirements for the building or demonstrate no structural interaction, including no loading on the vault from the building foundation.
- Detention vaults must be placed on a stable, well-consolidated foundation and bedding material.
- Detention vaults must not be placed in fill slopes, unless a geotechnical analysis for stability and constructability is provided.

Detention pipe is preferred over detention vaults for the public drainage system. Early conversations with SPU are encouraged if considering installation of a detention vault in the right-of-way.

Access

The following access requirements apply to detention vaults:

- Access must be provided for visual inspection of the flow control structure and for cleaning the entire floor area of the detention vault. A plan for access, including maintenance equipment access is required.
- Access may be provided by use of removable panels, hatches, or ring and cover. For any detention vault requiring entry for maintenance, ladders must be installed so that the egress path does not exceed 25 feet.
- All access must be readily accessible by maintenance vehicles, including structures located under buildings.
- The maximum depth from finished grade to the detention vault invert is 17 feet.
- Access must be provided over both the inlet pipe and outlet structure. Access openings must be positioned a maximum of 50 feet from any location within the detention vault. Additional access points may be needed on large vaults. Vaults must be designed to slope at least 5 percent from each side toward the center, forming a broad “v” to facilitate sediment removal. If more than one “v” is provided in the vault floor to minimize vault depth, access to each “v” must be provided. The sloping floor may not extend into the live volume section of the detention vault.
- Internal structural walls of large vaults must be provided with openings sufficient for maintenance access between cells. The openings must be sized and situated to allow access to the maintenance “v” in the vault floor.

Detention Chambers

Follow detention vault design criteria, except for access. For access requirements, refer to detention pipes (*Section 5.7.2.5*). For connections between chambers, use a 24-inch-minimum pipe. Detention chambers must also include air vents.

Stackable, Modular Detention Chambers

Design criteria are provided in this section for the following elements of a stackable, modular detention chamber:

- Flow entrance and presettling
- Sediment storage
- Chamber materials and layout
- Chamber bedding
- Liner
- Structural stability
- Observation/maintenance port

Design criteria are summarized below for each of these design elements.

Flow Entrance and Presettling

Inflow pipe or a manifold system must be connected to each stackable, modular detention chamber. Stormwater inflows must be routed through a catch basin or similar structure with a 2-foot-deep minimum sump and a downturned elbow (trap) before entering the BMP. The volume of the sump must be equal to the volume of a catch basin required by the current Director's Rules for side sewers. Presettling requirements are provided in *Section 4.4.5*.

Sediment Storage

Stackable, modular detention chambers must have 6 inches of dead storage for sediment. This sediment storage requirement can also be addressed by deepening the forebay at the inlet with an equivalent dead storage volume. The sediment storage must be within the open chamber above the aggregate bedding and liner.

Chamber Materials and Layout

Stackable, modular detention chambers can be constructed of a variety of different materials (i.e., plastic, concrete, aluminum, steel) and shapes (i.e., arch, box). Chamber spacing and depth of cover must be per the manufacturer's requirements.

Chamber Bedding

Stackable, modular detention chamber bedding is specified by the manufacturer. Minimum bedding must be from 6 inches below the chamber to an elevation one half the height of the chamber on the outside of the chamber. Chambers must be bedded with uniformly graded, washed gravel with a nominal size from 0.75 to 1.5inch diameter. The minimum void volume must be 30 percent. These requirements can be met with City of Seattle Mineral Aggregate Type 4.

Liner

A low permeability liner or an impermeable liner must be placed at the bottom and sides of a stackable, modular detention chamber where the chamber abuts soil or other in situ material. An impermeable liner is required if the facility is within the horizontal setbacks and site constraint areas that are required for infiltrating BMPs per Step 2 of *Section 3.2*. Refer to the liner specifications in *Appendix E*.

Structural Stability

The following structural requirements apply to stackable, modular detention chambers:

- Chambers must meet structural requirements for overburden support, buoyancy, and traffic loading as appropriate. Provide a load analysis and submit structural plans for review.
- Chambers must be watertight and must be field tested as described in *Section 5.7.3.7*.
- Chambers are not allowed to be incorporated into or underneath a building.
- Chambers must be placed on a stable, well-consolidated foundation and bedding material.
- Chambers must not be placed in fill slopes, unless a geotechnical analysis for stability and constructability is provided.

Observation/Maintenance Port

Stackable, modular detention chambers must be equipped with observation/maintenance ports to measure the drawdown time following a storm, to monitor sedimentation to determine maintenance needs, and to provide access for sediment removal. Observation/maintenance ports at a 50-foot minimum spacing are required at:

- All inlets
- All outlets
- Any sediment forebay/trap

The observation/maintenance ports must consist of a 12-inch minimum diameter opening with unobstructed view down to the bottom of the chamber. The ports must have locking lids. If the port includes a pipe that extends through the chamber, the pipe must be perforated or slotted pipe and must include notches or space at the bottom to allow for sediment removal through the pipe.

5.7.3.6. BMP Sizing

Pre-sized Approach for Flow Control

The Pre-sized Approach may be used for projects with new and replaced hard surface areas up to 10,000 square feet. Under the Pre-sized Approach (refer to *Section 4.1.2*), pre-sized detention vaults may be used to achieve Pre-developed Pasture and Peak Control Standards. Sizing factors were not developed for other detention chamber shapes other than a typical detention vault. Sizing factors for rectangular detention vaults receiving runoff from hard surfaces are provided in Table 5.45. Sizing factors are organized by detention depth, contributing area, and flow control standard. To use these sizing factors to meet flow control

standards, the facility must meet the general requirements for vaults outlined in this section, plus the following specific requirements:

- Sizing equations are applicable for contributing areas between 2,000 and 10,000 square feet.
- Vault area must be sized using the applicable sizing equation.
- The low flow orifice diameter must be 0.5 inch.
- Invert of overflow must be set at the designated detention (i.e., live storage) depth (3 or 4 feet) above the invert of the low flow orifice. For intermediate depths (between 3 and 4 feet), the vault area may be linearly interpolated.
- The vault must have vertical walls to the designated overflow height.

Table 5.45. Pre-sized Sizing Equations for Detention Vaults.

Detention Depth[a]	Contributing Area	Sizing Equation for Vault Area: Pre-developed Pasture Standard	Sizing Equation for Vault Area:	Sizing Equation for Vault Area: Peak Control Standard	Sizing Equation for Vault Area: Peak Control Standard Orifice Diameter for Construction
3 feet	2,000 – 5,000 sf	[0.0662 x A] + 38.9	0.5	[0.0525 x A] + 27.25	0.5
	5,001 – 7,500 sf	[0.0662 x A] + 38.9	0.5	[0.0525 x A] + 27.25	0.5
	7,501 – 10,000 sf	[0.0662 x A] + 38.9	0.5	[0.0525 x A] + 27.25	0.625
4 feet	2,000 – 8,000 sf	NA[b]	NA	[0.0365 x A] + 19.16	0.5
	8,001 – 10,000 sf	NA[b]	NA	[0.0365 x A] + 19.16	0.625

A – contributing hard surface area; NA – not applicable; sf – square feet.

For Peak Control Standard: Vault Area (sf) = Factor x [A (sf) ^ Integer].

Hard Surface Area Managed (sf) = [Vault Area (sf) ÷ Factor] ^ (1 ÷ Integer).

For Pre-developed Pasture Standard: Vault Area (sf) = [Factor x A (sf)] + Integer.

Hard Surface Area Managed (sf) = [Vault Area (sf) - Integer] ÷ Factor.

[a] Detention depth refers to live storage depth (i.e., does not include freeboard or sediment storage requirements).

[b] A vault with 4 feet of head above the low flow orifice is not applicable for sites subject to the Pre-developed Pasture Standard because the designer is required to reduce the head to at least 3 feet in an attempt to meet this standard (refer to *Section 4.1.3.2*).

The vault area is calculated as a function of the hard area routed to it. As an example, for the Peak Control Standard, the area for a vault with an overflow invert set at 4.0 feet above the low flow orifice and receiving runoff from between 3,000 and 10,000 square feet of hard surface would be calculated as:

0.0011 x [hard surface area (square feet) ^ 1.41]

All area units must be in square feet. A detention vault with 4 feet of head above the low flow orifice is not applicable for sites subject to the Pre-developed Pasture Standard because the designer is required to reduce the head to 3 feet in an attempt to meet this standard

(refer to *Section 4.1.3.2*). To meet the Pre-developed Pasture Standard, a detention vault with 3 feet of live storage depth must be used.

Modeling Approach for On-site Performance Standard and Flow Control

When using the continuous runoff model for vault sizing, the assumptions listed in Table 5.46 must be applied. It is recommended that detention vaults/chambers be modeled as a flat-bottomed detention vault/chamber or tank with an outlet structure that includes a low flow orifice. The contributing area, detention bottom area, overflow depth and orifice configuration should be iteratively sized until the Minimum Requirements for Flow Control are met (refer to *Volume 1*, *Section 5.3*).

Table 5.46. Continuous Modeling Assumptions for Detention Vaults/Chambers.

Variable	Assumption
Precipitation Series	SEPTS-99 unless otherwise adopted by the Director
Computational Time Step	5 minutes
HSPF Parameters	LSUR, SLSUR, NSUR must be adjusted per *Appendix F*
Inflows to Facility	Surface flow and interflow from total drainage area (including impervious and pervious contributing areas) connected to the facility
Precipitation and Evaporation Applied to Facility	No
Infiltration	No
Total Depth	Vault height (including freeboard) above the vault bottom (does not include sediment storage)
Outlet Structure	Low flow orifice, riser height and diameter
Low Flow Orifice	Invert of low flow orifice set at a minimum of 6 inches above the bottom of the vault

For smaller contributing areas, the minimum diameter for the low flow orifice (0.5 inch) will be too large to meet standard release rates, even with minimal head. Refer to *Section 4.1.3.2* for contributing area thresholds and an alternative modeling approach for smaller contributing areas. For scenarios where standard(s) cannot be met, the designer is advised to evaluate other BMPs. Evaluation of live storage depth less than 3 feet is not required. Refer to *Section 4.1.3.2* for additional flow control modeling guidance.

5.7.3.7. Minimum Construction Requirements

Refer to the construction-related issues outlined above as part of the design criteria. Additional construction requirements are as follows:

- Detention vault/chamber must be field tested for exfiltration (i.e., watertightness) as follows:
  - Plug the inlets and outlet and fill the vault/chamber to one-half the distance from the outlet invert to the top of the riser on the outlet structure.
  - The maximum allowable leakage must not exceed 1 percent of the volume over a 24hour test period.
- Submit field changes to the flow control device assembly, including elevation changes, to the Engineer of Record for confirmation that the device still meets the design requirements.

5.7.3.8. Operations and Maintenance Requirements

Detention vault/chamber O&M requirements are provided in *Appendix G* (*BMP No. 3*).

Document a plan for cleaning and maintenance access for any equipment and personnel required for stackable, modular detention chambers.

5.7.4. Detention Cisterns

5.7.4.1. Description

Detention cisterns are tanks used for the capture and detention of stormwater runoff. Runoff from roof downspouts can be routed to cisterns for detention and slow release to an approved point of discharge. Like other detention facilities, cisterns can be used to achieve reductions in peak flows and flow durations.

Detention cisterns can be combined with rainwater harvesting (refer to *Section 5.5.1*).

5.7.4.2. Performance Mechanisms

Detention cisterns provide peak flow attenuation by slowly releasing low flows through an orifice. The flow control performance of a detention cistern is a function of contributing area, storage volume, cistern height, and orifice size.

5.7.4.3. Applicability

Detention cisterns can be applied to meet or partially meet the requirements listed below.

BMP	On-site: List	On-site: Standard	Flow Control: Forest	Flow Control: Pasture	Flow Control: Peak	Water Quality: Basic	Water Quality: Enhanced Metals	Water Quality: Oil Control	Water Quality: Phosphorus	Conveyance
Detention Cistern		x	x[a]	x[a]	x					x

[a] Standard may be partially or completely achieved depending upon contributing area and minimum orifice size.

5.7.4.4. Site Considerations

Detention cisterns can be used to detain rooftop runoff in any type of new or retrofit development project. Cisterns may be used individually or connected to each other in series for greater detention and storage capacity. Detained stormwater and system overflows may be conveyed to an approved point of discharge or to another BMP such as bioretention.

5.7.4.5. Design Criteria

The following provides recommendations and requirements for the common components of cistern detention systems. A schematic for a typical detention cistern in shown in Figure 5.34. Design criteria are provided in this section for the following elements:

- Contributing area
- Collection system
- Screen/debris excluder
- Cistern
- Flow control orifice
- Overflow

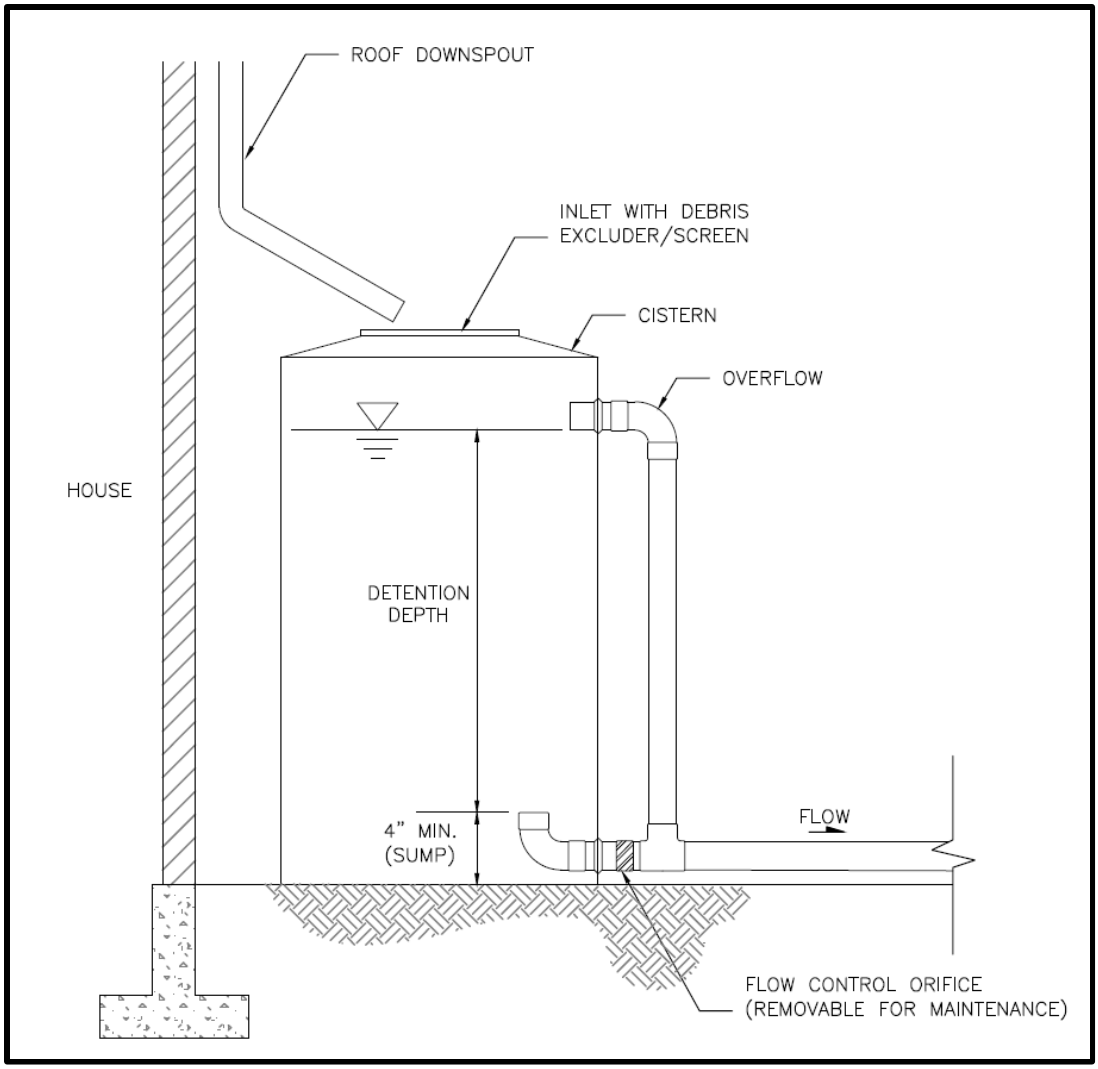


Figure 5.34. Detention Cistern.

Contributing Area

The area contributing runoff to a detention cistern must not be pollution generating (e.g., surfaces subject to vehicular traffic are not acceptable).

To protect the water quality of the rainwater harvested, avoid collecting runoff from roof surfaces composed of materials such as copper or zinc that may release contaminants into the system. Also avoid collecting runoff from roof materials treated with fungicides or herbicides.

Collection System

Collection systems include gutters and downspouts, as well as piping and any other conveyance needed to route runoff from the roof to the cistern.

Screens/Debris Excluder

A filter screen or other debris barrier is required to prevent insects, leaves, and other larger debris from entering the system. A self-cleaning inlet filter is recommended.

Cistern

Cisterns are commonly constructed of fiberglass, polyethylene, concrete, metal, or wood. Tanks can be installed at or below grade, and individually or in series.

Minimum requirements associated with cistern design include the following:

- Detention cisterns are subject to Land Use Code (SMC Title 23) setback requirements.
- All cisterns must be installed in accordance with manufacturer's installation instructions.
- Cisterns must be designed to prevent mosquitoes and other nuisance insects and animals from entering the cistern system. This can be done with tight-fitting covers and appropriate screening at all openings to the cistern.
- Opaque containers must be used for aboveground cisterns to prevent penetration of sunlight to minimize algal growth.
- Minimum cistern size must be that of a rain barrel (typically 55 gallons).

Flow Control Orifice

Minimum requirements associated with flow control orifice design include the following:

- As with other detention systems, the minimum diameter must be 0.25 inch for orifices located above ground, and 0.5 inch for orifices located underground. (Note: belowground facilities are not permitted for single-family residential sites unless approved by the Director.) See *Section 4.1.3.2* for modeling guidance when the minimum allowed orifice diameter does not allow the flow control standard to be met.
- Minimum 4-inch sump must be provided to protect the orifice from sediment.

Overflow

Cisterns must have an overflow to convey water exceeding the detention capacity of the system to an approved point of discharge or another BMP (e.g., bioretention area, vegetated cell, or infiltration trench) per *Section 4.3.3*. Conveyance may be provided by gravity flow or by pumps, but gravity flow is preferred.

5.7.4.6. BMP Sizing

Pre-sized Approach for Flow Control

The Pre-sized Approach may be used for projects with new and replaced hard surface areas up to 10,000 square feet. Under the Pre-sized Approach (refer to *Section 4.1.2*), pre-sized detention cisterns may be used to achieve Pre-developed Pasture and Peak Control Standards. Sizing factors for aboveground cisterns receiving runoff from a hard surface are provided in Table 5.47. Factors are organized by flow control standard, cistern overflow depth and contributing area. To use these sizing factors and equations to meet flow control standards, the facility must meet the general requirements for cisterns outlined in this section plus the following specific requirements:

- The cistern area must be sized using the applicable sizing factor or equation.
- The flow control orifice diameter must be 0.25 inch.

- The invert of the overflow must be set at the designated detention (i.e., live storage) depth (3 or 4 feet) above the invert of the flow control orifice. For intermediate depths (between 3 and 4 feet), the cistern area may be linearly interpolated.
- The cistern must have vertical walls to the designated overflow height.

Table 5.47. Pre-sized Sizing Factors and Equations for Aboveground Detention Cisterns.

Detention Depth[a]	Contributing Area (sf)	Sizing Factor/Equation for Cistern Area: Pre-developed Pasture Standard	Sizing Factor/ Equation for Cistern Area:	Sizing Factor/Equation for Cistern Area: Peak Control Standard	Sizing Factor/Equation for Cistern Area: Peak Control Standard Orifice Diameter for Construction
3 feet	≤ 2,000	10.6%	0.25	[0.0552 x A] - 2.3435	0.25
	2,001 – 3,500	10.6%	0.25	[0.0552 x A] - 2.3435	0.25
	3,501 – 5,000	408 sf	0.25	[0.0552 x A] - 2.3435	0.375
	5,001 – 9,999	0.00015 x [A ^ 1.74]	0.25	[0.0552 x A] - 2.3435	0.5
	10,000	0.00015 x [A ^ 1.74]	0.25	[0.0552 x A] - 2.3435	0.625
4 feet	≤ 2,000	6.4%	0.25	0.0141 x [A^1.1289]	0.25
	2,001 – 3,500	6.4%	0.25	0.0141 x [A^1.1289]	0.25
	3,501 – 5,000	6.4%	0.25	0.0141 x [A^1.1289]	0.375
	5,001 – 6,000	322 sf	0.25	0.0141 x [A^1.1289]	0.5
	6,001 – 9,999	0.0001 x [A ^ 1.73]	0.25	0.0141 x [A^1.1289]	0.5
	10,000	0.0001 x [A ^ 1.73]	0.25	0.0141 x [A^1.1289]	0.625

A – contributing hard surface area; sf – square feet.

For Sizing Factors: Cistern Area = Contributing Hard Surface Area x Factor (%)/100.
Hard Surface Area Managed = Cistern Area ÷ Factor (%)/100.

For Linear Equations: Cistern Area (sf) = [Factor x A (sf)] + Integer.
Hard Surface Area Managed (sf) = [Cistern Area (sf) - Integer] ÷ Factor.

For Power Equations: Cistern Area (sf) = Factor x [A (sf) ^ Integer].
Hard Surface Area Managed (sf) = [Cistern Area (sf) ÷ Factor] ^ (1 ÷ Integer).

The cistern bottom area is calculated as a function of the hard surface area routed to it. As an example, to meet the Pre-developed Pasture Standard, the area of a cistern with an overflow invert set at 3 feet above the flow control orifice and receiving runoff from between 5,000 and 10,000 square feet would be calculated as:

0.00015 x contributing hard surface area (square feet) ^ 1.74

All area values must be in units of square feet. For the same cistern receiving runoff from between 3,500 and 5,000 square feet, the cistern area would be 408 square feet.

Alternatively, cisterns can be sized using a continuous model as described in the next section.

Modeling Approach for On-site Performance Standard and Flow Control

Continuous modeling may be used to size detention cisterns using the procedures presented for detention vaults/chambers in *Section 5.7.3*. The assumptions provided in Table 5.46 must be applied.

5.7.4.7. Minimum Construction Requirements

Refer to the construction-related issues outlined above as part of the design criteria. An additional construction requirement is as follows:

- Submit field changes to the flow control device assembly, including elevation changes, to the Engineer of Record for confirmation that the device still meets the design requirements.

5.7.4.8. Operations and Maintenance Requirements

Detention cistern O&M requirements are provided in *Appendix G* (*BMP No. 24*). A plan must be submitted demonstrating how the O&M requirements will be met.

5.7.5. Other Detention Options

Designers and developers are encouraged to consider creative opportunities for providing detention, when it is required. Athletic fields, roofs, parking lots that are not continually in use, and other large surface areas may provide opportunities for stormwater storage. This section presents other design options for detaining flows to meet flow control requirements.

5.7.5.1. Use of Parking Lots for Additional Detention

Private parking lots may be used to provide additional detention storage for runoff events greater than the 50 percent annual probability (2-year recurrence interval), provided all of the following conditions are met:

- Depth of storage must be 3 inches or less for parking lots serving retail and office buildings and 6 inches or less for parking lots serving commercial truck traffic only for runoff events up to and including the storm event with a 1 percent annual probability (100year recurrence interval flow).
- The emergency overflow path must be identified and noted on the engineering plan. The overflow must not create a significant adverse impact to downhill properties or drainage system.
- Fire lanes used for emergency equipment must be free of ponding water for all runoff events up to and including the storm event with a 1 percent annual probability (100year recurrence interval flow).

5.7.5.2. Use of Roofs for Detention

Detention ponding on roofs may be used to meet flow control requirements provided all of the following conditions are met:

- The roof support structure must be analyzed by a structural engineer to address the weight of ponded water.
- The roof area must be sufficiently waterproofed to achieve a minimum service life of 30 years.
- The minimum pitch of the roof area must be 0.25 inch per foot.
- An overflow system must be designed to safely convey the peak flow with a 1 percent annual probability (100year recurrence interval flow).
- A mechanism must be included in the design to allow the ponding area to be drained for maintenance purposes or in the event the restrictor device is plugged.

5.8. Non-infiltrating BMPs

Non-infiltrating BMPs are designed to remove pollutants contained in stormwater runoff. Some non-infiltrating BMPs may provide low levels of flow control as a secondary benefit. The BMP categories in this section include:

- Non-infiltrating Bioretention
- Biofiltration Swales
- Filter Strips/Drains
- Sand Filters
- Wet Ponds
- Wet Vaults
- Stormwater Treatment Wetlands
- Combined Detention and Wet Pool Facilities
- Oil/Water Separators
- Proprietary and Emerging Water Quality Treatment Technologies
- Non-infiltrating Soil Cell Bioretention

5.8.1. Design Requirements for Non-infiltrating BMPs

5.8.1.1. Site and Design Considerations

Refer to each non-infiltrating BMP section for setback requirements intended to protect adjacent properties, receiving waters, and other critical areas (i.e., landslide-prone areas).

The Phosphorus Removal and Metals Treatment performance goals, described in *Sections* 3.5.2.2 and 3.5.2.3, respectively, include treatment train options in which more than one type of BMP is used and the sequence of BMPs is prescribed. The specific pollutant removal role of the second or third BMP in a treatment train often assumes that significant solids settling has already occurred.

This section summarizes the placement of non-infiltrating BMPs in relation to detention BMPs as shown in Table 5.48. Also note that oil control BMPs must be located upstream of other BMPs, and as close to the source of the oil-generating activity as possible.

Table 5.48. Non-infiltrating BMP Placement in Relation to Detention BMP.

Non-infiltrating BMP	Preceding Detention BMP	Following Detention BMP
Basic Biofiltration Swale (*Section 5.8.3*)	Allowed	Allowed—prolonged flows may reduce vegetation survival. Consider wet biofiltration swale instead.
Wet Biofiltration Swale (*Section 5.8.3*)	Allowed	Allowed.
Filter Strip (*Section 5.8.4*)	Allowed	Not allowed—must be installed before flows concentrate; cannot effectively be re-dispersed.
Basic or Large Sand Filter or Sand Filter Vault (*Section 5.8.5*)	Allowed—presettling and control of floatables needed	Allowed—sand filters downstream of detention BMPs may require field adjustments if prolonged flows cause sand saturation, anoxic conditions, and phosphorus release.

Table 5.48 (continued). Non-infiltrating BMP Placement in Relation to Detention BMP.

Non-infiltrating BMP	Preceding Detention BMP	Following Detention BMP
Basic or Large Wet Pond (*Section 5.8.6*)	Allowed	Allowed—less water level fluctuation in ponds downstream of detention may improve aesthetic qualities and performance.
Wet Vault (*Section 5.8.7*)	Allowed	Allowed.
Stormwater Treatment Wetland/Pond (*Section 5.8.8*)	Allowed	Allowed—less water level fluctuation and better plant diversity are possible if the stormwater wetland is located downstream of the detention BMP.
Proprietary and Emerging Water Quality Treatment Technologies (*Section 5.8.11*)	Allowed	Allowed—depending on the type of technology.

5.8.2. Non-infiltrating Bioretention

5.8.2.1. Description

Non-infiltrating bioretention facilities are earthen depressions or vertical walled containers with a designed soil mix and plants adapted to the local climate and soil moisture conditions. Stormwater is stored as surface ponding before it filters through the underlying bioretention soil. Stormwater that exceeds the surface storage capacity overflows to an adjacent drainage system. Treated water is collected by an underdrain and discharged. Bioretention facilities can be individual cells or multiple cells connected in series.

Unlike infiltrating bioretention (refer to *Section 5.4.4*), non-infiltrating bioretention facilities typically include a low-permeability or impermeable barrier to limit or prevent infiltration to the underlying soil. However, if all the horizontal setback requirements for infiltrating facilities are met and there are no geotechnical or contamination concerns, the liner may be omitted.

Two variations of non-infiltrating bioretention facilities are included in this section:

- **Non-infiltrating bioretention facility**: These bioretention facilities can have either sloped sides (e.g., an earthen depression with a liner) or vertical sides (e.g., vertical walled container). Non-infiltrating bioretention must have an underdrain. These facilities may or may not have an outlet control structure to attenuate underdrain flows prior to release.
- **Non-infiltrating bioretention facility series**: Non-infiltrating bioretention facilities with sloped sides or vertical sides may be connected in a series, with the overflows of upstream cells directed to downstream cells to provide additional flow control and/or treatment, and conveyance.

5.8.2.2. Performance Mechanisms

Non-infiltrating bioretention provides flow control via detention, attenuation, and losses due to interception, evaporation, and transpiration. Water quality treatment is accomplished through sedimentation, filtration, adsorption, uptake, or biodegradation and transformation of pollutants by soil organisms, soil media, and plants.

5.8.2.3. Applicability

Non-infiltrating bioretention can be designed to provide on-site stormwater management, flow control, and/or water quality treatment. These facilities can be applied to meet or partially meet the requirements listed below.

BMP	On-site: List	On-site: Standard	Flow Control: Forest	Flow Control: Pasture	Flow Control: Peak	Water Quality: Basic	Water Quality: Enhanced Metals	Water Quality: Oil Control	Water Quality: Phosphorus	Conveyance
Non-Infiltrating Bioretention	x	x[a]	x[a]	x[a]	x[a]	x	x			x[b]

[a] Standard may be partially or completely achieved depending upon ponding depth, contributing area, and use of orifice control.

[b] Non-infiltrating bioretention facilities may be connected in series, with the overflows of upstream cells directed to downstream cells to provide conveyance.

5.8.2.4. Site Considerations

Because typically non-infiltrating bioretention facilities do not infiltrate water to surrounding soils (water discharges via an underdrain and surface overflow), these BMPs are not subject to infiltration facility requirements. However, some infiltration requirements apply if a liner is not used (refer to *Volume 3, Section 5.8.2.5* below).

Non-infiltrating bioretention is not permitted if the underdrained water would be routed to a nutrient-critical receiving water unless using the optional High Performance Bioretention Soil Media (HPBSM) and polishing layer. Non-infiltrating bioretention is also not permitted within a setback equal to the height of the slope to a maximum of 50 feet from the top of steep slope or known landslide area.

Non-infiltrating bioretention is allowed in the side, front, and rear yard/setbacks that are required by the Land Use Code (SMC Title 23) in certain land use zones. However, if the facility extends above grade (e.g., a non-infiltrating bioretention planter that is partially or completely above the surrounding grade), then the amount of the yard/setback that it can cover may be restricted if the facility is over a certain height or width. Height is measured from the lowest adjacent grade. Width is the outside width and is measured perpendicular to the setback line.

Refer to the Land Use Code (SMC Title 23) for the specific heights and widths that trigger yard/setback coverage limitations for GSI features. Note: The requirements vary based on zoning and are not required in all zones.

Note: The “total storage capacity” mentioned in these code sections does not apply to non-infiltrating bioretention. Also, larger non-infiltrating bioretention planters may be permitted without restriction of the amount of yard/setback coverage if they meet the standards for retaining walls within a required yard/setback.

Refer to *Appendix C* for additional infeasibility criteria for the On-site List Approach.

5.8.2.5. Design Criteria

Typical components of non-infiltrating bioretention facilities with sloped sides and vertical sides are shown in Figures 5.35 and 5.36, respectively. The vertical sides of bioretention facilities may be constructed from concrete, steel or fiberglass and must be UV and corrosion resistant and able to withstand earth pressure if below ground. Alternative materials may be used with the permission of the Director.

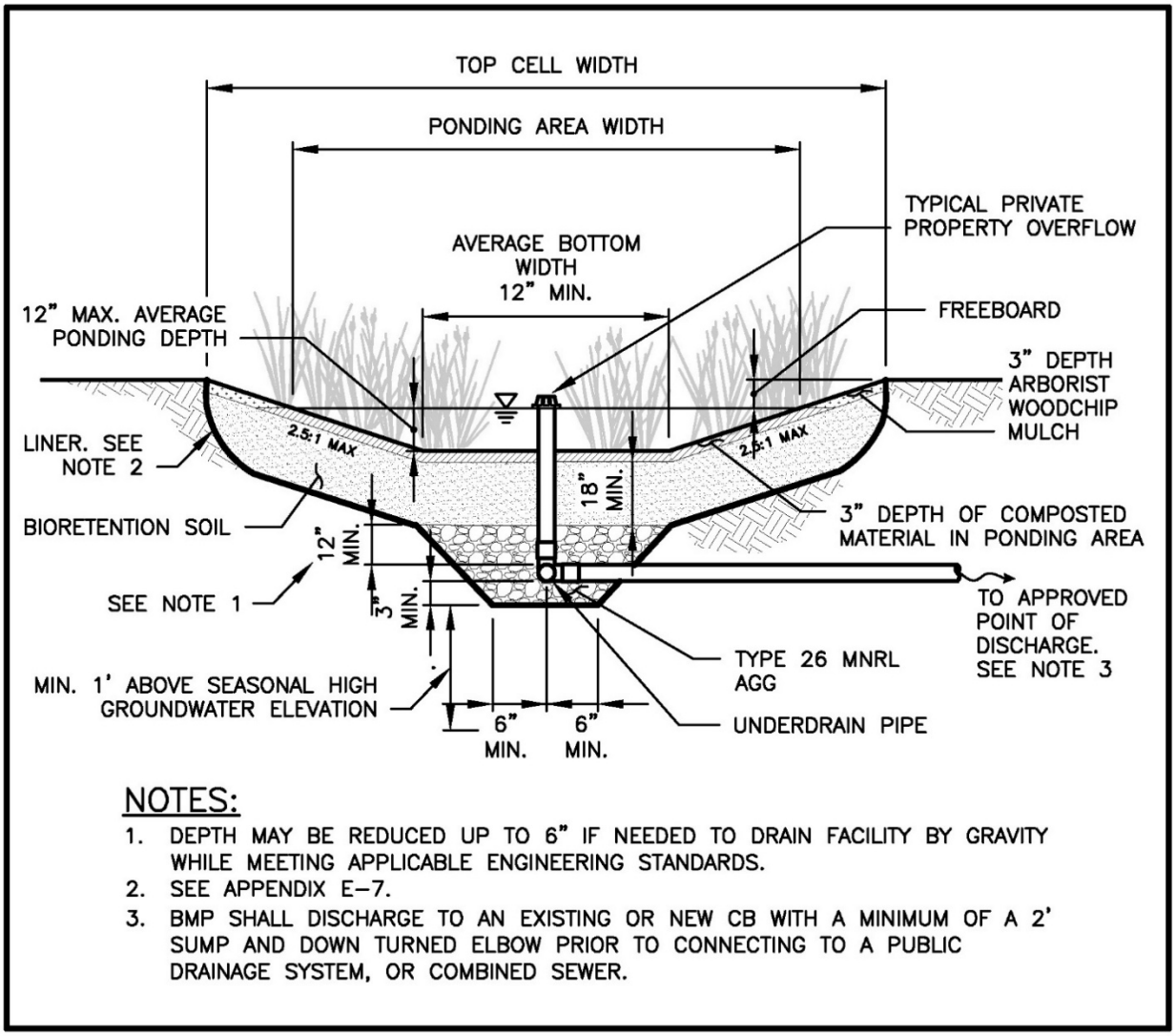


Figure 5.35. Non-infiltrating Bioretention Facility with Sloped Sides.

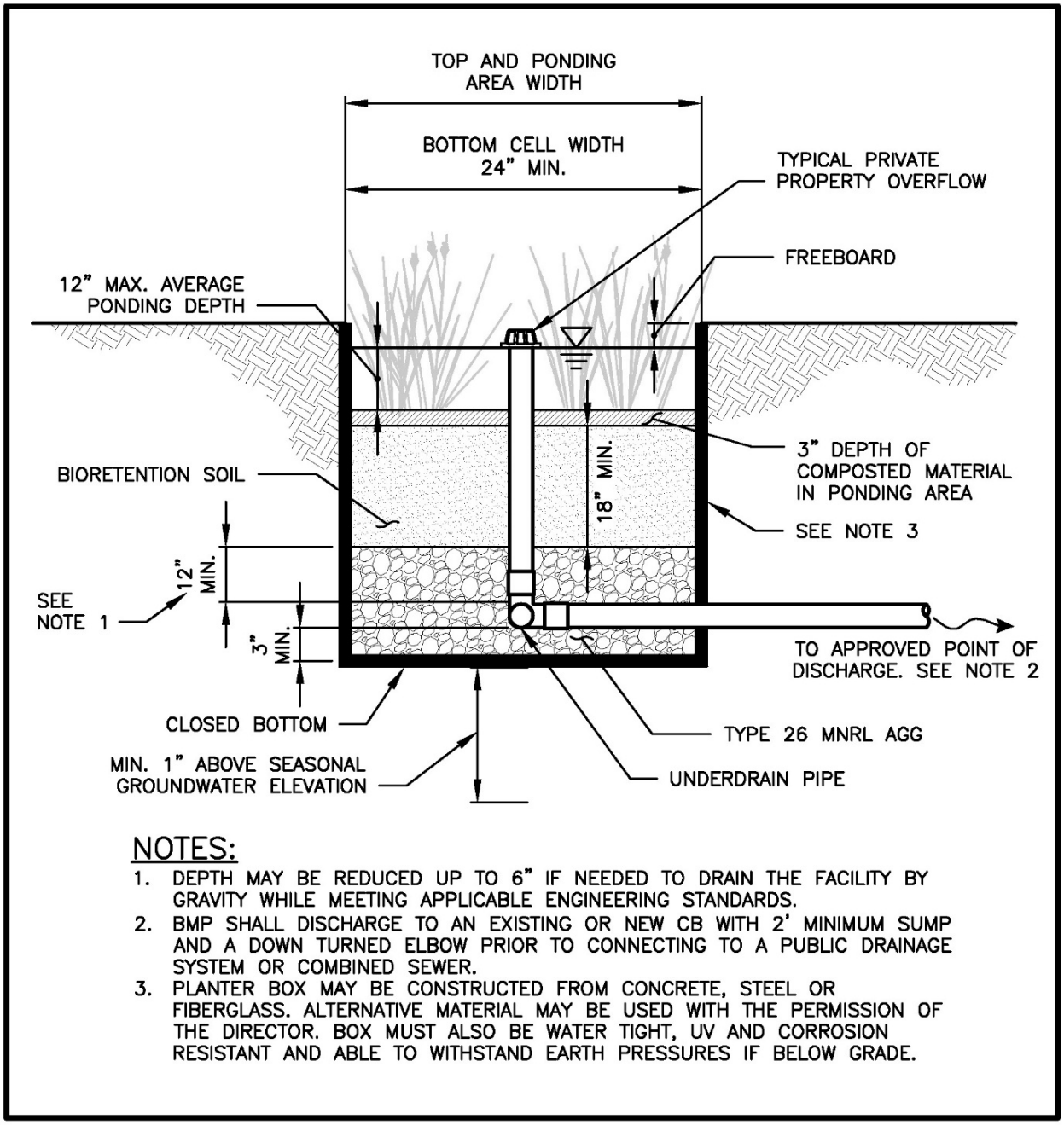


Figure 5.36. Non-infiltrating Bioretention Facility with Vertical Sides.

The design criteria for non-infiltrating bioretention are the same as presented for infiltrating bioretention in *Section 5.4.4*, with the following exceptions:

- Typically, non-infiltrating bioretention includes a hydraulic restriction layer to restrict or prevent infiltration into surrounding soils. The type of hydraulic restriction layer required depends on site setbacks:
    - If the area available for siting is within the setback for a contaminated site or landfill (refer to *Volume 3*, *Section 3.2*), an impermeable liner must be used to

create a hydraulic restriction layer. Refer to *Appendix E*, *Section E-7* for liner design criteria.

- If the area available for siting meets the setback from contamination and landfills, but not the other minimum horizontal setback requirements for infiltrating facilities (refer to *Volume 3*, *Section 3.2*), low-permeability liner or walls must be used as the hydraulic restriction layer. Refer to *Appendix E, Section E7* for liner design criteria.
- If Horizontal Setbacks and Site Constraints for infiltration can be met (refer to *Volume 3*, *Section 3.2*), no liner is required.

- Where the inflow or discharge line enters or exits the BMP, measures must be taken to prevent drainage from entering the trench backfill or pipe bedding such as factory boots or trench dams using bentonite, low density concrete fill, etc.
- The facility must be equipped with an underdrain.
- While not required, it is recommended that facilities with contributing drainage areas up to 5,000 square feet, be designed with a 0.25-inch-diameter removable and maintainable orifice to improve flow control performance.

5.8.2.6. BMP Sizing

Sizing for On-site List Approach

Non-infiltrating bioretention may be selected to meet the On-site List Requirement (refer to *Section 3.3.1* and *Appendix C* for infeasibility criteria). To meet the requirement, the facility must be sized according to the sizing factors provided in Table 5.49.

Factors are organized by cell ponding depth, contributing area, and side slope. To select the appropriate sizing factor the design ponding depth must be rounded down to the nearest depth in the sizing table, or sizing factors may be linearly interpolated for intermediate ponding depths (e.g., between 4 and 6 inches ponding).

The facility must meet the general requirements for non-infiltrating bioretention outlined in this section plus the following specific requirements:

- The bottom area must be sized using the applicable sizing factor.
- It is preferred that the bottom area is flat, but up to 3 percent slope is permitted.
- For facilities with sloped sides, the side slopes within the ponded area must be no steeper than 2.5H:1V.
- The bioretention soil depth must be a minimum of 18 inches.
- The average ponding depth for the cell must be no less than the selected ponding depth.

Table 5.49. On-site List Sizing for Non-infiltrating Bioretention.

Bioretention Configuration	Average Ponding Depth	Contributing Area (sf)	Sizing Factor for Facility Bottom Area: On-site List
Sloped sides	2 inches	Any	4.5%
	6 inches	≤2,000	2.5%
		2,001 – 43,560	2.8%
	12 inches	Any	2.0%
Vertical sides	2 inches	Any	6.0%
	6 inches	Any	4.0%
	12 inches	Any	2.8%

sf – square feet.

Bioretention Bottom Area = Contributing Hard Surface Area x Factor (%)/100.

Hard Surface Area Managed = Bioretention Bottom Area ÷ Factor (%)/100.

The bottom area for the cell is calculated as a function of the hard surface area routed to it. As an example, the bottom area of the bioretention cell with sloped sides would be equal to 2 percent of the hard surface area routed to it when the average ponding depth is 12 inches and contributing areas less than or equal to 2,700 square feet. For facilities with sloped sides, the top area is calculated as a function of the cell bottom area and the side slopes up to the total facility depth (i.e., ponding and freeboard depth).

Pre-sized Approach for Flow Control and Water Quality Treatment

The Pre-sized Approach may be used for projects with new and replaced hard surface areas up to 10,000 square feet. Under the Pre-sized Approach (refer to *Section 4.1.2*), pre-sized non-infiltrating bioretention facilities may be used to achieve Water Quality Treatment Standards. Sizing factors and equations for non-infiltrating bioretention facilities with underdrains are provided in Table 5.50. Factors are organized by side slopes (i.e., sloped sides or vertical sides), performance standard, facility ponding depth, and contributing area. To select the appropriate sizing factor, the design ponding depth must be rounded down to the nearest depth in the sizing table, or sizing factors may be linearly interpolated for intermediate ponding depths (e.g., between 6 and 12 inches ponding).

To use these pre-sized facilities to meet performance standards, the bioretention facility must meet the general requirements outlined in this section plus the following specific requirements:

- The bottom area must be sized using the applicable sizing factor or equation.
- It is preferred that the bottom area is flat, but up to a 3 percent slope is permitted.
- For facilities with sloped sides, the side slopes within the ponded area must be no steeper than 2.5H:1V.
- The bioretention soil depth must be a minimum of 18 inches.
- The average ponding depth for the cell must be no less than the selected ponding depth.

Table 5.50. Pre-sized Sizing Factors and Equations for Non-infiltrating Bioretention.

Bioretention Configuration	Average Ponding Depth	Contributing Area (sf)	Sizing Factor/ Equation for Facility Bottom Area Pre-developed Pasture Standard	Sizing Factor/ Equation for Facility Bottom Area Peak Control Standard for Capacity Constrained Areas[a]	Sizing Factor/ Equation for Facility Bottom Area Peak Control Standard for Combined Systems	Sizing Factor/ Equation for Facility Bottom Area Water Quality Treatment
Sloped sides	2 inches	0 – 10,000	NA[a]	NA[a]	NA[b]	1.3%
	6 inches	≤2,000	NA[a]	NA[a]	NA[b]	[0.0059 x A] - 3.215
		2,001 – 10,000	NA[a]	NA[a]	NA[b]	[0.0097 x A] - 1 1.297
	12 inches	≤ 2,700	NA[a]	NA[a] or 3%[c] [TBD]	NA[b]	0.4%
		2,701 – 10,000	NA[a]	NA[a] or 3%[c] [TBD]	NA[b]	[0.0052 x A] - 12.092
Vertical sides	6 inches	0 – 10,000	NA[a]	NA[a]	NA[b]	1.2%
	12 inches	0 – 10,000	NA[a]	NA[a] or 4.5%[c] [TBD]	NA[b]	1.0%

NA – not applicable; sf – square feet.

For Sizing Factors: Bioretention Facility Bottom Area = Contributing Hard Surface Area x Factor (%)/100
Hard Surface Area Managed = Bioretention Facility Bottom Area ÷ Factor (%)/100

For Sizing Equations: Bioretention Facility Bottom Area (sf) = [Factor x A (sf)] + Integer.
Hard Surface Area Managed (sf) = [Bioretention Bottom Area (sf) - Integer]÷ Factor.

[a] Bioretention facilities with underdrains are not capable of achieving the standard unless orifice controls are used.

[b] The Peak Control Standard sizing factors are not applicable when the project discharges to a combined sewer or its basin.

[c] When used to meet the Peak Control Standard, the facility size must not be larger than prescribed by the sizing factor (or sizing factor range) because flow control performance may be diminished for larger facilities (larger facilities will not pond water sufficiently to slow flows).

The *bottom area* for the bioretention facility area is calculated as a function of the hard surface area routed to it. As an example, to meet the Water Quality Treatment Standard, the bottom area of the bioretention facility with vertical sides and an average of 12 inches of ponding would be equal to 1 percent of the hard surface area routed to it. The bottom area of same facility with slopes sides would be calculated as: 0.0052 x contributing hard surface area 12.1. All area values must be in square feet. For facilities with sloped sides, the top area is calculated as a function of the cell bottom area and the side slopes up to the total facility depth (i.e., ponding and freeboard depth).

Instead of using the Pre-sized Approach, non-infiltrating bioretention facilities can be sized using a continuous simulation hydrologic model as described in the following section.

Modeling Approach for On-site Performance Standard, Flow Control, and Water Quality Treatment

When using continuous simulation hydrologic modeling to size non-infiltrating bioretention, the assumptions listed for infiltrating bioretention in Table 5.24 must be applied, with the exception that the facility is modeled with no infiltration to underlying soil. Refer to the *Approval Status of Continuous Simulation Models* section of the SWMMWW for a list of currently approved models. When using currently available modeling methods, non-infiltrating bioretention is not capable of meeting the Peak, Pre-developed Forested or Pre-developed

Pasture Standard without orifice control. When sizing for Water Quality Treatment, the facility must be designed to filter 91 percent of the total runoff volume through the bioretention soil.

5.8.2.7. Minimum Construction Requirements

Minimum construction requirements associated with non-infiltrating bioretention facilities include the following:

- Place bioretention soil in accordance with the requirements of City of Seattle Standard Specifications.
- Protect bioretention soil in cells from sediment during construction and do not use as sediment control facilities.

Refer to the Puget Sound LID Manual for additional guidance on bioretention construction.

5.8.2.8. Operations and Maintenance Requirements

Non-infiltrating bioretention O&M requirements are provided in *Appendix G* (*BMP No. 23*).

5.8.3. Biofiltration Swales

5.8.3.1. Description

A biofiltration swale is an open, gently sloped, vegetated channel designed to treat stormwater. Biofiltration swales are designed so that stormwater will flow evenly across the entire width of a densely vegetated channel. The four biofiltration swales described in this section are:

1. **Basic biofiltration swale**: a swale with a densely vegetated channel, with all runoff entering at the head of the swale.
2. **Wet biofiltration swale**: similar to the basic swale, but due to site conditions and/or influent conditions, this swale is designed to accommodate saturated soil conditions. It is appropriate for locations where the longitudinal slope is very low, water tables are high, or continuous low base flow is present.
3. **Continuous inflow biofiltration swale**: similar to the basic swale, but runoff enters at multiple locations along the length of the swale. The basic swale design is modified by increasing the swale length to achieve an equivalent average residence time.
4. **Compost-amended biofiltration swale**: same as the basic swale, but with a 3-inch compost blanket within the channel of the swale.

5.8.3.2. Performance Mechanisms

Pollutant removal occurs by filtration as stormwater moves through the vegetation, enhancing sedimentation, and trapping pollutants within the compost or vegetation.

5.8.3.3. Applicability

A swale can be designed for water quality treatment and conveyance of stormwater flow. This combined use can reduce development costs by eliminating the need for separate conveyance and treatment systems. Biofiltration swales are typically configured as flow-through systems, with little or no detention or storage. This BMP can be applied to meet the requirements as summarized below.

BMP	On-site: List	On-site: Standard	Flow Control: Forest	Flow Control: Pasture	Flow Control: Peak	Water Quality: Basic	Water Quality: Enhanced Metals	Water Quality: Oil Control	Water Quality: Phosphorus	Conveyance
Basic Biofiltration Swale						x	TT-A or TT-B		TT-A	x
Wet Biofiltration Swale						x	TT-A or TT-B		TT-A	x
Continuous Inflow Biofiltration Swale						x	TT-A or TT-B		TT-A	x
Compost-amended Biofiltration Swale						x	x	x		x

TT-A = Treatment Train A (must be followed by a Basic Sand Filter or Sand Filter Vault (*Section 5.8.5*)

TT-B = Treatment Train B (must be followed by an approved Proprietary and Emerging Water Quality Treatment Technology (*Section 5.8.11*)

Refer to *Section 3.5.2.2* for more information on Two-BMP Treatment Trains.

5.8.3.4. Site Considerations

The following are common considerations for determining the feasibility of biofiltration swales for a particular site.

- Setbacks and restrictions:
  - All biofiltration swales must be a minimum of 50 feet from the top of any steep (greater than 40 percent) slope. A geotechnical analysis and report must be prepared addressing the potential impact of the facility on a slope steeper than 15 percent.
  - The water surface at the outlet invert elevation must be set back 100 feet from existing septic system drain fields. This setback may be reduced with written approval of Public Health — Seattle & King County.
- Biofiltration swales are generally suitable for contributing areas of less than 5 acres.
- Biofiltration swales may be used for linear areas along roadways, driveways, and parking lots.
- Swales may be incorporated into a project's landscape design with either a mowable grass swale or water tolerant vegetation.
- Shaded areas, including deep channels, with less than 6 hours of sunlight during the summer months can inhibit vegetation growth.
- Stormwater runoff containing high concentrations of oil and grease impairs the treatment capability of a swale. Oil control options described in *Section 5.8.10* should be applied upstream of the biofiltration swale in these situations.
- Most biofiltration swales are designed to be on-line facilities with flows above the water quality design flow or volume passing through the facility with lesser or no pollutant removal. However, an offline design (where flows above the water quality design flows or volume are bypassed around the facility) may be preferred in some cases to avoid scour and damage to vegetation during high flows. An additional benefit of designing swales to be offline is that the stability check, which may make the swale larger, is not necessary (refer to *Sections 5.8.3.5, Design Criteria* and *Section 5.8.3.6, BMP Sizing*).
- Minimum footprint is 100 feet by 20 feet. The actual footprint will depend on the bottom width, side slopes, and length, which are all dependent on the design flows (refer to *Section 5.8.3.6, BMP Sizing*).
- Alignment should avoid sharp bends where erosion of the swale side slope can occur. However, gradual meandering bends in the swale are desirable for aesthetic purposes and to promote slower flow.
- Leaves and needles that can smother the grass or clog part of the swale flow path can be a maintenance concern. Landscaping plans should take into consideration the problems that falling leaves and needles can cause for swale performance and maintenance. Landscape planter beds should be designed and located so that soil does not erode from the beds and enter a nearby biofiltration swale.

- Wet biofiltration swales are applied where a basic biofiltration swale is desired but not allowed or advisable because one or more of the following conditions exist:
  - The swale is on till soils and is downstream of a detention pond providing flow control.
  - Saturated soil conditions are likely because of seeps, continuous base flow, or high groundwater on the site.
  - Longitudinal slopes are less than 2 percent.
- A continuous inflow biofiltration swale is recommended when the following conditions exist:
  - Inflows are not concentrated or when flow enters at frequent points along the swale.
  - Unconcentrated inflow occurs along roadways that that have no curbs, where runoff sheet flows across the shoulder to the swale.
- A continuous inflow biofiltration swale is not appropriate when significant lateral flows enter a swale at some point downstream from the head of the swale. In this situation, the swale length must be recalculated from the point of entry to provide adequate treatment for the increased flow.

Additional site considerations may apply depending on site conditions and other factors.

5.8.3.5. Design Criteria

The following provides a description and requirements for the components of biofiltration swales. Typical plan and profile views of a biofiltration swale are provided in Figure 5.37. Some or all of the components may be used for a given application depending on the site characteristics and restrictions, pollutant loading, and design objectives. Design criteria are provided in this section or in Volume V of the SWMMWW for the following elements:

Design Element	SWMMWW Design Criteria	Seattle-specific Design Criteria
Level spreaders	x	x
Underdrain (if any)	x	x
Low-flow drains (if any)		x
Outlet and overflow		x
Access		x
Soil amendment		x
Vegetation criteria	x	x
Dividing berm	x	
Check dams or steps (if any)	x	
High-flow bypass (if any)	x	

Refer to BMP T9.10 — Basic Biofiltration Swale, BMP T9.20 — Wet Biofiltration Swale, and BMP T9.30 — Continuous Inflow Biofiltration Swale in Volume V of the SWMMWW for specific design criteria. Refer to the WSDOT Highway Runoff Manual under BMP RT.04 — Biofiltration Swale for design criteria for compost-amended biofiltration swales (CABS). In addition to

criteria developed by Ecology and WSDOT, the City has also developed specific design criteria for several design elements which are summarized below.

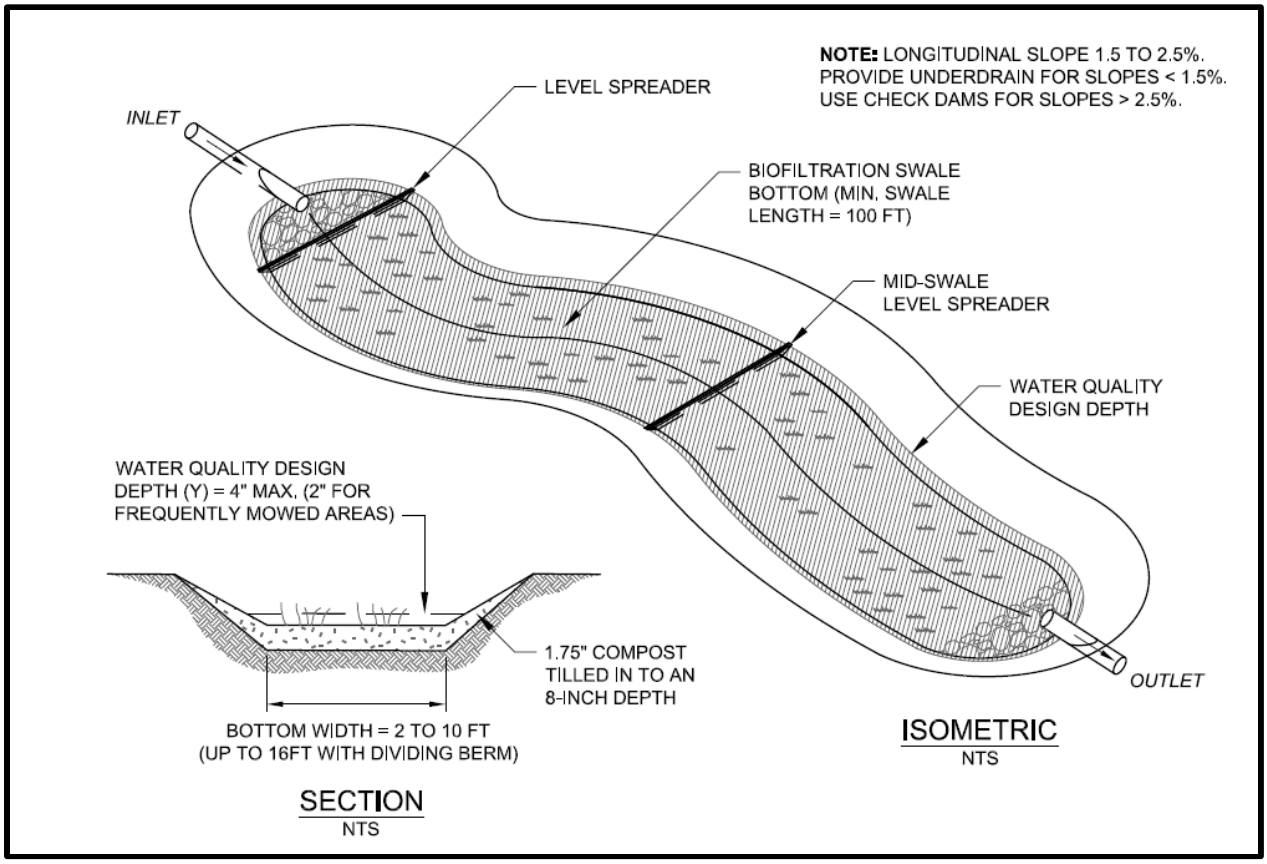


Figure 5.37. Biofiltration Swale Plan and Profile.

Level Spreaders

Refer to BMP T9.10 — Basic Biofiltration Swale, BMP T9.20 — Wet Biofiltration Swale, and BMP T9.30 — Continuous Inflow Biofiltration Swale in Volume V of the SWMMWW for biofiltration swale design considerations.

In addition, the City of Seattle requires level spreaders at the toe of vertical drops (check dams). Design guidelines and example design figures for level spreaders are provided in *Appendix E*.

Underdrains

Refer to BMP T9.10 — Basic Biofiltration Swale, BMP T9.20 — Wet Biofiltration Swale, and BMP T9.30 — Continuous Inflow Biofiltration Swale in Volume V of the SWMMWW for design considerations.

In addition, the City of Seattle requires underdrains for swales less than 1.5 percent longitudinal slope on till soils.

Low-flow Drains

Low-flow drains are narrow surface drains filled with pea gravel that run lengthwise through the swale to discharge base flows; they should not be confused with underdrains. Wet biofiltration swales are typically preferred when seeps, continuous base flow, or high groundwater is present. Alternatively, if a low-flow drain is proposed, the following requirements apply to biofiltration swales installed in Seattle:

- If a swale will receive base flows because of seeps and springs on site, then either a low-flow drain must be provided or a wet biofiltration swale must be used. In general, base flows less than 0.01 cubic feet per second (cfs) per acre can be handled with a low-flow drain. If flows are likely to be in excess of this level, a wet biofiltration swale should be used. Low-flow drains are not required for wet biofiltration swales.
- If a low-flow drain is used, it must extend the entire length of the swale.
- The low-flow drain must be a minimum of 6 inches deep, and its width must be no greater than 5 percent of the calculated swale bottom width. Adjust the bottom width accordingly to maintain the necessary design bottom width for treatment.
- If an anchored plate or concrete sump is used for flow spreading at the swale inlet, the plate or sump wall must have a v-notch (maximum top width equal to 5 percent of swale width) or holes to allow preferential exit of low flows into the drain. Additional design guidelines for level spreaders are provided in *Appendix E*.

Outlet and Overflow

All biofiltration swales must include an outlet and overflow to an approved point of discharge per *Section 4.3.3*.

Access

Access requirements specific to biofiltration swale installations in Seattle are summarized below.

Access Requirement	Basic and Continuous Inflow Biofiltration Swale	Wet Biofiltration Swale
Access locations	Half the length of the swale	Inflow and outflow only
Access road width	Minimum of 10 feet	Minimum of 10 feet
Access road curves	Minimum width of 15 feet and a minimum outside radius of 40 feet	Minimum width of 15 feet and a minimum outside radius of 40 feet
Wheel strips made of modular grid pavement (refer to *Section 5.4.6*)[a]	Support 16,000-pound vehicle Firm underlying soil or structural fill (not amended topsoil) Fill or cover with underlying soil (no amendments) and seed with grass Strip width = 18 inches Not counted as treatment area Not allowed in biofiltration swales with underdrains	Not allowed

[a] If a low-flow drain is also needed, a portion of the wheel strip may be filled with pea gravel as appropriate to form the drain.

Soil Amendment

The following requirements must be followed for biofiltration swales installed in Seattle:

- The condition of the soil is critical to support healthy grass growth. Native topsoil that has been stockpiled on site or in-situ soil may be used provided that it meets the soil quality criteria described in *Section 4.5.2*. Soil amendments are required if underlying soil is not suitable. Refer to *Section 5.1* for information regarding Soil Amendment BMP requirements.
- If the longitudinal slope is less than 1.5 percent (requiring the use of underdrains along the swale length), the subgrade should contain 10 percent or more of sand to promote infiltration of standing water. If sand is added to promote drainage, the soil or sand substrate must still be amended with compost.

Vegetation Criteria

Refer to BMP T9.10 — Basic Biofiltration Swale, BMP T9.20 — Wet Biofiltration Swale, and BMP T9.30 — Continuous Inflow Biofiltration Swale in Volume V of the SWMMWW for biofiltration swale vegetation criteria. The following additional vegetation criteria must be followed for biofiltration swales installed in Seattle:

- Grass must be established throughout the entire treatment area of the biofiltration swale subject to the following provisions:
  - Seeding is best performed in spring (mid-March to June) or fall (late September to October). For summer seeding, sprinkler systems or other measures for watering grass seed must be provided.
  - Seed may be applied via hydroseeding or broadcast application.
  - Irrigation is required during the first summer following installation if seeding occurs in spring or summer. Swales seeded in the fall may not need irrigation. Site planning must address the need for sprinklers or other means of irrigation.
- Swales are subject to both dry and wet conditions and accumulation of sediment and debris. A mixture of dry-area and wet-area grass species that can continue to grow through silt deposits is most effective. Acceptable grass seed mixes for the Seattle area are provided in the City of Seattle Standard Specifications (9-14). As an alternative to these mixes, a horticultural or erosion control specialist may develop a seed specification tailored to the site. *Appendix E* includes a plant list for biofiltration swales that lists grasses or other plants that are particularly tolerant of wet conditions.
- Sod may be used where needed to initiate adequate growth. If sod is used, the sod must be grown from a seed mix suitable for a biofiltration swale and clay content must be less than 10 percent.
- During seeding, slow-release fertilizers may be applied to speed the growth of grass. If the swale is discharges to a nutrient-critical receiving water, low phosphorus fertilizers (such as formulations in the proportion 3:1:3 NPK or less) or a slow-release phosphorus formulation such as rock phosphate or bone meal should be used. A typical fertilizer application rate should be 2 pounds per 1,000 square feet. If animal manures are used in the fertilizer, they must be sterilized to avoid leaching fecal coliform bacteria into receiving waters.

- A grassy swale should be incorporated into the project site landscape design. Shrubs may be planted along the edges of a swale (above the water quality treatment level) provided that exposure of the swale bottom to sunlight and maintenance accessibility are not compromised. Note: For swales used to convey high flows, the plant material selected must bind the soil adequately to prevent erosion.

5.8.3.6. BMP Sizing

Refer to BMP T9.10 — Basic Biofiltration Swale, BMP T9.20 — Wet Biofiltration Swale, and BMP T9.30 — Continuous Inflow Biofiltration Swale in Volume V of the SWMMWW for BMP Sizing considerations.

Biofiltration swale design procedures are described in the SWMMWW for the following steps:

- Preliminary steps (P)
- Design steps for biofiltration swale capacity (D)
- Stability check steps (SC)

Seattle-specific guidance for Preliminary Step P-1 includes the following:

- For offline swales, the high flow bypass must be designed so that all flows up to and including the water quality design flow rate are directed to the swale. The water quality design flow rate (Q) is calculated by multiplying the design flow determined by an approved continuous runoff model by an offline ratio of 3.0.
- For on-line swales, Q is determined by multiplying the design flow determined by an approved continuous runoff model by an on-line ratio of 1.65.

5.8.3.7. Minimum Construction Requirements

Minimum construction requirements associated with biofiltration swales include the following:

- Grade biofiltration swales to attain uniform longitudinal and lateral slopes.
- Avoid compaction during construction.
- Do not put biofiltration swales into operation until areas of exposed soil in the contributing drainage areas have been sufficiently stabilized. Deposition of eroded soils can impede the growth of grass in the swale and reduce water quality treatment effectiveness. Therefore, erosion and sediment control measures must remain in place until the biofiltration swale vegetation is established (refer to *Volume 2, Construction Stormwater Control*).
- Protect newly constructed biofiltration swales from stormwater flows until grass has been established by diverting flows or by covering the swale bottom with clear plastic until the grass is well rooted. If these actions are not feasible, place an erosion control blanket per City of Seattle Standard Specification 9-14.5(2) over the freshly applied seed mix. Sod may be used as a temporary cover during the wet season, but sodded areas must be reseeded with a suitable grass mix as soon as the weather is conducive to seed germination. Remove sod before reseeding.

5.8.3.8. Operations and Maintenance Requirements

Basic, wet, and continuous inflow biofiltration swale O&M requirements are provided in *Appendix G* (*BMPs No. 9 and 10*). Compost-amended biofiltration swale O&M requirements can be found in the WSDOT Highway Runoff Manual under BMP RT.04 — Biofiltration Swale.

5.8.4. Filter Strips/Drains

5.8.4.1. Description

A filter strip is a grassy slope that receives unconcentrated runoff from adjacent hard surfaces such as a parking lots, driveways, or roadways. Filter strips are graded to maintain sheet flow over their entire width. Compost and other amendments can be incorporated into filter strips designs to provide metals treatment (refer to *Section 3.5.2.3*). The following three types of filter strip BMPs are described in this section:

1. **Vegetated filter strip**: a flat filter strip with no side slopes. Polluted stormwater is distributed as sheet flow across the inlet width of the filter strip.
2. **Compost-amended vegetated filter strip (CAVFS)**: A metals treatment option, similar to the vegetated filter strip, but the filter area is compost-amended to improve infiltration characteristics, increase surface roughness, and improve plant sustainability. Once permanent vegetation is established, the advantages of the CAVFS are higher surface roughness, greater retention and infiltration capacity, improved removal of soluble cationic contaminants through sorption, improved overall vegetative health, and a reduction of invasive weeds. Compost-amended systems have somewhat higher construction costs due to more expensive materials, but require less land area for water quality treatment, which can reduce overall costs.
3. **Media filter drain (MFD)**: Previously referred to as the ecology embankment, a linear flow-through stormwater treatment device that can be sited along roadway side-slopes (conventional design) and medians (dual MFD), borrow ditches, or other linear depressions. Cut-slope applications may also be considered. MFDs have four basic components: a gravel no-vegetation zone, a vegetated filter strip, the MFD mix bed, and an optional gravel-filled underdrain trench or layer of crushed surfacing base course (CSBC). The layer of CSBC must be porous enough to allow treated flows to freely drain away from the MFD mix.

5.8.4.2. Performance Mechanisms

Filter strips remove pollutants primarily by filtration as stormwater moves through the grass blades. This enhances sedimentation and traps pollutants which adhere to the grass and thatch. Pollutants can also be adsorbed by the underlying soil when infiltration occurs, but the extent of infiltration depends on the type of soil, the density of grass, and the slope of the filter strip. The MFD removes suspended solids, phosphorus, and metals from roadway runoff through physical straining, ion exchange, carbonate precipitation, and biofiltration.

5.8.4.3. Applicability

A filter strip can be designed for both treatment and conveyance of stormwater flow. This combined use can reduce development costs by eliminating the need for separate conveyance and treatment systems. Vegetated filter strips, CAVFS, and MFDs are typically configured as flow-through systems, with little or no detention or storage. This BMP can be applied to meet the requirements as summarized below.

BMP	On-site: List	On-site: Standard	Flow Control: Forest	Flow Control: Pasture	Flow Control: Peak	Water Quality: Basic	Water Quality: Enhanced Metals	Water Quality: Oil Control	Water Quality: Phosphorus	Conveyance
Vegetated Filter Strip						x	TT-A or TT-B		TT-A or TT-B	x
CAVFS						x	x			x
MFD						x	x			x

TT-A = Treatment Train A (must be followed by a Linear Sand Filter (*Section 5.8.5*).

TT-B = Treatment Train B (must be preceded by a Linear Sand Filter (*Section 5.8.5*).

Refer to *Section 3.5.2.2* for more information on Two-BMP Treatment Trains.

5.8.4.4. Site Considerations

The following are site considerations for determining the feasibility of filter strips for a particular site.

- Setbacks and restrictions:
  - The filter strips are not typically permitted within landslide-prone areas as defined by the Regulations for Environmentally Critical Areas (SMC, Section 25.09.030).
  - The filter strips are not typically permitted within a setback above a steep slope area (SMC, Section 25.09.020). The setback is calculated as 10 times the height of the steep slope area (to a 500foot maximum setback). Filter strips within this setback may be feasible provided a slope stability analysis is completed by a geotechnical engineer. The analysis must determine the effects that filter strip would have on the steep slope area and adjacent properties.
  - For sites with septic systems, the point of discharge to filter strip must be downgradient of the drainfield primary and reserve areas.
- Filter strips are suitable for sites with a maximum lateral slope of the contributing area of 2 percent.
- Filter strips are suitable for sites with a maximum longitudinal slope of the contributing area of 5 percent. Contributing areas with longitudinal slopes steeper than 5 percent should either use a different BMP or must provide energy dissipation and flow spreading mechanisms upslope of the upper edge of the filter strip.
- Filter strips are designed as on-line facilities. They are designed to receive continuous sheet flow from contributing areas and should not be located downstream of detention facilities or other concentrated flows.
- MFDs can be used in areas with longitudinal slopes less than 5 percent.

Additional site considerations may apply depending on site conditions and other factors.

5.8.4.5. Design Criteria

Refer to BMP T9.40 — Vegetated Filter Strip, BMP T7.40 — CAVFS, and BMP T8.40 — MFD in Volume V of the SWMMWW for filter strip design criteria. Additional descriptions, applications, and design details are provided in the WSDOT Highway Runoff Manual under BMP RT.02 — Vegetated Filter Strip and RT.07 — MFD. The City allows the use of MFDs per the Ecology-approved designs outlined in the WSDOT Highway Runoff Manual.

5.8.4.6. BMP Sizing

Filter strips must be designed to meet the criteria listed in Table 5.51. Refer to BMP T9.40 — Vegetated Filter Strip, BMP T7.40 — CAVFS, and BMP T8.40 — MFD in Volume V of the SWMMWW for additional information on filter strip sizing methods.

Table 5.51. Basic and Compost-amended Vegetated Filter Strip Design and Sizing Criteria.

Design Parameter	Vegetated Filter Strip	CAVFS	MFD
Longitudinal slope	1 – 33%	1 – 15%	5%
Lateral slope	NA	NA	2 – 25%
Maximum velocity	0.5 foot/second	0.5 foot/second	NA
Maximum water depth	1 inch	1 inch	NA
Manning's roughness coefficient	0.35	0.40 to 0.55[a]	NA
Minimum hydraulic residence time at Water Quality Design Flow Rate	9 minutes	NA	NA
Minimum length	NA[c]	NA	NA
Maximum side slope	Inlet edge ≥ 1 inch lower than contributing paved area	Inlet edge ≥ 1 inch lower than contributing paved area	NA
Max. tributary drainage flow path	150 feet	150 feet	150 feet
Max. longitudinal slope of contributing area	5% (steeper than 5% need upslope flow spreading and energy dissipation)	5% (steeper than 5% need upslope flow spreading and energy dissipation)	5%
Max. lateral slope of contributing area	2% (at the edge of the strip inlet)[b]	2% (at the edge of the strip inlet)[b]	NA

[a] Manning's n ranges from 0.40 (hydroseeded, grass maintained at 95% density and 4-inch length via mowing, periodic re-seeding, and possible landscaping with shrubs) to 0.55 (top-dressed with ≥3 inches compost or mulch [seeded or landscaped]).

[b] A stepped series of flow spreaders installed at the head of the strip could compensate for slightly steeper slopes.

[c] Length based on achieving required hydraulic residence time.

5.8.4.7. Minimum Construction Requirements

Minimum construction requirements associated with filter strips include the following:

- Install an erosion control blanket below the design water depth of a vegetated filter strip, at least 4 inches of topsoil, and the selected seed mix. Use a straw mulch or sod above the water line. Refer to *Volume 2, Construction Stormwater Control* for erosion and sediment control BMPs.
- Do not put filter strips into operation until areas of exposed soil in the contributing drainage areas have been sufficiently stabilized. Deposition of eroded soils can impede the growth of grass in the filter strip and reduce treatment effectiveness. Erosion and

sediment control measures must remain in place until the filter strip vegetation is established.

- Avoid compaction of filter strip areas during construction.

5.8.4.8. Operations and Maintenance Requirements

Vegetated filter strip O&M requirements are provided *Appendix G* (*BMP No. 11*). CAVFS and MFD O&M requirements can be found in the WSDOT Highway Runoff Manual under BMP RT.02 — Vegetated Filter Strip and RT.07 — MFD.

5.8.5. Sand Filters

5.8.5.1. Description

Sand filters are used to provide water quality treatment. The following three sand filter BMPs are described in this section:

1. **Sand filter basins**: Like an infiltration pond, the sand filter basin is an impoundment that temporarily stores stormwater runoff so that it can infiltrate, but instead of infiltrating through the underlying soil, stormwater passes through a constructed sand bed. Sand filters can be sized as either a basic or a large facility to meet different water quality objectives. Sand filter basins are designed with underdrains to collect and route runoff following treatment to the downstream conveyance system.
2. **Sand filter vaults**: A sand filter vault is similar to a sand filter basin, except that the entire facility is installed below grade in a vault. It typically consists of a presettling cell (if pretreatment is not already provided) and a sand filtration cell. Like a sand filter basin, a vault can be sized as either a basic or a large facility to meet different water quality objectives.
3. **Linear sand filters**: Linear sand filters are similar to sand filter vaults, except the vault is configured as a long, mustow, linear system. The vault contains two cells or chambers, one for removing coarse sediment and the other containing sand overlying an underdrain. Runoff usually enters the settling chamber as unconcentrated flow from an adjacent area and overflows to a central weir into the sand portion of the vault.

5.8.5.2. Performance Mechanisms

Sand filters treat stormwater primarily via physical filtration. As stormwater passes through the sand media, pollutants are trapped in the small spaces between sand grains, or adhere to the sand surface. Over time, soil bacteria may also grow in the sand bed and some biological removal may occur.

Sand filter media can also be amended with steel fiber and crushed calcitic limestone to increase dissolved metals removal. Use of amended sand filters is allowed with the permission of the Director.

5.8.5.3. Applicability

A sand filter BMP can be applied to meet the requirements as summarized below.

BMP	On-site: List	On-site: Standard	Flow Control: Forest	Flow Control: Pasture	Flow Control: Peak	Water Quality: Basic	Water Quality: Enhanced Metals	Water Quality: Oil Control	Water Quality: Phosphorus	Conveyance
Basic Sand Filter						x	TT-A, TT-B, or TT-C		TT-A, TT-B, TT-C, or TT-D	x
Large Sand Filter[a]						x	x		x	x
Sand Filter Vault						x	TT-A, TT-B, or TT-C		TT-A, TT-B, TT-C, or TT-D	x
Large Sand Filter Vault						x	x		x	x
Linear Sand Filter						x	TT-E or TT-F	x[b]	TT-E or TT-F	x

TT-A = Treatment Train A (must be preceded by a Basic Wet Pond (*Section 5.8.6*), Wet Vault (*Section 5.8.7*), Basic Combined Detention/Wetpool (*Section 5.8.9*)

TT-B = Treatment Train B (must be preceded by a Biofiltration Swale (*Section 5.8.3*)

TT-C = Treatment Train C (must be followed by an approved Proprietary and Emerging Water Quality Treatment Technology (*Section 5.8.11*)

TT-D = Treatment Train D (must be preceded by a Stormwater Treatment Wetland (*Section 5.8.8*)

TT-E = Treatment Train E (must be followed by a Filter Strip (*Section 5.8.4*)

TT-F = Treatment Train F (must be preceded by a Filter Strip (*Section 5.8.4*)

Refer to *Section 3.5.2.2* for more information on Two-BMP Treatment Trains

[a] Large sand filters are required to be sized to 95% of runoff volume to meet metals and phosphorus treatment requirement.

[b] Linear sand filter may not be used for oil control if it is used to satisfy any other treatment requirement.

5.8.5.4. Site Considerations

Refer to BMP T8.10 — Basic Sand Filter Basin, BMP T8.11 — Large Sand Filter Basin, BMP T8.20 — Sand Filter Vault, and BMP T8.30 — Linear Sand Filter in Volume V of the SWMMWW for site considerations related to sand filters. The following site considerations also apply to sand filters installed in Seattle:

- Sand filters are not allowed within steep slopes, known landslide areas, and their 15-foot buffers as defined by the regulations for ECAs (SMC, Section 25.09.012). For sand filters within a setback equal to the height of the slope to a maximum of 50 feet from the top of steep slope and known landslide area, a slope stability assessment must be completed by a licensed geotechnical engineer or engineering geologist considering the effects on slope stability due to a leaking or damaged detention BMP. More stringent exfiltration (i.e., watertightness) testing of sand filter vaults within a 50-foot setback from the top of the steep slope and known landslide area may be required.

- A sand filter can add landscape interest and should be incorporated into the project landscape design.
- Interior side slopes may be stepped with flat areas to provide informal seating with a game or play area below.
- Perennial beds can be planted above the overflow water surface elevation. However, large shrubs and trees are not recommended because shading limits evaporation and can inhibit drying of the filter surface. In addition, falling leaves and needles can clog the filter surface, requiring more frequent maintenance.

Additional site considerations may apply depending on site conditions and other factors.

5.8.5.5. Design Criteria

The following provides a description and requirements for the components of sand filters. Some or all of the components may be used for a given application depending on the site characteristics and restrictions, pollutant loading, and design objectives. Design criteria are provided in this section or in Volume V of the SWMMWW for the following elements:

Design Element	SWMMWW Design Criteria	Seattle-specific Design Criteria
Presettling	x	x
Liner	x	x
Geometry and composition	x	x
Structural requirements	x	x
Underdrains (if any)	x	x
Sand media	x	x
Vegetation (if any)		x
Access	x	x
Offline/on-line facilities	x	
Inlets and outlets	x	

Refer to BMP T8.10 — Basic Sand Filter Basin, BMP T8.11 — Large Sand Filter Basin, BMP T8.20 — Sand Filter Vault, and BMP T8.30 — Linear Sand Filter in Volume V of the SWMMWW for sand filter basin and sand filter vault design criteria. In addition to Ecology's criteria, the City has also developed specific design criteria for several design elements which are summarized below.

Presettling

Presettling is required to prevent clogging and extend the service life of the sand filter media. Presettling design requirements are described in *Section 4.4.5*. Refer to BMP T8.10 — Basic Sand Filter Basin, BMP T8.11 — Large Sand Filter Basin, BMP T8.20 — Sand Filter Vault, and BMP T8.30 — Linear Sand Filter in Volume V of the SWMMWW for sand filter basin and sand filter vault presettling requirements.

The following additional criteria apply specifically to sand filter vaults installed in Seattle:

- The presettling cell bottom may be longitudinally level or inclined toward the inlet.

- To facilitate sediment removal, the presettling cell bottom must also slope from each side toward the center at a minimum of 5 percent, forming a broad "v."
- More than one "v" may be used to minimize presettling cell depth.

Liners

Refer to BMP T8.10 — Basic Sand Filter Basin, BMP T8.11 — Large Sand Filter Basin, BMP T8.20 — Sand Filter Vault, and BMP T8.30 — Linear Sand Filter in Volume V of the SWMMWW for sand filter liner requirements.

- Refer to *Appendix E* for additional information on liner design criteria.

Geometry and Composition

Refer to BMP T8.10 — Basic Sand Filter Basin, BMP T8.11 — Large Sand Filter Basin, BMP T8.20 — Sand Filter Vault, and BMP T8.30 — Linear Sand Filter in Volume V of the SWMMWW for sand filter basin and sand filter geometry and composition requirements.

The following additional criterion applies to all sand filter types installed in Seattle:

- Depth of storage over the filter media (d) must be 6 feet maximum

The following additional criterion applies specifically to linear sand filters installed in Seattle:

- If separated from traffic areas, a linear sand filter may be covered or open, but if covered, the cover must be removable for the entire length of the filter. Covers must be grated if flow to the filter is from sheet flow.

Structural Requirements

Refer to BMP T8.10 — Basic Sand Filter Basin, BMP T8.11 — Large Sand Filter Basin, BMP T8.20 — Sand Filter Vault, and BMP T8.30 — Linear Sand Filter in Volume V of the SWMMWW for sand filter structural requirements.

The following additional criteria apply specifically to linear sand filters installed in Seattle:

- A linear sand filter vault must be concrete (precast/prefabricated or cast-in-place). The concrete must conform to the "Material" requirements for wet vaults (refer to *Section 5.8.7.5*).
- At the discretion of SDCI, the sediment cell may be made of materials other than concrete, provided water can be evenly spread for uniform delivery into the sand filter cell.
- Where linear sand filters are located in traffic areas, they must meet the structural requirements specified for wet vaults (refer to *Section 5.8.7.5*). The sediment cell must have a removable grated cover that meets HS25 traffic loading requirements. The cover over the sand filter cell may be either solid or grated.

Underdrains

Underdrains are required to allow the sand media to dry out between events. Refer to BMP T8.10 — Basic Sand Filter Basin, BMP T8.11 — Large Sand Filter Basin, BMP T8.20 — Sand

Filter Vault, and BMP T8.30 — Linear Sand Filter in Volume V of the SWMMWW for sand filter underdrain requirements.

The following additional requirements for underdrains also apply to sand filters installed in Seattle:

- If a drain strip is used for lateral drainage, the strip must be placed at the slope specified by the manufacturer but at least at 0.5 percent. All drain strips must extend to the central collector pipe. Drain strip installations must be analyzed for conveyance because manufactured products vary in the amount of flow they are designed to handle.
- Underdrain pipes must be per City of Seattle Standard Plan No. 291.
- A geotextile fabric (refer to specifications in *Appendix E*) must be used between the sand layer and drain rock or gravel and placed so that 2 inches of drain rock/gravel is above the fabric. Drain rock must be 0.75- to 1.5-inch rock or gravel backfill, washed free of clay and organic material. Cover the geotextile fabric with 1 inch of drain rock/gravel. Use 0.75- to 1.5-inch drain rock or gravel backfill, washed free of clay and organic material. These requirements can be met with City of Seattle Mineral Aggregate Type 4.

Sand Media

Refer to BMP T8.10 — Basic Sand Filter Basin, BMP T8.11 — Large Sand Filter Basin, BMP T8.20 — Sand Filter Vault, and BMP T8.30 — Linear Sand Filter in Volume V of the SWMMWW for sand filter media requirements.

The following additional requirement for sand media also applies to sand filters installed in Seattle:

- Sand filters must drain freely. Sand media cannot be saturated for extended periods because under these conditions, oxygen can be depleted, releasing pollutants such as dissolved metals and phosphorus that are more mobile under anoxic conditions. To prevent this release of pollutants that have accumulated in the media, sand filters must be designed to drain the water quality design storm volume within 72 hours.

Vegetation

Vegetation requirements for basic and large sand filter basins are not included in Volume V of the SWMMWW; however, the City has developed the following guidelines for grass cover for sand filter basins installed in Seattle:

- No topsoil may be added to sand filter beds because fine-grained materials (e.g., silt and clay) reduce the hydraulic capacity of the filter.
- Grass must tolerate the demanding environment of the sand bed. Sand filters experience long periods of saturation during the winter wet season, followed by extended dry periods during the summer. Modeling predicts that sand filters will be dry about 60 percent of the time in a typical year. Consequently, vegetation must be capable of surviving drought, as well as wet conditions.
- *Appendix E* includes a plant list for sand filters. These species can generally survive approximately 1 month of submersion while dormant in the winter (until about

February 15), but they can only withstand about 1 to 2 weeks of submersion after mid-February.

- Several grass species in the plant list in *Appendix J* can withstand summer drying and are fairly tolerant of infertile soils. In general, planting a mixture of three or more species is recommended. This ensures better coverage since tolerance of the different species is somewhat different, and the best adapted grasses will spread more rapidly than the others. Legumes, such as clover, fix nitrogen and can thrive in low-fertility soils such as sands. This makes them particularly good choices for planting the sand filter bed.
- A sports field sod grown in sand may be used on the sand surface. No other sod may be used due to the high clay content in most sod soils.
- To prevent overuse that could compact and potentially damage the filter surface, permanent structures (e.g., playground equipment or bleachers) are not permitted. Temporary structures or equipment must be removed for filter maintenance.
- Seed should be applied in spring or mid to late fall unless irrigation is provided. If the filter is seeded during the dry summer months, surface irrigation is required to ensure that the seeds germinate and survive. Seed must be applied at 80 pounds per acre.
- Slow-release fertilizers may be applied to improve germination.
- Low phosphorus fertilizers (such as formulations in the proportion 3:1:3 N-P-K or less) or a slow-release phosphorus formulation should be used.

Access

Refer to BMP T8.10 — Basic Sand Filter Basin, BMP T8.11 — Large Sand Filter Basin, BMP T8.20 — Sand Filter Vault, and BMP T8.30 — Linear Sand Filter in Volume V of the SWMMWW for sand filter access requirements.

The following additional criteria apply specifically to sand filter vaults installed in Seattle:

- Provision for access is the same as for wet vaults (refer to *Section 5.8.7.5*). However, the arch culvert sections allowed for wet vaults may not be used for sand filter vaults. Free access to the entire sand bed is needed for maintenance. Removable panels must be provided over the entire sand bed.
- An access road must be provided to the inlet and outlet of a sand filter for inspection and maintenance purposes.

5.8.5.6. BMP Sizing

Sand filters must be designed to capture and treat 91 percent of the total runoff volume (95 percent for large sand filters designed to meet metals or phosphorus treatment) as calculated by an approved continuous runoff model. Only 9 percent of the total runoff volume (5 percent for large sand filters designed to meet metals or phosphorus treatment) may bypass or overflow from the sand filter facility. A flow splitter may be used to facilitate bypass. Design guidelines for flow splitters are provided in *Appendix E*. The following design criteria apply to all sand filters, unless otherwise noted for Sand Filter Vaults and Linear Sand Filters.

Two methods are provided for sizing sand filters (Simplified Sizing Approach and Facility Modeling), both of which are based on Darcy's law:

Q = KiA

Where:

Q = water quality design flow (cfs)

K = hydraulic conductivity of the media (fps)

A = surface area perpendicular to the direction of flow (sf)

i = hydraulic gradient (ft/ft) for a constant head and constant media depth

$$i = \frac{h + L}{L}$$

Where:

h = average depth of water above the filter (ft), defined as d/2

d = maximum water storage depth above the filter surface (ft)

L = thickness of sand media (ft)

Although it is not seen directly, Darcy's law underlies both the simple and the modeling design methods. V, or more correctly, 1/V, is the direct input in the sand filter design. The relationship between V and K is revealed by equating Darcy's law and the equation of continuity, Q = VA. (Note: When water is flowing into the ground, V is commonly called the infiltration rate. It is ordinarily measured via a soil infiltration test.)

Specifically:

Q = KiA and Q = VA so,

VA = KiA or V = Ki

Note that V ≠ K. The infiltration rate is not the same as the hydraulic conductivity, but they do have the same units (distance per time). K can be equated to V by dividing V by the hydraulic gradient i, which is defined above. The hydraulic conductivity K does not change with head nor is it dependent on the thickness of the media, only on the characteristics of the media and the fluid. The hydraulic conductivity of 1 inch per hour (2.315×10^{-5} fps) used in this design is based on bench-scale tests of conditioned rather than clean sand. This design hydraulic conductivity represents the average sand bed condition as silt is captured and held in the filter bed. Unlike the hydraulic conductivity, the infiltration rate V changes with head and media thickness, although the media thickness is constant in the sand filter design. Table 5.52 shows values of V for different water depths d (d = 2h).

Table 5.52. Sand Filter Design Parameters.

Facility ponding depth d (ft)	1 ft	2 ft	3 ft	4 ft	5 ft	6 ft
Infiltration Rate V (in/hr)[a]	1.33	1.67	2.00	2.33	2.67	3.00
1/V (min/in)	45	36	30	26	22.5	20

[a] The infiltration rate is not used directly, but is provided for information. V equals the hydraulic conductivity, K, times the hydraulic gradient, i. The hydraulic conductivity used is 1 in/hr. The hydraulic gradient = (h + L)/L, where h = d/2 and L = the sand depth (1.5 ft).

Simplified Sizing Approach

The simplified sizing approach is taken from the *King County Surface Water Design Manual*. It uses standard values to define filter hydraulic characteristics for determining the sand surface area. This method is useful for planning purposes, for a first approximation to begin iterations in the modeling method, or when use of a computer model is not desired or available. The simplified sizing method very often results in a larger filter than the modeling method. More robust calculation methods, using an approved continuous runoff model, may be used (refer to the following section on modeling method).

King County developed the simplified sizing approach to design sand filters that meet the required treatment volume without performing detailed modeling. Steps for the simplified sizing approach are summarized below.

- *Step 1 — Determine maximum depth of water above sand filter*. This depth is defined as the depth at which water begins to overflow the reservoir pond, and it depends on site topography and hydraulic constraints. The depth is chosen by the designer.
- *Step 2 — Determine site characteristics*. Determine the total number of hard surface acres and the total number of grass acres draining to the sand filter. Determine whether the site is on till or outwash soils.
- *Step 3 — Calculate minimum required surface area for the sand filter*. Determine the sand filter area by multiplying the values in Table 5.53 by the site acreage from Step 2 using the following equation:

$$A_{sf} = 0.7(T_i A_i + T_{tg} A_{tg} + T_{og} A_{og})$$

Where:

A_{sf} = sand filter area (sf)

0.7 = adjustment factor to account for routing effect on size

$T_{i,tg,og}$ = tributary area per soil/cover type (acres)

$A_{i,tg,og}$ = filter area per soil/cover type (sf/acre) from Table 5.53.

Table 5.53. Sand Filter Area Increments for Various Soil and Cover Types.

Treatment Goal	Maximum Depth above Filter (ft)	Soil and Cover Types [filter area (sf)/tributary area (acre)]: A_i Hard Surface	Soil and Cover Types [filter area (sf)/tributary area (acre)]: A_t Till Grass	Soil and Cover Types [filter area (sf)/tributary area (acre)]: A_{og} Outwash Grass
BASIC	6	760	160	140
	3	1,140	240	210
	1	1,711	360	314
LARGE	6	1,179	279	250
	3	1,769	419	370
	1	2,654	629	550

Forested areas may be ignored. Vegetated areas other than grass may still be represented as grass for the simple sizing method, or the detailed routing method may be employed using actual cover types.

The values in Table 5.53 were derived as follows. Flows were estimated using the KCRTS model for one acre of the cover types selected in the table. Darcy's law ($Q = Ki\ A$) was then used to determine sand filter area using this flow Q, the hydraulic gradient i for the various ponding depths given, and a hydraulic conductivity k of 2.3 X 10^{-5} fps (1 in/hr). The hydraulic gradient i was calculated as $(h+l)/\ l$, where h = the average depth of water above the filter, taken to be the ponding depth $d/2$, and l = the thickness of the sand layer, which is 1.5 ft. The hydraulic conductivity represents a partially plugged sand condition found by bench-scale testing using successive trials with turbid water.

For depths between the values given in the table, areas can be interpolated. For depths outside the range presented in the table, the Facility Modeling method must be used.

- *Step 4 — Size the underdrain system*. The underdrain system is sized to convey the peak filtered flows to the outlet. Underdrains can be used in lieu of analyzing conveyance capacity for feeder pipes (refer to Design Criteria section). Strip drains, if used, must be analyzed for conveyance per manufacturer's specifications.

The collector pipe (i.e., the pipe collecting flows from the rest of the underdrain system) must be sized to convey the 2year, 15minute peak flow with 1 foot of head above the invert of the upstream end of the collector pipe.

Intent — The underdrain must be able to remove standing water from beneath the sand. If standing water remains, the sand will remain saturated. This could cause oxygen depletion and reduced conditions in the sand, allowing some pollutants to become mobile and be released from the filter to downstream receiving waters.

Simple Method Sizing Example:

For a site with 2 acres of hard surface area and 2 acres of till grass draining to the sand filter, and 3 feet of head above the filter and using the parameters for Basic Sand Filter Basins from Table 5.53, the required sand area for a basic size sand filter would be as follows:

(2 acres x 1,140 sf/acre) + (2 acres x 240 sf/acre) = 2,760 sf

Because the site is located in Seattle, the "regional scale factor" (refer to Step 1) is 1.0. Multiply 2,760 square feet by the 0.7 adjustment factor (refer to Step 4).

2,760 sf x 1.0 x 0.7 = 1,930 sf

The required sand bed area is therefore 1,930 square feet.

Note: Find the total facility area by adding 3H:1V side slopes for the 3-foot ponding depth plus extra vertical height to convey the 100-year flow. For example, if the total pond depth is 3.5 feet, the sand filter will require a total land area of (44 feet + 10.5 feet) x (44 feet + 10.5 feet) = 2.970 square feet, plus access and setback requirements.

Modeling Approach

When using continuous modeling to size a sand filter, apply the assumptions listed in Table 5.54.

Table 5.54. Sand Filter Design and Sizing Criteria.

Variable	Basic Sand Filter Basin	Large Sand Filter Basin	Sand Filter Vault	Linear Sand Filter
Precipitation Series	SEPTS-99 unless otherwise adopted by the Director	SEPTS-99 unless otherwise adopted by the Director	SEPTS-99 unless otherwise adopted by the Director	SEPTS-99 unless otherwise adopted by the Director
Computational Time Step	15 minutes	15 minutes	15 minutes	15 minutes
HSPF Parameters	LSUR, SLSUR, NSUR must be adjusted per *Appendix F*	LSUR, SLSUR, NSUR must be adjusted per *Appendix F*	LSUR, SLSUR, NSUR must be adjusted per *Appendix F*	LSUR, SLSUR, NSUR must be adjusted per *Appendix F*
Inflows to Facility	Continuous model output for applicable water quality design flow rate and volume	Continuous model output for applicable water quality design flow rate and volume	Continuous model output for applicable water quality design flow rate and volume	Continuous model output for applicable water quality design flow rate and volume
Ponding Depth	Maximum water depth over the filter media	Maximum water depth over the filter media	Maximum water depth over the filter media	Maximum of 1 foot
Precipitation Applied to Facility	Yes	Yes	No	Yes (grated cover) No (solid cover)
Evaporation Applied to Facility	Yes	Yes	No	Yes (grated cover) No (solid cover)
Media depth	18 inches or other as designed	18 inches or other as designed	18 inches or other as designed	Minimum of 12 inches of sand and 8 inches of drain rock
Sand Media Hydraulic Conductivity	1 inch per hour	1 inch per hour	1 inch per hour	1 inch per hour
Use Wetted Surface Area	Only if side slopes are 3H:1V or flatter	Only if side slopes are 3H:1V or flatter	No	No

5.8.5.7. Minimum Construction Requirements

Refer to BMP T8.10 — Basic Sand Filter Basin, BMP T8.11 — Large Sand Filter Basin, BMP T8.20 — Sand Filter Vault, and BMP T8.30 — Linear Sand Filter in Volume V of the SWMMWW for sand filter minimum construction requirements.

5.8.5.8. Operations and Maintenance Requirements

Sand filter O&M requirements are provided in *Appendix G* (*BMPs No. 15* and *16*).

5.8.6. Wet Ponds

5.8.6.1. Description

Wet ponds are constructed stormwater ponds that retain a permanent pool of water (i.e., a wet pool or dead storage) at least during the wet season.

As an option, a shallow marsh area can be created within the permanent pool volume to provide additional treatment for nutrient removal. Peak control can be provided in the live storage area above the permanent pool.

5.8.6.2. Performance Mechanisms

The volume of the wet pool, which slows down the velocity of incoming stormwater, allows particulates and particulate-bound pollutants to settle and is a key factor in determining wet pond effectiveness. Biological uptake also acts as a secondary pollutant removal mechanism.

5.8.6.3. Applicability

Wet ponds can be applied to meet the requirements as summarized below. Wet ponds can be combined with detention storage to provide flow control (refer to *Section 5.8.9*).

BMP	On-site: List	On-site: Standard	Flow Control: Forest	Flow Control: Pasture	Flow Control: Peak	Water Quality: Basic	Water Quality: Enhanced Metals	Water Quality: Oil Control	Water Quality: Phosphorus	Conveyance
Basic Wet Pond						x	TT-B		TT-A	x
Large Wet Pond[a]						x	x		x	x

TT-A = Treatment Train A (must be followed by a Basic Sand Filter or Sand Filter Vault (*Section 5.8.5*)

TT-B = Treatment Train B (must be followed by a Sand Filter or Sand Filter Vault (*Section 5.8.5*) or an approved Proprietary and Emerging Water Quality Treatment Technology (*Section 5.8.11*)

Refer to *Section 3.5.2.2* for more information on Two-BMP Treatment Trains

[a] A large wet pond requires a wet pool volume at least 1.5 times greater than for a basic wet pond.

5.8.6.4. Site Considerations

Site considerations for wet ponds are the same as those outlined for detention ponds under *Section 5.7.1.4*. Wet ponds require a larger area than a biofiltration swale or a sand filter, but can be integrated into the contours of a site fairly easily and function well for any size project.

Wet ponds work best when the water already in the pond is moved out en masse by incoming flows; a phenomenon called “plug flow.” Because treatment works on this displacement principle, the wet pool storage of wet ponds may be provided below the groundwater level without interfering unduly with treatment effectiveness. However, if combined with a detention function, the live storage must be above the seasonal high groundwater level.

Wet ponds are not allowed within steep slopes, known landslide areas, and their 15-foot buffers as defined by the regulations for ECAs (SMC, Section 25.09.012). For wet ponds within a setback equal to the height of the slope to a maximum of 50 feet from the top of steep slope and known landslide area, a slope stability assessment must be completed by a licensed

geotechnical engineer or engineering geologist considering the effects on slope stability due to a leaking or damaged BMP.

5.8.6.5. Design Criteria

Design criteria for wet ponds are generally the same as those outlined for detention ponds in *Section 5.7.1.5*. Some or all of the components may be used for a given application depending on the site characteristics and restrictions, pollutant loading, and design objectives. Design criteria are provided in this section or in Volume V of the SWMMWW for the following elements:

Design Element	SWMMWW Design Criteria	Seattle-specific Design Criteria
Pond geometry	x	x
Berms and baffles	x	Refer to Detention Ponds (*Section 5.7.1.5*)
Presettling basin	x	x
Overflow structure	x	Refer to Detention Ponds (*Section 5.7.1.5*)
Access	x	Refer to Detention Ponds (*Section 5.7.1.5*)
Vegetation and landscaping	x	x
Inlets and outlets	x	

Refer to BMP T10.10: Wetponds — Basic and Large in Volume V of the SWMMWW for wet pond design criteria. In addition to Ecology's criteria, the City has also developed specific design criteria for several design elements, which are summarized below.

Pond Geometry

A wet pond typically consists of two cells within the wet pond that are separated by a baffle or a berm. A baffle is a vertical divider placed across the entire width of the pond, stopping short of the bottom. A berm is a vertical divider typically built up from the bottom, or if in a vault, connects all the way to the bottom.

Seattle specific requirements include the following:

- The full-length berm or baffle promotes plug flow and enhances quiescence and laminar flow through as much of the entire water volume as possible. Alternative methods to the full-length berm or baffle that provide equivalent flow characteristics may be approved on a case-by-case basis by the City.
- Sediment storage must be provided in the first cell. The sediment storage must have a minimum depth of 1 foot. A fixed sediment depth monitor must be installed in the first cell to gauge sediment accumulation unless an alternative gauging method is proposed.
- The minimum depth of the first cell must be 4 feet, exclusive of sediment storage requirements. The depth of the first cell may be greater than the depth of the second cell.
- Maximum pond depth (excluding sediment storage) must not exceed 8 feet. Deep ponds (greater than 8 feet) may stratify during summer and create low oxygen

conditions near the bottom resulting in re-release of phosphorus and other pollutants back into the water. For wet pool depths in excess of 6 feet, it is recommended that some form of recirculation be provided in the summer, such as a fountain, aerator, or small amount of base flow, to prevent stagnation and low dissolved oxygen conditions.

- The ratio of flow path length to width from the inlet to the outlet must be at least 3:1. The flow path length is defined as the distance from the inlet to the outlet, as measured at mid-depth. The width at mid-depth can be calculated as follows: width = (average top width + average bottom width)/2.
- Wet ponds with wet pool volumes less than or equal to 4,000 cubic feet may be single celled (i.e., no baffle or berm is required). However, it is especially important in this case that the flow path length be maximized. The ratio of flow path length to width must be at least 4:1 in single celled wet ponds but should preferably be 5:1. In addition, a gravity drain for maintenance must be provided 12 to 18 inches from the pond bottom.

Berms and Baffles

A berm or baffle must extend across the full width of the wet pond and tie into the wet pond side slopes. Berm and baffle design criteria for wet ponds are the same as those outlined for detention ponds in *Section 5.7.1.5*.

Presettling

Refer to BMP T6.10 — Presettling Basin in Volume V of the SWMMWW for presettling basin design criteria.

Additional presettling requirements for wet ponds installed in Seattle include:

- Provide 1-foot minimum sediment storage depth.
- Provide 1-foot minimum freeboard (above the design water surface elevation).
- If the runoff will be in direct contact with the soil, line the presettling basin in accordance with the provisions in *Appendix E*.
- Catch basins used for presettling must be per City of Seattle Standard Plan No. 240, 241, or equivalent.

Overflow Structure

Overflow structure design criteria for wet ponds are the same as those outlined for detention ponds under *Section 5.7.1.5*.

Access

Access requirements for wet ponds are the same as those outlined for detention ponds under *Section 5.7.1.5*.

Vegetation and Landscaping

Refer to BMP T10.10: Wetponds — Basic and Large in Volume V of the SWMMWW for vegetation and landscaping requirements.

Additional vegetation and landscaping requirements for wet ponds installed in Seattle include:

- Exposed earth on the pond bottom and interior side slopes must be sodded or seeded with an appropriate seed mixture. All remaining areas of the tract must be vegetated or stabilized before the pond is put into operation.
- No trees or shrubs may be planted within 10 feet of inlet or outlet pipes or drainage structures such as spillways or flow spreaders. Species with roots that seek water, such as willow or poplar, must be avoided within 50 feet of pipes or drainage structures.
- Shrubs that form a dense cover should be planted on slopes above the water quality design water surface on at least three sides. The purpose of planting is to discourage waterfowl use of the pond and to provide shading. *Appendix J* includes a plant list for wet pond peripheries.
- Planting is restricted on berms that impound water either permanently or temporarily during storms. Note: This restriction does not apply to cut slopes that form pond banks, only to berms.
    - Trees or shrubs may not be planted on portions of water-impounding berms taller than 4 feet high. Only grasses may be planted on berms taller than 4 feet.
    - Trees planted on portions of water-impounding berms less than 4 feet high must be small, not higher than 20 feet mature height, and have a fibrous root system. *Appendix J* provides a list of small trees with these characteristics.
    - These trees reduce the likelihood of blow-down trees, or the possibility of channeling or piping of water through the root systems, which may contribute to structural failure on berms that retain water.
- All landscape material, including grass, must be planted in topsoil of sufficient organic content and depth. Native underlying soils may be suitable for planting if amended per Soil Amendment BMP requirements in *Section 5.1*.
- Soil in which trees or shrubs are planted may require additional enrichment or additional compost top-dressing. Consult a certified arborist for site-specific recommendations.
- For a naturalistic effect, as well as ease of maintenance, trees or shrubs should be planted in clumps to form “landscape islands” rather than evenly spaced.
    - The landscaped islands must be a minimum of 6 feet apart, and if set back from fences or other barriers, the setback distance should also be a minimum of 6 feet. Where tree foliage extends low to the ground, the 6 feet of setback should be counted from the outer dripline of the trees (estimated at maturity). This setback allows a 6foot-wide mower to pass around and between clumps.
- Evergreen trees and other trees that produce relatively little leaf-fall (such as Oregon ash, mimosa, or locust) are preferred.
- Trees should be set back so that branches do not extend over the pond (to prevent leaf-drop into the water).
- Drought tolerant species are recommended.

5.8.6.6. BMP Sizing

Refer to BMP T10.10: Wetponds — Basic and Large in Volume V of the SWMMWW for BMP Sizing considerations.

5.8.6.7. Minimum Construction Requirements

Refer to BMP T10.10: Wetponds — Basic and Large in Volume V of the SWMMWW for minimum construction requirements. Additional minimum construction requirements for wet ponds installed in Seattle are the same as those outlined for detention ponds under *Section 5.7.1.7*.

5.8.6.8. Operations and Maintenance Requirements

Wet pond O&M requirements are provided in *Appendix G* (*BMP No. 12*).

5.8.7. Wet Vaults

5.8.7.1. Description

Wet vaults are drainage facilities that contain permanent pools of water that are filled during the initial runoff from a storm event. They are similar to wet ponds, except the wet pool is constructed below grade.

5.8.7.2. Performance Mechanisms

Wet vaults are designed to optimize water quality treatment by dissipating energy and providing retention time in order to settle out particulate pollutants. Being underground, the wet vault lacks the biological pollutant removal mechanisms, such as algae uptake, present in surface wet ponds. Wet vaults are believed to be ineffective in removing dissolved pollutants such as soluble phosphorus or metals, such as copper.

5.8.7.3. Applicability

A wet vault can be applied to meet the requirements as summarized below. Wet vaults can be combined with detention storage to provide flow control (refer to *Section 5.8.9*).

BMP	On-site: List	On-site: Standard	Flow Control: Forest	Flow Control: Pasture	Flow Control: Peak	Water Quality: Basic	Water Quality: Enhanced Metals	Water Quality: Oil Control	Water Quality: Phosphorus	Conveyance
Wet Vault						x	TT-A[a] or TT-B		TT-B	x
Wet Vault and API oil/water separator						x		x		x

[a] The Media Filter media must be of a nature that has the capability to remove dissolved metals effectively as approved by Ecology and accepted by the Director.

TT-A = Treatment Train A (must be followed by Basic Sand Filter, Sand Filter Vault, or an approved Proprietary and Emerging Water Quality Treatment Technology [*Section 5.8.11*]).

TT-B = Treatment Train B (must be followed by Basic Sand Filter or Sand Filter Vault).

Refer to *Section 3.5.2.2* for more information on Two-BMP Treatment Trains.

5.8.7.4. Site Considerations

The following site considerations can help determine the feasibility of a wet vault for a particular site:

- Vault location and vault material approval is required, and may require geotechnical analysis.
- Wet vaults are not allowed within steep slopes, known landslide areas, and their 15-foot buffers as defined by the regulations for ECAs (SMC, Section 25.09.012). For wet vaults within a setback equal to the height of the slope to a maximum of 50 feet from the top of steep slope and known landslide area, a slope stability assessment must be completed by a licensed geotechnical engineer or engineering geologist considering the effects on slope stability due to a leaking or damaged BMP. More stringent exfiltration (i.e., watertightness) testing of wet vaults within a 50-foot setback from the top of the steep slope and known landslide area may be required.

- Consider wet vaults where there are space limitations precluding the use of other treatment BMPs.
- Consider how the wet vault grates and access points fit within a site plan, including restrictions for safety considerations and restriction of pollutants entering through grates. Grates must not operate as inlets. Generally, the surrounding area should be sloped away from grates.
- Consider how access will be provided for Vactor trucks for sediment removal.

Additional site considerations may apply depending on site conditions and other factors.

5.8.7.5. Design Criteria

As with wet ponds, the primary design factor that determines the removal efficiency of a wet vault is the volume of the facility. The larger the volume, the higher the potential for pollutant removal. Performance is also improved by avoiding dead zones (like corners) where little exchange occurs, using large length-to-width ratios, dissipating energy at the inlet, and ensuring that flow rates are uniform to the extent possible and not increased between cells.

The methods for designing the wet vault are identical to the methods for designing wet ponds. The following provides a description and requirements for the components of wet vaults. Typical design details and concepts for the wet vault are shown in Figure 5.38. Some or all of the components may be used for a given application depending on the site characteristics and restrictions, pollutant loading, and design objectives. Design criteria are provided in this section for the following elements:

- Wet vault geometry
- Wet vault configuration
- Inlet, outlet and bypass, if used
- Modifications if combining with a baffle oil/water separator
- Modifications if combining with detention
- Access to cells for maintenance
- Structural requirements

Wet Vault Geometry

The minimum flow length-to-width ratio is 3:1. A greater ratio is desirable. The inlet and outlet should be at opposing corners of the vault to increase the flow path, if possible. Wet pool depths for vaults are the same as specified for wet ponds except for the following modifications:

- The sediment storage must average 1 foot.
- The depth above sediment storage to the water quality design water surface must be a minimum of 4 feet deep since planting cannot be used to prevent resuspension of sediment in shallow water (as it can in open ponds) and to provide for a submerged inlet.
- The maximum depth from finished grade to the vault invert must be 17 feet to allow for removing sediment by Vactor.

Wet Vault Configuration

The vault must be separated into three cells by a wall and a baffle (baffle can be removable). The following criteria apply:

- A wall must be placed at approximately one-third of the wet vault length.
- The wall height must be set no higher than the water quality design water surface, and no lower than 1 foot below.
- A baffle must be placed downstream of the wall, with a minimum distance between the wall and the baffle of 5 feet.
- The baffle must extend from a minimum of 1 foot above the water quality design water surface to a minimum of 1 foot below the invert elevation of the inlet pipe.
- The lowest point of the baffle must be a minimum of 2 feet from the bottom of the vault, and greater if feasible.

Note: If the vault is less than 2,000 cubic feet (inside dimensions), the vault may be one-celled.

Inlet, Outlet and Bypass

The following criteria apply to inlets, outlets, and bypasses:

- The number of inlets to the wet vault should be limited, and the flow path length must be maximized from inlet to outlet for all inlets to the vault.
- The inlet to the wet vault must be submerged with the inlet pipe invert a minimum of 3 feet from the vault bottom (not including sediment storage). The top of the inlet pipe should be submerged at least 1 foot, if possible.

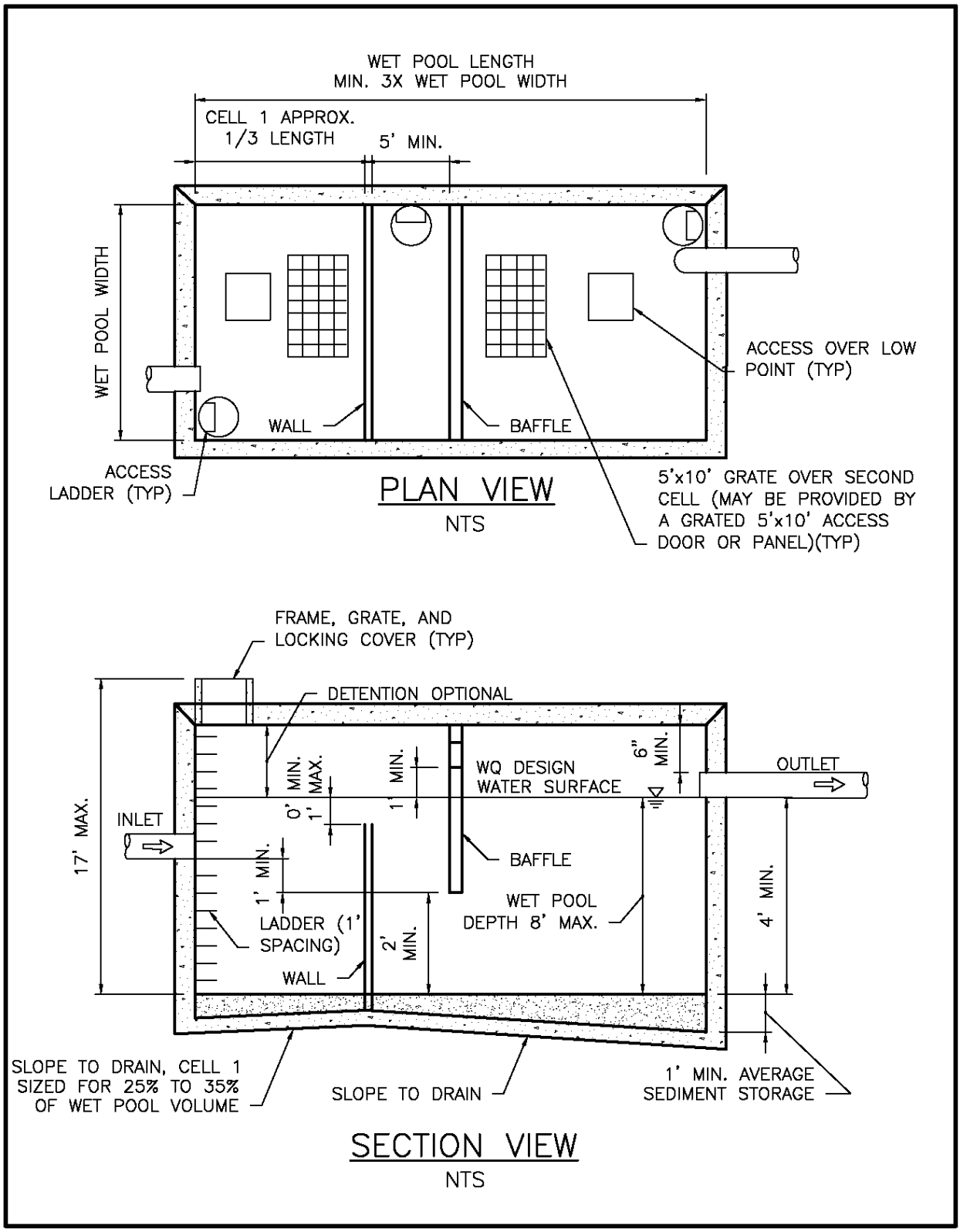


Figure 5.38. Typical Wet Vault.

The submerged inlet is to dissipate energy of the incoming flow. The distance from the bottom is to minimize resuspension of settled sediments. Alternative inlet designs that accomplish these objectives are acceptable.

- Unless designed as an offline facility, the capacity of the outlet pipe and available head above the outlet pipe must be designed to convey the design flow for developed site conditions with a 1 percent annual probability (100year recurrence) without overtopping the vault. The available head above the outlet pipe must be a minimum of 6 inches.
- In single cell wet vaults (without a baffle), the outlet pipe must be back-sloped or have a tee section, the lower arm of which must extend 1 foot below the water quality design water surface to provide for trapping of oils and floatables in the vault.
- In a combination wet vault with detention, the outlet pipe must have a flow control riser tee that extends a minimum of 2 feet below the water quality design water surface.
- Where pipes enter and leave the vault, they must be watertight.
- Valved and piped bypass of flows for maintenance is preferred. This isolates the wet vault for safe entry, prevents resuspension of particle pollutants during a cleaning operation, and manages the volume of water for disposal during cleaning.

Modifications if Combining with a Baffle Oil/Water Separator

If the project site is a high-use site and a wet vault is proposed, the vault may be combined with a baffle oil/water separator to meet the water quality treatment requirements with one facility rather than two. Structural modifications and added design criteria are provided below. However, the maintenance requirements for baffle oil/water separators must be adhered to, in addition to those for a regular wet vault. This will result in more frequent inspection and cleaning than for a wet vault. Refer to *Section 5.8.10.8* for information on maintenance of baffle oil/water separators.

The sizing procedures for the baffle oil/water separator (*Section 5.8.10.6*) must be run as a check to ensure the vault is large enough. If the oil/water separator sizing procedures result in a larger vault size, increase the wet vault size to match.

An oil retaining baffle must be provided near the vault outlet. The baffle must not contain a high-flow overflow, or else the retained oil will be washed out of the vault during large storms.

Additional design criteria for a combined wet vault with baffle oil/water separator are as follows:

- The vault must have a minimum length-to-width ratio of 5:1.
- The vault must have a design water depth-to-width ratio of between 1:3 to 1:2.
- The vault must be watertight and must be coated to protect from corrosion.
- Separator vaults must have a shutoff mechanism on the outlet pipe to prevent oil discharges during maintenance and to provide emergency shut-off capability in case of a spill. A valve box and riser must also be provided.

- Wet vaults used as oil/water separators must be offline and must bypass flows greater than the offline water quality design flow (i.e., the water quality design flow multiplied by the offline factor of 3.0.

This design minimizes the entrainment and/or emulsification of previously captured oil during very high flow events.

Modifications if Combining with Detention

The design criteria for detention vaults/chambers and wet vaults must both be met, with the exception of the modifications included in BMP T10.40 — Combined Detention and Wetpool Facilities in Volume V of the SWMMWW.

Access to Cells for Maintenance

Refer to the access criteria listed under Detention Vaults/Chambers (*Section 5.7.3.5*). Access must be provided to allow personnel to enter and provide emergency egress from all cells of a wet vault using the following criteria:

- For vaults with greater than 1,250 square feet of floor area, a 5foot by 10foot removable panel must be provided over the inlet pipe (instead of a standard frame, grate and solid cover). Alternatively, a separate access vault may be provided.
- For vaults under roadways, the removable panel must be located outside the travel lanes. Alternatively, multiple standard locking maintenance hole covers may be provided. Removable panels must be at grade, have stainless steel lifting eyes, and weigh no more than 5 tons per panel.
- All access openings, except those covered by removable panels, must have round, solid locking lids, or 3foot-square locking covers.
- Vaults with widths of 10 feet or less must have removable lids.
- Internal structural walls of large vaults must be provided with separate access risers or openings sufficient for maintenance access between cells.

Structural Requirements

Wet vaults must conform with the “Materials” and “Structural Stability” criteria specified for detention vaults/chambers in *Section 5.7.3.5*.

Additional structural design criteria for a combined wet vault with baffle oil/water separator are as follows:

- The vault floor must be sloped to drain to access points with the intent to allow flushing to Vactor points for sediment removal.
- A minimum of 50 square feet of grate must be provided over each cell. For vaults in which the surface area of the second cell is greater than 1,250 square feet, 4 percent of the top must be grated. This requirement may be met by one grate or by many smaller grates distributed over the second cell area. Note: a grated access door can be used to meet this requirement.

The grate allows air contact with the wet pool in order to minimize stagnant conditions which can result in oxygen depletion, especially in warm weather.

- All metal parts must be corrosion-resistant. Galvanized materials must not be used since galvanized metal contributes zinc to stormwater, sometimes in very high concentrations. Grates must be coated for corrosion resistance with elastomeric epoxy or marine paint without zinc.
- The cells of a wet vault must not be divided into additional subcells by internal walls. If internal structural support is needed, it is preferred that post and pier construction be used to support the vault lid rather than walls. Any walls used within cells must be positioned so as to lengthen, rather than divide, the flow path.

Treatment effectiveness in wet pool facilities is related to the extent to which plug flow is achieved and short-circuiting and dead zones are avoided. Structural walls placed within the cells can interfere with plug flow and create significant dead zones, reducing treatment effectiveness.

5.8.7.6. BMP Sizing

Refer to Wet Ponds (*Section 5.8.6.6*) for BMP Sizing information.

5.8.7.7. Minimum Construction Requirements

Refer to the construction-related issues outlined above as part of the design criteria. Additional construction requirements include:

- Vault floor must be sloped to drain.
- Wet vaults must be field tested for exfiltration (i.e., watertightness) as follows:
  - Plug the inlets and outlet and fill the vault to the top of the wet pool volume (plus one-half the distance from the outlet invert to the top of the riser on the outlet structure for a combination detention/wet vault).
  - The maximum allowable leakage must not exceed 1 percent of the volume over a 24hour period.
- All sediment must be removed at the end of construction.

5.8.7.8. Operations and Maintenance Requirements

Wet vault O&M requirements are provided in *Appendix G* (*BMP No. 13*).

5.8.8. Stormwater Treatment Wetlands

5.8.8.1. Description

Stormwater treatment wetlands are similar to wet ponds, but also provide a shallow marsh area to allow the establishment of emergent wetland aquatic plants, which improves pollutant removal.

5.8.8.2. Performance Mechanisms

Stormwater treatment wetlands remove sediment, metals, and pollutants that bind to humic or organic acids primarily through settling and biological uptake. Secondary performance mechanisms include filtration and soil adsorption. Phosphorus removal in stormwater wetlands is highly variable; therefore, stormwater treatment wetlands are not expected to provide phosphorus control.

In land development situations, wetlands are usually constructed for two main reasons: to replace or mitigate impacts when natural wetlands are filled or impacted by development (mitigation wetlands); and to treat stormwater runoff (stormwater treatment wetlands). Mitigation wetlands may not be used as stormwater treatment facilities, because stormwater treatment functions are not compatible with normal wetland function.

5.8.8.3. Applicability

A stormwater treatment wetland can be applied to meet the requirements as summarized below. Stormwater treatment wetlands can be combined with detention storage to provide flow control (refer to *Section 5.8.9*).

BMP	On-site: List	On-site: Standard	Flow Control: Forest	Flow Control: Pasture	Flow Control: Peak	Water Quality: Basic	Water Quality: Enhanced Metals	Water Quality: Oil Control	Water Quality: Phosphorus	Conveyance
Stormwater treatment wetland						x	x		TT-A	x

TT-A = Treatment Train A (must be followed by a Basic Sand Filter or Sand Filter Vault (*Section 5.8.5*).

Refer to *Section 3.5.2.2* for more information on Two-BMP Treatment Trains.

5.8.8.4. Site Considerations

Refer to BMP T10.30 — Stormwater Treatment Wetlands in Volume V of the SWMMWW for site considerations. Additional site considerations may apply depending on site conditions and other factors. Refer to Volume V of the SWMMWW for stormwater treatment wetland setback requirements.

5.8.8.5. Design Criteria

The following provides a description and requirements for the components of stormwater treatment wetlands. Some or all of the components may be used for a given application depending on the site characteristics and restrictions, pollutant loading, and design

objectives. Design criteria are provided in this section or in Volume V of the SWMMWW for the following elements:

Design Element	SWMMWW Design Criteria	Seattle-specific Design Criteria
Inlets and outlets	x	x
Wetland geometry	x	
Lining requirements	x	
Access and setbacks	x	
Planting requirements	x	

Refer to BMP T10.30 — Stormwater Treatment Wetlands Volume V of the SWMMWW for design criteria. In addition to Ecology's criteria, the City has also developed specific design criteria for inlets and outlets which are summarized below.

Inlets and Outlets

Refer to Wet Ponds (*Section 5.8.6.5*) for inlet and outlet requirements.

The following additional requirements apply to Stormwater Treatment Wetlands installed in Seattle:

- Inlets and outlets must be placed to maximize the flow path through the facility. The ratio of flow path length to width from the inlet to the outlet must be at least 3:1. The flow path length is defined as the distance from the inlet to the outlet, as measured at mid-depth. The width at mid-depth can be calculated as follows: width = (average top width + average bottom width)/2.
- To the extent possible, create a complex microtopography within the wetland. Design the flow path to maximize sinuous flow between wetland cells.

5.8.8.6. BMP Sizing

Refer to BMP T10.30 — Stormwater Treatment Wetlands in Volume V of the SWMMWW for BMP sizing.

5.8.8.7. Minimum Construction Requirements

Construction requirements are the same as for Wet Ponds (*Section 5.8.6.7*).

5.8.8.8. Operations and Maintenance Requirements

Stormwater treatment wetland O&M requirements are provided in *Appendix G* (*BMP No. 14*).

5.8.9. Combined Detention and Wet Pool Facilities

5.8.9.1. Description

Combined detention and water quality wet pool facilities have the appearance of a detention facility but contain a permanent pool of water as well. The following design procedures, requirements, and recommendations cover differences in the design of the stand-alone water quality facility when combined with detention storage. Site considerations, setbacks, and other typical siting and design considerations for combined facilities are the same as specified for each individual facility, unless noted below. The following combined facilities are addressed in this section:

- Detention/wet pond (basic and large)
- Detention/wet vault
- Detention/stormwater wetland.

There are two sizes of the combined wet pond, a basic and a large, but only a basic size for the combined wet vault and combined stormwater wetland. The facility sizes (basic and large) are related to the treatment performance goals (refer to *Section 3.5.2*).

5.8.9.2. Performance Mechanisms

The intent of a combined detention and wet pool facility is to provide water quality treatment in addition to flow control. The three types of combined facilities provide water quality treatment as follows:

- A combined detention/wet pond provides pollutant removal via settling and biological uptake.
- A combined detention/wet vault provides pollutant removal via settling.
- A combined detention/stormwater wetland provides pollutant removal via settling, biological uptake, filtration, and soil adsorption.

5.8.9.3. Applicability

Combined detention and wet pool facilities can be applied to meet the requirements as summarized below.

BMP	On-site: List	On-site: Standard	Flow Control: Forest	Flow Control: Pasture	Flow Control: Peak	Water Quality: Basic	Water Quality: Enhanced Metals	Water Quality: Oil Control	Water Quality: Phosphorus	Conveyance
Combined detention and wet pond			x	x	x	x	TT-B		TT-A	x
Combined detention and wet vault			x[a]	x[a]	x[a]	x	TT-B		TT-A	x
Combined detention and stormwater wetland			x	x	x	x	TT-B		TT-A	x

[a] Standard may be partially or completely achieved depending upon contributing area and minimum orifice size.

TT-A = Treatment Train A (must be followed by a Basic Sand Filter or Sand Filter Vault (*Section 5.8.5*).

TT-B = Treatment Train B (must be followed by a Basic Sand Filter or Sand Filter Vault (*Section 5.8.5*) or an approved Proprietary and Emerging Water Quality Treatment Technology (*Section 5.8.11*).

Refer to *Section 3.5.2.2* for more information on Two-BMP Treatment Trains.

5.8.9.4. Site Considerations

Refer to BMP T10.40 — Combined Detention and Wet Pool Facilities in Volume V of the SWMMWW for site considerations and setback requirements. Additional site considerations may apply depending on site conditions and other factors.

5.8.9.5. Design Criteria

Refer to BMP T10.40 — Combined Detention and Wetpool Facilities in Volume V of the SWMMWW for design criteria.

Combined Detention and Wet Vault

The design criteria for detention vaults/chambers and wet vaults must both be met, except the modifications included in BMP T10.40 — Combined Detention and Wetpool Facilities in Volume V of the SWMMWW.

Combined Detention and Stormwater Wetland

The design criteria for detention ponds and stormwater wetlands must both be met, except the modifications included in BMP T10.40 — Combined Detention and Wetpool Facilities in Volume V of the SWMMWW.

5.8.9.6. BMP Sizing

Refer to BMP T10.40 — Combined Detention and Wetpool Facilities in Volume V of the SWMMWW for BMP sizing.

5.8.9.7. Minimum Construction Requirements

Construction requirements are the same as for Wet Ponds (*Section 5.8.6.7*).

5.8.9.8. Operations and Maintenance Requirements

Detention and wet pool O&M requirements are provided in *Appendix G* (*BMPs No. 1*, *No. 3*, *No. 12*, *No. 13.*, *and No. 14*).

5.8.10. Oil/Water Separators

5.8.10.1. Description

Oil/water separators rely on passive mechanisms that take advantage of oil being lighter than water. Oil rises to the surface and can be periodically removed. The two types of oil/water separators typically used for stormwater treatment described in this section are the baffle type or American Petroleum Institute (API) oil/water separator and the coalescing plate (CP) oil/water separator:

1. **Baffle type separator (API)**: Baffle (API) oil/water separators use vaults that have multiple cells separated by baffles extending down from the top of the vault. The baffles block oil flow out of the vault. Baffles are also commonly installed at the bottom of the vault to trap solids and sludge that accumulate over time. In many situations, simple floating or more sophisticated mechanical oil skimmers are installed to remove the oil once it has separated from the water.
2. **Coalescing plate (CP) separator**: CP separators are typically manufactured units consisting of a baffled vault containing several inclined corrugated plates stacked and bundled together. The plates are equally spaced (typical plate spacing ranges from 0.25 to 1 inch) and are made of a variety of materials, the most common being fiberglass and polypropylene. Efficient separation results because the plates reduce the vertical distance oil droplets must rise in order to separate from the stormwater. Once they reach the plate, oil droplets form a film on the plate surface. The film builds up over time until it becomes thick enough to migrate upward along the inclined plate. When the film reaches the edge of the plate, oil is released as large droplets which rise rapidly to the surface, where the oil accumulates until the unit is maintained. Because the plate pack increases treatment effectiveness significantly, CP separators can achieve a specified treatment level with a smaller vault size than a simple baffle separator.

5.8.10.2. Performance Mechanisms

Oil/water separators are designed to remove free oil and are not generally effective in removing oil that has become either chemically or mechanically emulsified or dissolved in the stormwater.

5.8.10.3. Applicability

Oil/water separators can be applied to meet the requirements listed below.

BMP	On-site: List	On-site: Standard	Flow Control: Forest	Flow Control: Pasture	Flow Control: Peak	Water Quality: Basic	Water Quality: Enhanced Metals	Water Quality: Oil Control	Water Quality: Phosphorus	Conveyance
API oil/water separator								x		
CP oil/water separator								x		

API oil/water separators are not effective in removing low concentrations of oil, and therefore, are not recommended for use on sites with very dilute concentrations of TPH. Other stormwater facilities, such as sand filters, biofiltration swales, and emerging water quality treatment technologies may be more applicable under these conditions. Linear sand filters are also approved for oil control (refer to *Section 5.8.5*). Spill control separators are often used as a source control BMP but are not permitted as a stormwater treatment oil control BMP. Refer to *Volume 4, Source Control* for additional details on spill prevention and control.

5.8.10.4. Site Considerations

The following considerations can influence the feasibility of API oil/water separators for a particular site:

- Oil/water separators must be installed upstream of other water quality treatment BMPs (except wet vaults), pumps, and conveyance structures that introduce turbulence.
- Oil/water separators may be located upstream or downstream of flow control BMPs.
- Oil/water separators must be located offline and bypass the incremental portion of flows that exceed the offline water quality design flow rate using a flow splitter (refer to *Section 4.2.1*). If it is not possible to locate the separator offline (e.g., roadway intersections), try to minimize the size of the area requiring oil control, and use the on-line water quality design flow rate (refer to *Section 4.2.1*).
- Oil/water separators must not be used for removal of dissolved or emulsified materials such as coolants, soluble lubricants, glycols (anti-freeze), and alcohols.
- Oil/water separators are best located in areas where the contributing drainage area is nearly all impervious and a fairly high load of TPH is likely to be generated.
- Excluding unpaved areas helps to minimize the amount of sediment entering the vault, which reduces the need for maintenance. Pretreatment should be considered if the level of total suspended solids (TSS) in the inlet flow would cause clogging or otherwise impair the long-term efficiency of the separator.

The following considerations can influence the feasibility of CP separators for a particular site:

- CP separators are typically smaller than API separators and are suitable for sites where space is limited.
- CP separator designs may be required to add pretreatment for TSS that could cause clogging of the CP separator or otherwise impair the long-term effectiveness of the separator.
- Typical applications of CP oil/water separators include inflows from small contributing drainage areas (fueling stations, maintenance shops, etc.) due to space limitations. However, if plugging of the plates is likely, then a new design basis for the baffle type API separator may be considered on an experimental basis.

Additional site considerations may apply depending on site conditions and other factors.

5.8.10.5. Design Criteria

The following provides a description and requirements for the components of oil/water separators. Some or all of the components may be used for a given application depending on the site characteristics and restrictions, pollutant loading, and design objectives. Design criteria are provided in this section for the following elements:

- Vault geometry
- Vault structure
- Baffles
- Separator plates
- Material requirements
- Inlet and outlet
- Access

Note: The following criteria apply to both API baffle and CP separators, unless otherwise specified.

Vault Geometry

Oil/water separator vaults are typically divided in three compartments: a forebay, an oil separation cell, and an afterbay:

- The length of the forebay must be a minimum of 0.33 the length of the vault (L), but 0.5 L is recommended.
- The surface area of the forebay must be at least 20 square feet per 10,000 square feet of tributary impervious area draining to the separator.
- The forebay is designed primarily to trap and collect sediment and debris, support plug flow conditions, and reduce turbulence.
- The oil separation cell traps and holds oil as it rises from the water column, and it serves as a secondary sediment collection area.
- The afterbay provides a relatively oil-free cell before the outlet and provides a secondary oil separation area.

The following criteria apply specifically to API separator bay vaults (Figure 5.39):

- The design water depth must be no deeper than 8 feet unless approved by the Director. Depths greater than 8 feet may be permitted on a case-by-case basis, taking into consideration the potential for depletion of oxygen in the water during the warm summer months.
- Baffle separator vaults must have a minimum length-to-width ratio of 5:1.
- Baffle separator vaults must have a design water depth-to-width ratio of between 0.3 and 0.5.

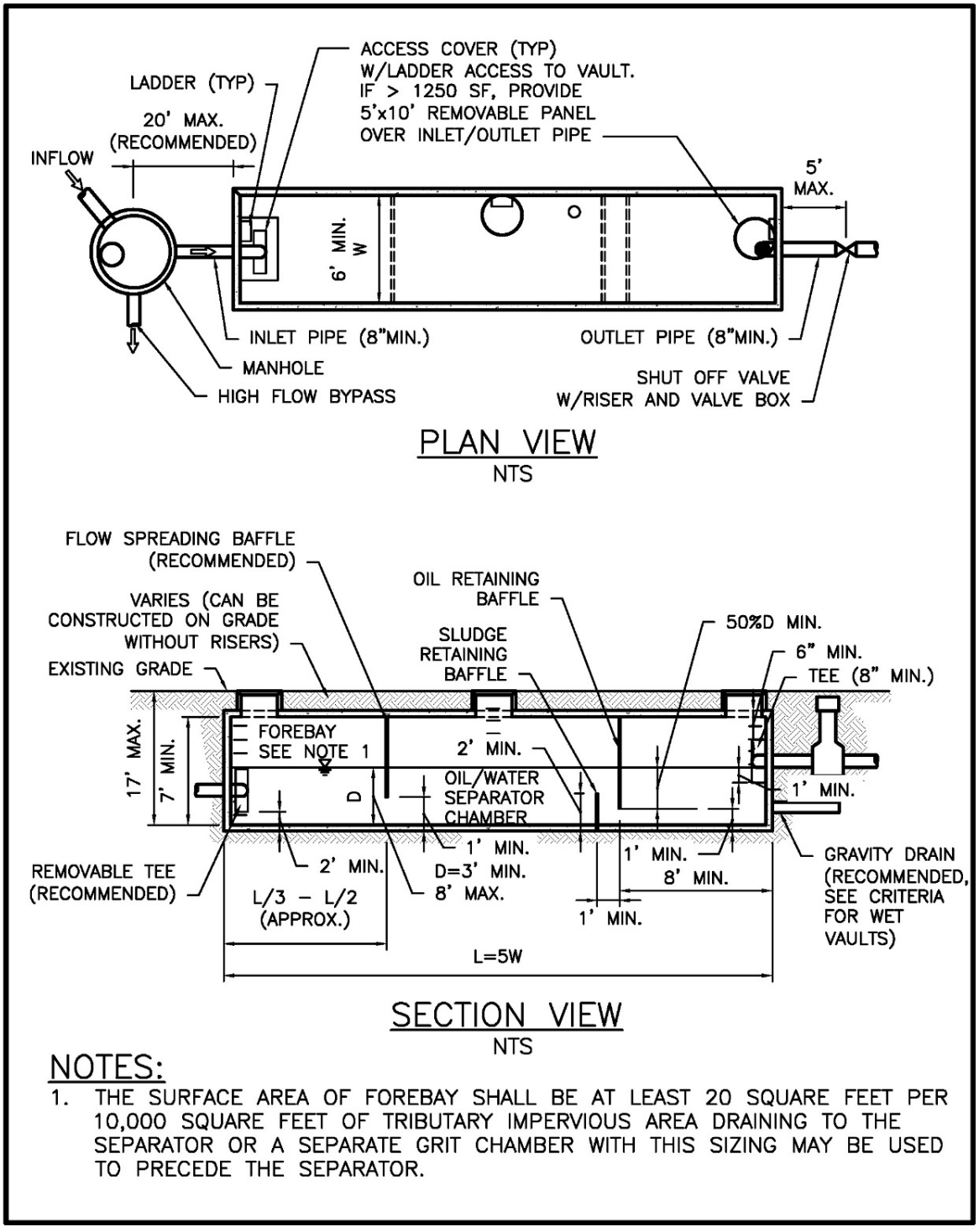
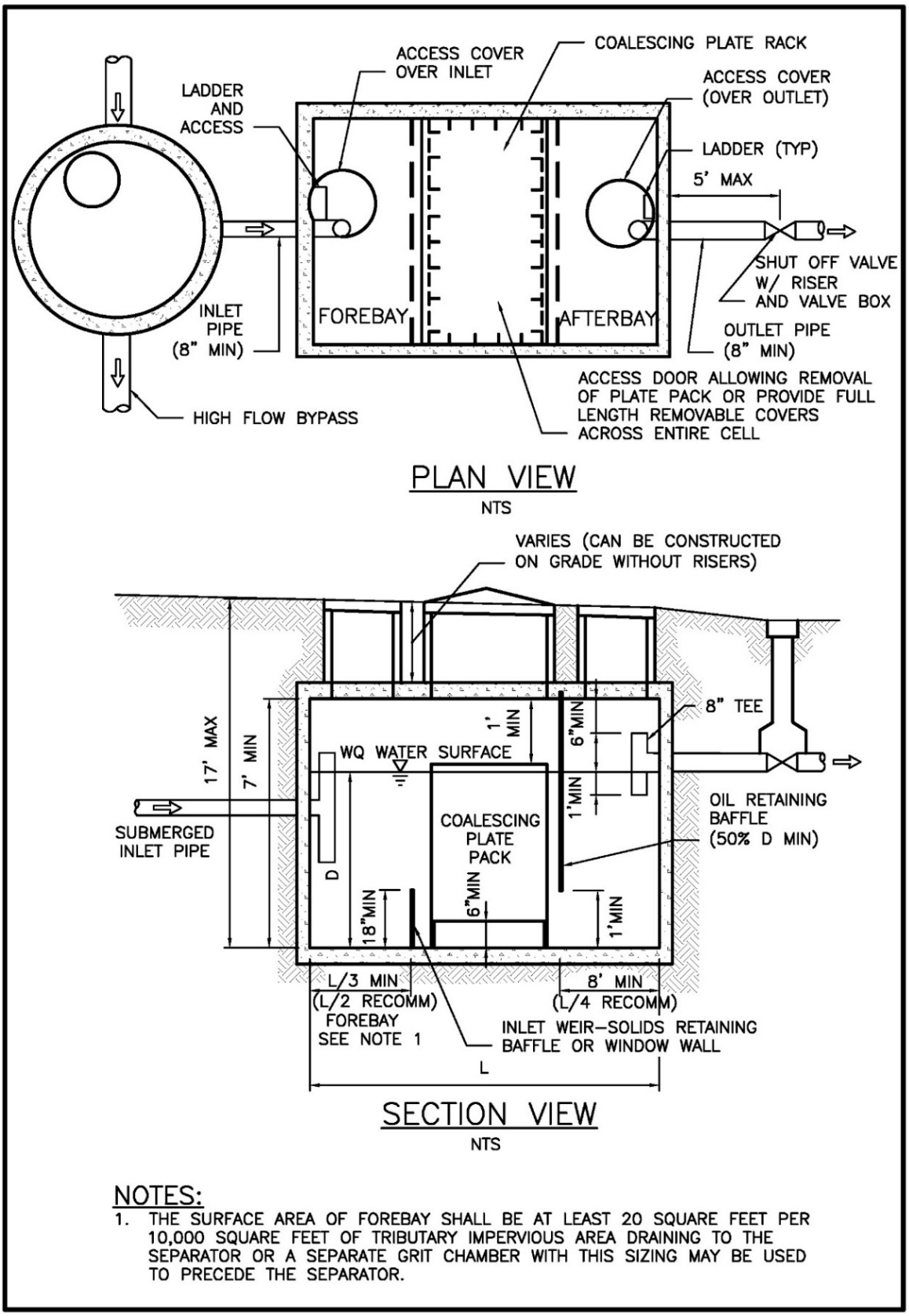


Figure 5.39. Typical API (Baffle Type) Separator.

The following criteria apply specifically to CP separators (Figure 5.40):

- In lieu of an attached forebay, a separate grit chamber, sized to be at least 20 square feet per 10,000 square feet of tributary impervious area, may precede the oil/water separator.



NOTES:

1. THE SURFACE AREA OF FOREBAY SHALL BE AT LEAST 20 SQUARE FEET PER 10,000 SQUARE FEET OF TRIBUTARY IMPERVIOUS AREA DRAINING TO THE SEPARATOR OR A SEPARATE GRIT CHAMBER WITH THIS SIZING MAY BE USED TO PRECEDE THE SEPARATOR.

Figure 5.40. Typical Coalescing Plate Separator.

Vault Structure

The following criteria apply to both API and CP separator bays:

- Separator vaults must be watertight.
- Separator vaults must have a shutoff mechanism on the outlet pipe to prevent oil discharges during maintenance and to provide emergency shutoff capability in the event of a spill. A valve box and riser must be provided.
- Roughing screens for the forebay or upstream of the separator to remove debris, should be used if needed. Screen openings should be approximately 0.75 inch.
- A gravity drain for maintenance is recommended if grade allows. The drain invert should be at a depth equal to the depth of the oil retaining baffle. Deeper drains are encouraged where feasible.
- If large amounts of oil are likely to be captured, a bleed-off pipe and separate waste oil tank can be located adjacent to the vault to channel separated oils into the tank. This improves the overall effectiveness of the facility, especially if maintenance is only performed annually. It also improves the quality of the waste oil recovered from the facility.
- Absorbents and/or skimmers should be used in the afterbay.

Baffles

The following criteria apply specifically to API separator bay vaults:

- A removable flow-spreading baffle, extending from the surface to a depth of up to half of the vault depth (D) is recommended to spread flows. Design guidelines for level spreaders are provided in *Appendix E*.
- A removable oil retaining baffle must be provided and located approximately one-quarter of the distance from the outlet wall or a minimum of 8 feet, whichever is greater (the 8foot minimum is for maintenance purposes). The oil-retaining baffle must extend from the elevation of the water surface to a depth of at least 50 percent of the design water depth and at least 1 foot from the separator bottom. Various configurations are possible, but the baffle must be designed to minimize turbulence and entrainment of sediment.
- The removable bottom baffle (sediment-retaining baffle) must be a minimum of 24 inches and located at least 1 foot from the oil-retaining baffle. A “window wall” baffle may be used, but the area of the window opening must be at least three times greater than the area of the inflow pipe.
- Baffles may be fixed rather than removable if additional entry ports and ladders are provided so that both sides of the baffle are accessible by maintenance crews.
- Baffle height to water depth ratios should be 0.85 for top baffles and 0.15 for bottom baffles.

The following criteria apply specifically to CP separators:

- An oil-retaining baffle must be provided. For large units, a baffle position of one-quarter of the distance from the outlet wall is recommended. The oil-retaining baffle must extend from the water surface to a depth of at least 50 percent of the design water depth and at least 1 foot from the separator bottom. Various configurations are

possible, but the baffle must be designed to minimize turbulence and entrainment of sediment.

- A bottom sediment-retaining baffle must be provided upstream of the plate pack. The minimum height of the sludge-retaining baffle must be 18 inches. Window walls may be used, but the window opening must be a minimum of three times greater than the area of the inflow pipe.

Coalescing Plate Separators

The following criteria apply specifically to CP separators:

- Plates must be inclined at 45 to 60 degrees from the horizontal. This range of angles exceeds the angle of repose of many solids, and therefore, provides more effective droplet separation while minimizing the accumulation of solids on the individual plates.
- Plates must have a minimum spacing of 0.5inch and have corrugations.
- Plates must be securely bundled in a plate pack for ease of removal and cleaning (with high-pressure rinse or equivalent).
- The plate pack must be a minimum of 6 inches from the vault bottom for sediment storage.
- There should be 1 foot of head space between the top of the plate pack and the bottom of the vault cover.

Material Requirements

The following guidelines apply when selecting oil/water separator materials:

- Vault baffles must be concrete, stainless steel, fiberglass reinforced plastic, or another acceptable material, and must be securely fastened to the vault.
- The following criteria applies specifically to CP separators:
    - Plate packs must be made of fiberglass, stainless steel, or polypropylene, unless otherwise recommended by the manufacturer and approved by the Director.
    - The entire space between the sides of the plate pack and the vault wall must be filled with a solid but light-weight removable material such as a plastic or polyethylene foam to reduce short-circuiting around the plate pack. Rubber flaps are not effective for this purpose.

Inlet and Outlet

The following inlet and outlet criteria apply to both types of oil/water separators:

- The separator inlet must be submerged. A tee section may be used to submerge the incoming flow and must be at least 2 feet from the bottom of the tank and extend above the water quality design water surface.
- The submerged inlet is to dissipate energy of the incoming flow. The distance from the bottom is to minimize resuspension of settled sediments. Extending the tee to the surface allows air to escape the flow, thus reducing turbulence. Alternative inlet designs that accomplish these objectives are acceptable.
- The vault outlet pipe must be sized to pass the water quality design flow before overflow. The vault outlet pipe must be back-sloped or have a tee extending 1 foot above and below the water quality design water surface to provide for secondary

trapping of oils and floatables in the wet vault. Note: The invert of the outlet pipe sets the water quality design water surface elevation.

Access Requirements

Access requirements are the same as for wet vaults (*Section 5.8.7.5*).

The following access requirements also apply for CP separators:

- Access to the compartment containing the plate pack must be a removable panel or other access able to be opened wide enough to remove the entire coalescing plate bundle from the cell for cleaning or replacement. Doors or panels must have stainless steel lifting eyes, and panels must weigh no more than 5 tons per panel.
- A parking area or access pad (25foot by 15foot minimum) must be provided near the coalescing plate bundles to allow for their removal from the vault by a truck-mounted crane or backhoe, and to allow for extracting accumulated solids and oils from the vault using a Vactor truck.

5.8.10.6. BMP Sizing

For offline separators, the high flow bypass must be designed so that all flows up to and including the water quality design flow rate are directed to the separator. Design guidelines for flow splitters are provided in *Appendix E*. The water quality design flow rate is calculated by multiplying the design flow rate determined using an approved continuous simulation model by the offline ratio of 3.0. For on-line separators, the water quality design flow rate is calculated by multiplying the flow rate determined using an approved continuous simulation model by the on-line ratio of 1.65. Separators must be designed as offline facilities wherever possible.

The API and CP sizing method is based on the horizontal velocity of the bulk fluid (V_h), the oil rise rate (V_t), the residence time (t_m), width, depth, and length considerations as follows:

1. Determine the oil rise rate, V_t, using Stokes' Law (Water Pollution Control Federation 1985) or empirical determination. Stokes Law assumes that flow is laminar and that oil droplets are spherical shaped. Stokes Law equation for rise rate, V_t (ft/min):

   $$V_t = [1.97 * g * (\sigma_w - \sigma_o) * D^2] / (18 * \eta_w)$$

   Where:

   V_t = oil rise rate (cm/sec)
   1.97 = conversion factor (cm/sec to ft/min)
   g = gravitational constant (981 cm/sec^2)
   D = diameter of the oil particle (cm)
   σ_w = water density in grams per cubic centimeter (gm/cc) at 32°F
   σ_o = oil density
   η_w = dynamic viscosity of water (gm/cm-sec) at water temperature of 32°F, (Refer to American Petroleum Institute 1990)

Use:

g = 981 cm/sec^2
D = 60 microns (0.006 cm)
σ_w = 0.999 gm/cc at 32°F
σ_o = Select conservatively high oil density. For example, if diesel oil @ σ_o = 0.85 gm/cc and motor oil @ σ_o = 0.90 gm/cc can be present then use σ_o = 0.90 gm/cc. If oil density is unknown then use σ_o = 0.90 gm/cc to be conservative.
η_w = 0.017921 gm/cm-sec

2. Determine Q:

   Q = the 15-minute Water Quality design flow rate in ft^3/min multiplied by the offline facility ratio of 3.0 or the online facility ratio of 1.65. Note that some continuous hydrologic models give the water quality design flow rate in ft^3/sec. Multiply this flow rate by 60 to obtain the flow rate in ft^3/min.

3. Calculate horizontal velocity of the bulk fluid, V_h (in ft/min) and water depth in separator (d) in feet.

   V_h = 15Vt
   d = $(Q/2V_h)^{0.5}$

   Note: Separator water depth (d) must be: $3 \leq d \leq 8$ feet to minimize turbulence (American Petroleum Institute 1990; US Army Corps of Engineers 1994). If the calculated depth is less than 3 feet, an API separator is not appropriate for the site. If the calculated depth exceeds 8 feet, consider using two separators.

4. Calculate the minimum residence time (t_m), in minutes, of the separator at depth d:

   t_m = d/V_t

5. Calculate the minimum length of the separator section, l(s):

   l(s) = $(F * Q * t_m)/(w * d) = F * (V_h/V_t) * d$

   Where:

   F = turbulence and short -circuiting factor (1.65)
   Use depth/width (d/w) ratio of 0.5 (American Petroleum Institute 1990)

   For other dimensions, including the length of the forebay, the length of the afterbay, and the overall length, L; refer to Figure 5.40.

6. Calculate $V = l(s) * w * d = F * Q * t_m$, and $A_h = w * l(s)$

   V = minimum hydraulic design volume (cubic feet)
   A_h = minimum horizontal area of the separator (square feet).

CP separators follow the same sizing method as API separators. Calculate the projected (horizontal) surface area of plates needed using the following equation:

$$A_p = Q/V_t = Q/[0.00386 * (\sigma_w - \sigma_o/\eta_w)]$$

$$A_p = A_a(\text{cosine } b)$$

Where:

A_p = projected surface area of the plate (ft^2); 0.00386 is unit conversion constant
Q = the on-line (1.65) or offline (3.0) adjustment factor x the 15-minute water quality design flow rate (ft^3/min)
V_t = Rise rate of 0.033 ft/min, or empirical determination, or Stokes Law based
σ_w = density of water at 32°F
σ_o = density of oil at 32°F
A_a = actual plate area (ft^2) (one side only)
b = angle of the plates with the horizontal in degrees (usually varies from 45 to 60 degrees)
η_w = viscosity of water at 32°F.

5.8.10.7. Minimum Construction Requirements

The following are construction requirements associated with the construction of an oil/water separator:

- Follow the manufacturer's recommended construction procedures and installation instructions, as well as any applicable City requirements.
- Upon completion of installation, thoroughly clean and flush the oil/water separator prior to operation.
- Specify appropriate performance tests after installation and shakedown, and/or provide certification by a licensed engineer that the separator is functioning in accordance with design objectives.

5.8.10.8. Operations and Maintenance Requirements

Oil/water separator O&M requirements are provided in *Appendix G* (*BMP No. 18 and 19*).

5.8.11. Proprietary and Emerging Water Quality Treatment Technologies

This section describes how the City will evaluate the use of proprietary and emerging water quality treatment technologies.

5.8.11.1. Description

To receive Ecology approval for use in stormwater applications in Washington, new technologies must be evaluated following Ecology's technology assessment protocols (TAPE and CTAPE), which establish guidelines for evaluating the performance of water quality treatment technologies in achieving different levels of performance (i.e., pretreatment, basic, metals, phosphorus, oil). The evaluation process requires manufacturers to field test the performance of new water quality treatment technologies. After the successful completion of field testing, the manufacturer submits a technology evaluation report (TER) to Ecology for review and approval. Information about Ecology's evaluation process can be found at the following website (https://ecology.wa.gov/Regulations-Permits/Guidance-technical-assistance/Stormwater-permittee-guidance-resources/Emerging-stormwater-treatment-technologies).

Under the technology assessment process, Ecology assigns "Use Level Designations" to emerging technologies based on the results of the TAPE and CTAPE evaluation. Ecology establishes the use level for each technology and its associated performance level based on the relevance, amount, and quality of performance data available as defined below:

- **GULD — General Use Level Designation**: A General Use Level Designation (GULD) is assigned to technologies for which the performance monitoring demonstrates with a sufficient degree of confidence, that the technology is expected to achieve Ecology's performance goals. There is a not limit to the number of systems which can be installed in Washington once the technology receives a GULD. Use is subject to conditions, including design restrictions and sizing, documented in a use level designation letter prepared by Ecology.
- **CULD — Conditional Use Level Designation**: A Conditional Use Level Designation (CULD) is assigned to technologies that have considerable field performance data not collected per the TAPE protocol. CULD technologies may be installed at up to 10 locations provided that the manufacturer and/or developer agree to conduct performance monitoring per the TAPE protocol at a minimum of one installation. Units that are in place do not have to be removed after the specified time period. Use is subject to conditions, including design restrictions and sizing, documented in a use level designation letter prepared by Ecology.
- **PULD — Pilot Use Level Designation**: A Pilot Use Level Designation (PULD) is assigned to new technologies that have limited performance monitoring data or that only have laboratory performance data. The PULD allows limited use of the technology to allow performance monitoring to be conducted. PULD technologies may be installed at up to 5 locations provided that the manufacturer and/or developer agree to conduct performance monitoring per the TAPE protocol at all installations. Use is subject to conditions, including design restrictions and sizing, documented in a use level designation letter prepared by Ecology.

5.8.11.2. Performance Mechanisms

Ecology (2024) has established different performance goals for water quality treatment technologies based on the types of pollutants that they are effective in removing and their applicable use for water quality treatment. Proprietary technologies use a wide variety of mechanisms to achieve these performance goals. This section has further information on a sub-set of proprietary technologies that have achieved a GULD designation using primarily filtration and adsorption. In addition to being TAPE approved, these proprietary technologies have undergone the New Jersey Corporation for Advanced Technology (NJCAT) lab testing protocol to determine mass loading capacity values (NJCAT 2025).

5.8.11.3. Applicability and Restrictions

The following table lists TAPE approved proprietary technologies with GULD designation that have undergone the NJCAT lab testing protocol. The table indicates the performance goal categories for which the BMPs are approved (e.g., basic, metals) and the BMP system type (either vertical flow media filter or cartridge media filter). The NJCAT verification procedure requires laboratory testing, which determines the sediment mass load capacity of each technology using a synthetic silica sand. This information is used to calculate mass loading ratios (MLRs) which are applied to the water quality design flow rate to adjust system sizing to account for variable solids loading from different land uses. The objective of using the MLR sizing approach is to size BMPs such that they require annual maintenance no matter the degree of sediment loading they receive. See section 5.8.11.6, step 2 for more information on applying the MLRs to the BMPs listed in the table below.

Note: Some manufacturers have multiple media blends available, not all of which have received GULD approval. Other proprietary technologies may be applicable, refer to Ecology's TAPE web page.

BMP	**Water Quality:** Basic	**Water Quality:** Metals	**Water Quality:** Oil Control	**Water Quality:** Phosphorus	**BMP System Type**
Aqua-Filter®	x				Vertical Flow Media Filter
	x				Vertical Flow Media Filter
BayFilter® (Silica sand, perlite, activated alumina media)	x			x	Filter Cartridge System
EcoPure Biofilter® 3-Cell	x	x		x	Vertical Flow Media Filter
EcoPure Biofilter® 2-Cell	x			x	Vertical Flow Media Filter
EcoStream®	x	x		x	Vertical Flow Media Filter
Filterra®	x	x	x	x	Vertical Flow Media Filter
PerkFilter® (Zeolite, perlite, carbon media)	x			x	Filter Cartridge System

BMP	Water Quality: Basic	Water Quality: Metals	Water Quality: Oil Control	Water Quality: Phosphorus	BMP System Type
StormFilter® (Zeolite, perlite, granular activated carbon media)	x				Filter Cartridge System
StormFilter® (PhosphoSorb Media)	x			x	Filter Cartridge System
StormGarden	x			x	Vertical Flow Media Filter
StormKleener®	x				Filter Cartridge System
StormScape®	x				Vertical Flow Media Filter
StormVault (Sierra Blend)	x				Vertical Flow Media Filter
Up-Flo® (Filter Ribbons)	x			x	Filter Cartridge System
MWS-Linear Modular Wetland®	x	x		x	Vertical Flow Media Filter
MWS-360 Modular Wetland®	x	x		x	Filter Cartridge System
BioPod®	x	x		x	Vertical Flow Media Filter
The Kraken®	x			x	Filter Cartridge System

Note: Hydraulic conductivity differs from sizing for basic treatment. Use the lowest applicable hydraulic conductivity when sizing.

The Director will accept technologies approved by Ecology as described below:

- GULD technologies for use on parcels will be accepted subject to the conditions of use established by in the use level designation established by Ecology and sized for mass loading targeting annual maintenance. Use in the right-of-way is subject to approval by SPU and early consultation is encouraged. Not all GULD approved BMPs will be acceptable.
- CULD technologies will be accepted on a limited basis provided that the project owner signs an agreement with the City stating that the owner will modify/upgrade the system in accordance with any conditions that Ecology may require as part of the final GULD designation and sized for mass loading targeting annual maintenance. The owner must also file annual reports as outlined by the City.
- PULD technologies will be accepted on a limited basis to enable manufacturers to obtain data to help fulfill the requirements of the TAPE protocol. These projects must be approved in advance by the Director of SPU, be sized for mass loading targeting

annual maintenance and have an approved monitoring plan reviewed by Ecology, and provide a financial bond to provide clean-up and replacement in the event of failure.

5.8.11.4. Site Considerations

Site considerations for vegetated vertical flow media filter (e.g., Filterra®, Aqua-Ponic®, StormScape®, StormGarden®, StormVault®, BioPod®, MWS-Linear Modular Wetland®, EcoStream®) installation are primarily regarding grading and landscaping. For systems with curb inlets, both the flow entrance to the system and bypass to a catch basin are important considerations and need to be analyzed together. Landscaping within these systems must be from the approved list.

Site considerations for the MWS-Linear Modular Wetland® and EcoPure Biofilter systems are dependent on grading, hydraulics, and landscaping. Landscaping within the system must be from the approved list. The chambers must be accessible for replacement of the filter media as needed.

Site considerations for the filter cartridge systems (e.g., BayFilter®, Perk Filter®, StormFilter® StormKleener, Up-Flo®, MWS-360®, and Kraken®) are primarily hydraulic and how to select cartridges, group cartridges and in which kind of structure. Multiple cartridges in a maintenance hole or vault will most likely be easier to remove and replace. Vaults, maintenance hole and catch basin installations and stacked or unstacked cartridges may be allowed. Within the right-of-way, maintenance hole and vault installation are preferred. Multiple heights of cartridge systems and required heads for filter function are available. Backwater conditions may restrict the use of these technologies, and both the structure elevations and anticipated water surface elevations of the surrounding drainage system must be considered.

No specific setbacks or restrictions apply to closed bottom facilities. The following setbacks and restrictions apply to open bottom facilities.

- All open bottom facilities must be a minimum of 50 feet from the top of any steep (greater than 40 percent) slope. A geotechnical analysis and report must be prepared addressing the potential impact of the open bottom facility on a slope steeper than 15 percent.
- The water surface at the outlet invert elevation must be set back 100 feet from existing septic system drain fields. This setback may be reduced with written approval of Public Health — Seattle & King County.

5.8.11.5. Design Criteria

In addition to the manufacturer's design criteria and the conditions of use in Western Washington required by Ecology, Seattle has adopted design criteria on piping and access and manufacturer review.

Piping

Inlet, outlet and interior piping must have a minimum size of 6 inches. To the extent feasible, piping should be straight with as few bends and turns as possible to reduce headloss and minimize the potential for sediment to accumulate in the piping system.

Access

Access for lifting equipment to remove and replace filter cartridges is required. For filter cartridge systems in a vault or maintenance hole configuration where individual cartridges are not directly below the lid or cover of the structure, a plan for the safe removal and replacement is required.

Manufacturer Review

Design review with the manufacturer of the proprietary technology is required to check grading and variables that are specific to the proposed installation. Sizing requirements in *Section 5.8.11.6* are in addition to the manufacturer's requirements.

5.8.11.6. BMP Sizing

The City has developed sizing criteria for a subset of the proprietary treatment systems. The sizing criteria are based on a target level of once-a-year maintenance to ensure meeting the operations and maintenance requirements established in the Ecology use level designations for each technology. Facilities would not be inspected multiple times during the first year as required by TAPE, but would be designed to perform for 1 year under normal circumstances before maintenance is required.

The sizing criteria were developed using information from each manufacturer regarding how much solid material can be removed before the hydraulic capacity of their system is reduced to the point where it can no longer treat the required design storm without bypassing flow. Solids loading capacity information is fairly limited and each manufacturer uses different methods to evaluate. In the absence of standardized testing protocols, the City has used data currently available from the manufacturers. TSS loadings are presented in Table 3.5. It is anticipated that sizing criteria may be modified as more manufacturer testing information becomes available in the future.

For the subset of proprietary technologies in *Section 5.8.11.3*, application of the mass loading ratios will satisfy these requirements for basic treatment. For requirements other than basic treatment, or for other proprietary technologies, separate calculations demonstrating that they meet the annual maintenance goal for mass loading typical for the land use in Seattle are required.

Step 1: Determine the water quality design flow rate

Use an approved continuous model to determine the off-line or, downstream of detention if applicable) water quality design flow rate using the following assumptions. The filtration component of these proprietary technologies is always off-line because the approved BMPs all have internal bypasses is included in the structures, consequently they should be sized as off-line facilities.

Variable	Assumption
Precipitation Series	SEPTS-99 unless otherwise adopted by the Director
Computational Time Step	15 minutes
HSPF Parameters	LSUR, SLSUR, NSUR must be adjusted per *Appendix F*
Inflows to Facility	Surface flow from total drainage area (including impervious and pervious contributing areas) routed to facilities.

Step 2: Adjust the water quality design flow rate

For basic, metals, or phosphorous treatment requirements for the proprietary technologies in *Section 5.8.11.3*, adjust the water quality design flow rate using the mass loading ratios below. Multiply the flow rate determined in Step 1 by the mass loading ratio based on the BMP system type listed in *Section 5.8.11.3*.

Zoning Categories	Mass Loading Ratios[a,b]: Filter Cartridge Systems	Mass Loading Ratios[a,b]: Vertical Flow Media Filter Systems[c]
Parcels zoned as NR, RSL, LR, or MFR Non-arterial streets adjacent to properties zoned as NR, RSL, LR, or MFR	2.5	1.6
Parcels zoned as neighborhood/ commercial, downtown, major institutions, master planned community, or residential/ commercial Arterial streets with adjacent property zoned as neighborhood/commercial, downtown, major institutions, master planned community, or residential/commercial	2.6	1.6
Parcels zoned as manufacturing/industrial Non-arterial or arterial streets with adjacent property zoned as manufacturing/industrial	3.7	2.3

[a] Mass loading ratios were developed based on a limited set of commonly used proprietary technologies using a mean total suspended solids concentration (refer to Table 3.5) and assumed use of an offline water quality design flow rate. The mass loading ratios can be applied to the TAPE approved proprietary technologies that have underdone NJCAT laboratory testing listed in section 5.8.11.3. For other proprietary technologies, or other assumptions, refer to *Section 3.5*.

[b] When applicable, designer must round up to the nearest whole cartridge or next largest vault size.

[c] A mass loading ratio is not required for Filterra® systems designed with the oil control treatment flow rate of 50 in/hr. This sizing will also meet basic or metals treatment without the application of a mass loading ratio.

Note: A mass loading ratio is not required for underdrained surfaces where the drainage passes through a gravel layer before entering the underdrain pipe and the downstream BMP (e.g. discharge from sports fields, play areas, etc.).

NR = Neighborhood Residential

RSL = Residential Small Lot

LR = Low-rise Multifamily

MFR = Multifamily Residential

Step 3: Select the size of facility or number of cartridges

Determine the sizing criteria and design requirements for the specific proprietary technology and specific configuration (offline or downstream of detention facility) described in the Ecology GULD documentation.

Use the modified design flow rate from Step 2 to select the size of facility or number of cartridges needed. Round up as necessary.

5.8.11.7. Minimum Construction Requirements

The following are construction requirements with the construction of proprietary technologies:

- Follow the manufacturer's recommended construction procedures and installation instructions as well as any applicable City requirements.
- Follow the manufacturer's requirements for flow rate restrictions (orifice).
- Protect the media filter systems from construction flows. Thoroughly clean structures and replace media or media cartridges if impacted from construction flows.

5.8.11.8. Operations and Maintenance Requirements

Refer to Ecology's website and the manufacturer's website for facility-specific maintenance requirements (https://ecology.wa.gov/Regulations-Permits/Guidance-technical-assistance/Stormwater-permittee-guidance-resources/Emerging-stormwater-treatment-technologies).

O&M requirements for proprietary technology filter cartridge systems (e.g., Bay Filter®, FloGard Perk Filter®, and StormFilter®), the Filterra® system, and MWS-Linear Modular Wetland® are included in *Appendix G* (*BMP No. 17, 21, and 22*). BMPs sized using the mass loading ratios as required in *Section 5.8.11.6* are not required to inspect the facility multiple times during the first year of operation or develop a site-specific inspection/maintenance schedule as indicated in the Ecology GULD approval. Annual maintenance, including filter cartridge replacement as needed is required.

5.8.12. Non-infiltrating Soil Cell Bioretention

5.8.12.1. Description

Non-infiltrating soil cell bioretention is a modular proprietary pavement suspension system originally designed to support growth of urban trees by increasing soil volume and reducing soil compaction adjacent to trees. This BMP is commonly used in two applications:

1. Constrained sites, where there is limited space to site bioretention
2. Sites with additional hardscape needs, such as sidewalks or trails

The standard design of this BMP is modified to act similarly to a non-infiltrating bioretention facility using a 12-inch depth of designed soil mix (bioretention cell) within the soil cell bioretention to facilitate stormwater runoff management. Stormwater runoff is conveyed to soil cell bioretention that support overlying hardscape. The runoff is detained within the soil cell modules, ponding above the bioretention cell (and below the overlying hardscape), until it filters through the designed soil mix layer. Runoff that exceeds the ponding storage and filtration capacities overflows to a drainage system. Non-infiltrating soil cell bioretention can be stacked soil cell modules and/or multiple modules connected to one another. Infiltrating soil cell bioretention may require one or more trees to be planted within the facility footprint outside of the soil cell modules unless determined to be infeasible (refer to *Section 3.3.1* and *Appendix C* for infeasibility criteria).

The non-infiltrating soil cell bioretention option is used when the measured infiltration rate of the underlying soils is less than 0.3 inches/hour or when a hydraulically restrictive layer is required (e.g., impermeable liner, low-permeability barrier, etc.). Stormwater filters through the designed soil mix and then is collected by an underdrain and discharged to the downstream drainage system.

Non-infiltrating soil cell bioretention may be connected in series, with the overflows of upstream bioretention cells directed to downstream bioretention cells to provide additional flow control and/or treatment capacity and conveyance. Individual non-infiltrating bioretention facilities are defined as separate ponding areas delineated by a distinct overflow to a downstream BMP or point of discharge.

5.8.12.2. Performance Mechanisms

Non-infiltrating soil cell bioretention may provide some flow control via detention, attenuation, and losses due to infiltration, interception, evaporation, and transpiration. Water quality treatment is accomplished through sedimentation, filtration, adsorption, uptake, or biodegradation and transformation of pollutants by soil organisms, soil media, and the tree (if required or used).

5.8.12.3. Applicability

Non-infiltrating soil cell bioretention can be designed to provide on-site stormwater management and/or water quality treatment. This BMP can be applied to meet or partially meet the requirements listed below.

BMP	On-site: List	On-site: Standard	Flow Control: Forest	Flow Control: Pasture	Flow Control: Peak	Water Quality: Basic	Water Quality: Enhanced Metals	Water Quality: Oil Control	Water Quality: Phosphorus	Conveyance
Non-infiltrating soil cell bioretention	x	x[a]				x	x		x[b]	

[a] Standard may be partially or completely achieved depending upon ponding depth, degree of underdrain elevation, infiltration rate, and contributing area.

[b] Refer to Soil Suitability Criteria in *Section 4.5.2*.

Non-infiltrating soil cell bioretention may be constructed in conjunction with other stormwater BMPs to achieve other performance standards.

5.8.12.4. Site Considerations

Non-infiltrating soil cell bioretention have minimum requirements similar to those associated with non-infiltrating bioretention and tree planting and retention. In addition, non-infiltrating soil cell bioretention in the ROW must meet the minimum clearances and planting strip widths for the tree(s) found in Seattle Streets Illustrated, the Right-of-Way Improvements Manual (refer to SDOT/SDCI Director's Rules 04 2017/31 2017).

5.8.12.5. Design Criteria

This section provides a description, recommendations, and requirements for the components of non-infiltrating soil cell bioretention. Typical components of non-infiltrating soil cell bioretention are shown in Figure 5.41 and 5.42. Refer to *Appendix C* for additional infeasibility criteria for the On-site List Approach. Further guidance can be found in SPU's Green Stormwater Infrastructure Manual for Capital Improvement Projects.

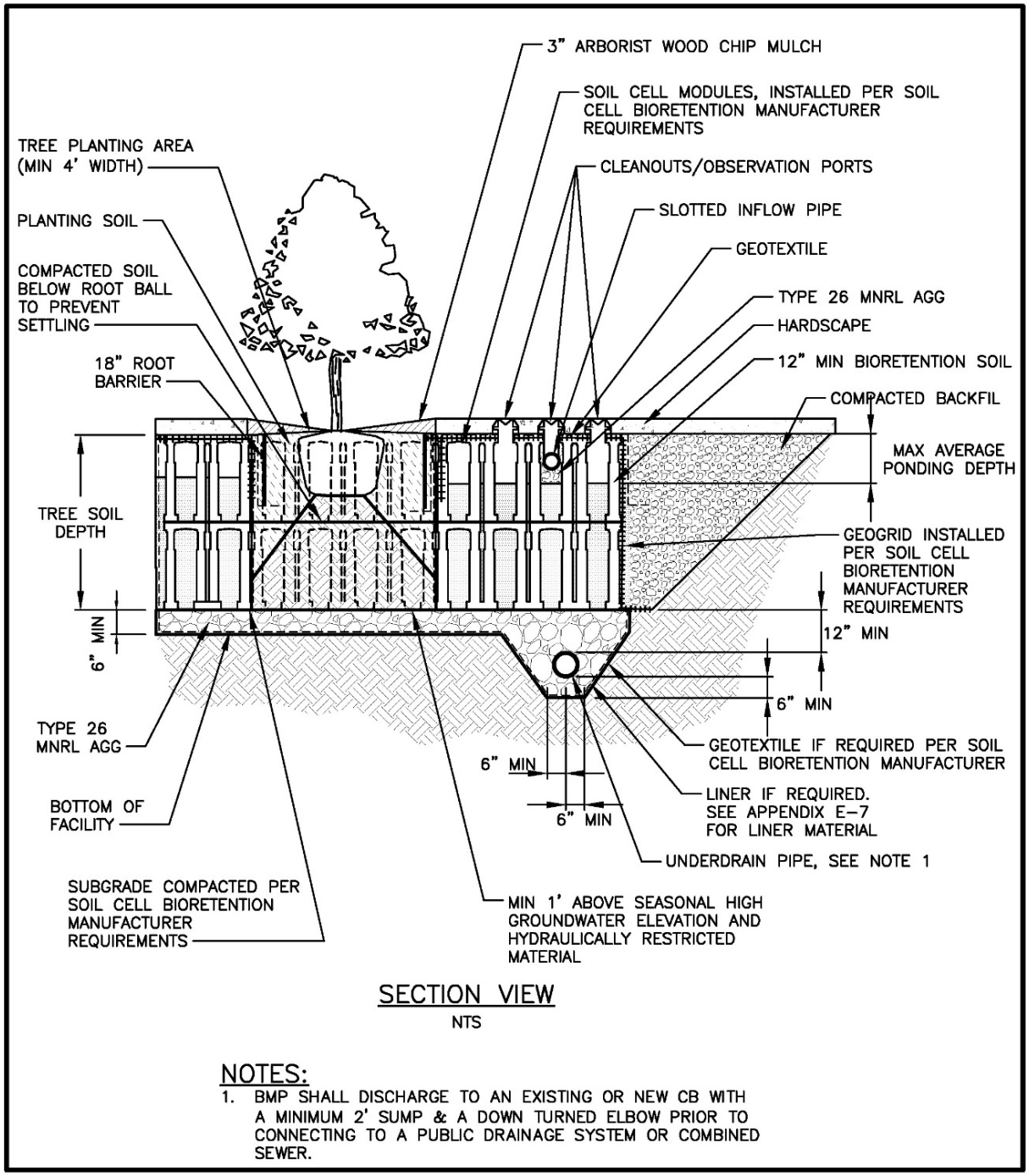


Figure 5.41. Non-infiltrating Soil Cell Bioretention Profile.

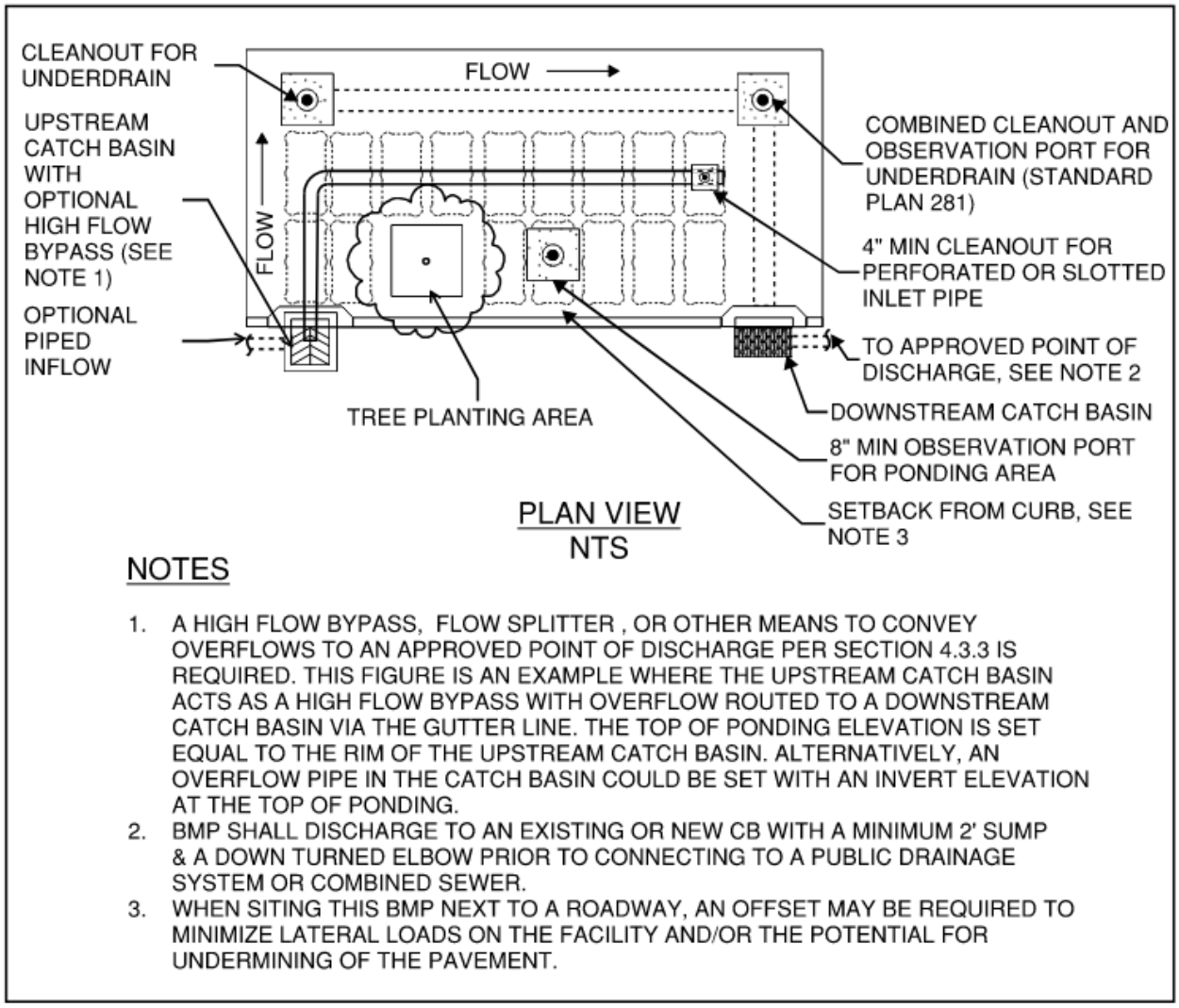


Figure 5.42. Non-infiltrating Soil Cell Bioretention Plan.

The design criteria for the non-infiltrating soil cell bioretention is the same as for infiltrating bioretention in *Section 5.4.4* for the following elements:

1. Contributing area
2. Flow entrance
3. Bioretention soil
4. Flow restrictor (optional)

The design criteria for the non-infiltrating soil cell bioretention is the same as for infiltrating soil cell bioretention in *Section 5.4.10* for the following elements:

1. Presettling
2. Ponding area
3. Cleanout and observation ports

4. Overflow
5. Plants
6. Tree (if required)
7. Mulch layer
8. Hardscapes
9. Manufacturer design requirements

The following elements are different from infiltrating bioretention and infiltrating soil cell bioretention and are discussed in detail below:

1. Subgrade
2. Underdrain
3. Geotextile
4. Liners (if required)

Subgrade

The subgrade of non-infiltrating bioretention must be compacted to meet the soil cell bioretention manufacturer requirements.

Underdrain

Non-infiltrating soil cell bioretention must be equipped with an underdrain. The underdrain pipe diameter will depend on hydraulic capacity required. The underdrain can be connected to a downstream BMP, such as another soil cell bioretention as part of a connected system, or to an approved point of discharge.

The minimum requirements associated with the underdrain design include:

- Slotted pipe per City of Seattle Standard Plan No. 291.
- Underdrain pipe must have a minimum diameter of 6 inches in the ROW and 4 inches outside of the ROW.
- Underdrain pipe slope must be no less than 0.5 percent.
- Pipe must be placed in filter material with at least 6 inches of material on all sides of the pipe. Refer to Figure 5.41 for required pipe bedding dimensions.
- The filter material for the underdrain must extend at least 6 inches below the bottom of the facility. Refer to Figure 5.41 for underdrain dimensions.
- Filter material must meet the specifications of City of Seattle Mineral Aggregate Type 26 (gravel backfill for drains, City of Seattle Standard Specifications).

- Underdrains must be equipped with cleanouts and observation ports as follows:
  - For right-of-way projects, underdrains must have a cleanout per City of Seattle Standard Plans at the upstream end and a combined cleanout and observation ports per City of Seattle Standard Plan No. 281 a minimum of every 100 feet along the pipe. No cleanouts are required within a run from underdrain maintenance hole to underdrain maintenance hole except at bends.
  - For non-right-of-way projects, underdrains must have a cleanout at the upstream end (Figure 5.42) and a combined cleanout and observation ports (City of Seattle Standard Plan No. 281) a minimum of every 100 feet along the pipe. Cleanouts and observation ports must be non-perforated pipe (sized to match underdrain diameter) and must meet the requirements in the Side Sewer Directors' Rule.

Geotextile

For non-infiltrating soil cell bioretention, a geotextile and geogrid are required. Minimum requirements associated with the geotextile and geogrid design include:

- Use a geotextile and geogrid recommended by the manufacturer's specifications and by a geotechnical engineer for the given subgrade soil type or aggregate.
- Use a geotextile and geogrid that passes water at a greater rate than the design infiltration rate for the existing subgrade soils.

Liners (if required)

For non-infiltrating soil cell bioretention, a liner may be required. The minimum requirements for liners, if required, including the following:

- If the area available for siting is within the setback for a contaminated site or landfill (refer to *Volume 3, Section 3.2*), an impermeable liner must be used to create a hydraulic restriction layer. Refer to *Appendix E, Section E7* for liner design criteria.
- If the area available for siting meets the setback from contamination and landfills, but not the other minimum horizontal setback requirements for infiltrating facilities (refer to *Volume 3, Section 3.2*), low-permeability liner or walls must be used as the hydraulic restriction layer. Refer to *Appendix E, Section E7* for liner design criteria.
- If Horizontal Setbacks and Site Constraints for infiltration can be met (refer to *Volume 3, Section 3.2*), no liner is required.

5.8.12.6. BMP Sizing

Sizing for On-site List Approach

Non-infiltrating soil cell bioretention may be selected to meet the On-site List Requirement (refer to *Section 3.3.1* and *Appendix C* for infeasibility criteria). To meet the requirement, non-infiltrating soil cell bioretention must be sized according to the sizing factors provided in Table 5.55.

Factors are organized by cell ponding depth. To select the appropriate sizing factor:

1. The design ponding depth must be rounded down to the nearest depth in the sizing table, or sizing factors may be linearly interpolated for intermediate ponding depths (e.g., between 2 and 6 inches ponding).

The BMP must meet the general requirements for non-infiltrating soil cell bioretention outlined in this section plus the following specific requirements:

1. The bottom area must be sized using the applicable sizing factor.
2. It is preferred that the bottom area is flat, but up to 3 percent slope is permitted.
3. The bioretention soil depth must be a minimum of 18 inches.
4. The average ponding depth for the bioretention cell must be no less than the selected ponding depth.
5. If the soil cell bioretention includes a tree, additional tree planting area is required. Refer to *Sections 5.2.5.2* and *5.4.4.5* for more information about tree planting area, depth, and volume sizing. Equations to calculate the facility size is included after Table 5.30 in *Section 5.4.10.6*.

Table 5.55. On-site List Sizing for Non-Infiltrating Soil Cell Bioretention.

Average Ponding Depth	Contributing Area (sf)	Sizing Factor for Soil Cell Bioretention Bottom Area[a]: On-site List
2 inches	Any	6.6%
6 inches	Any	4.4%
12 inches	Any	3.1%

sf = square feet.

Bioretention Cell Bottom Area = Contributing Hard Surface Area x Factor (%)/100.

Hard Surface Area Managed = Bioretention Cell Bottom Area ÷ Factor (%)/100.

[a] Soil cell bioretention bottom area is 10% larger than bioretention cell bottom area to account for the soil cell modules, but it does not include the tree planting area. If the soil cell bioretention includes a tree, additional tree planting area is required. Refer to *Sections 5.2.4.2 and 5.4.10.5* for more information about sizing tree planting area, depth, and volume sizing. Equations needed to calculate the soil cell bioretention with tree volume are included in *Section 5.4.10.6*.

Pre-sized Approach for Flow Control and Water Quality Treatment

The Pre-sized Approach may be used for projects with new and replaced hard surface areas up to 10,000 square feet. Under the Pre-sized Approach (refer to Section 4.1.2), simple equations are used to calculate the size of "pre-designed" bioretention cell portion of non-infiltrating soil cell bioretention subject to specific design requirements (e.g., ponding depth). Sizing factors and equations for the bioretention cell portion of non-infiltrating soil cell bioretention are provided in Table 5.56.

Pre-sized non-infiltrating soil cell bioretention may be used to achieve the Pre-developed Pasture, Peak Control, and Water Quality Treatment Standards. Sizing factors are organized by ponding depth, contributing area, and performance standard. To select the appropriate sizing factor or equation:

1. The design ponding depth must be rounded down to the nearest depth in the sizing table, or sizing factors may be linearly interpolated for intermediate ponding depths (e.g., between 2 and 6 inches ponding).

Table 5.56. Pre-sized Sizing Factors and Equations for Non-infiltrating Soil Cell Bioretention.

Average Ponding Depth	Contributing Area (sf)	Sizing Factor/Equation for Soil Cell Bioretention Bottom Area[a]: Pre-developed Pasture Standard	Sizing Factor/Equation for Soil Cell Bioretention Bottom Area[a]: Peak Control Standard	Sizing Factor/Equation for Soil Cell Bioretention Bottom Area[a]: Water Quality Treatment Standard[b]
2 inches	0 – 10,000	NA[b]	NA[b]	1.8%
6 inches	0 – 10,000	NA[b]	NA[b]	1.4%
12 inches	0 – 10,000	NA[b]	5.0%[c]	1.1%

NA – not applicable; sf – square feet.

For Sizing Factors: Bioretention Cell Bottom Area = Contributing Hard Surface Area x Factor (%)/100.
Hard Surface Area Managed = Bioretention Cell Bottom Area ÷ Factor (%)/100.

[a] Soil cell bioretention bottom area is 10% larger than bioretention cell bottom area to account for the soil cell modules, but it does not include the tree planting area. If the soil cell bioretention includes a tree, additional tree planting area is required. Refer to *Sections 5.2.4.2 and 5.4.10.5* for more information about sizing tree planting area, depth, and volume sizing. Equations needed to calculate the soil cell bioretention with tree volume are included in *Section 5.4.10.6*.

[b] Pre-sized Approach may be used to meet basic water quality treatment. Metals water quality treatment may be achieved if soil suitability criteria are met (refer to *Section 4.5.2*).

[c] When used to meet the Peak Control Standard, the facility size must not be larger than prescribed by the sizing factor (or sizing factor range) because flow control performance may be diminished for larger facilities (larger facilities will not pond water sufficiently to slow flows).

To use these pre-sized facilities to meet performance standards, non-infiltrating soil cell bioretention must meet the general requirements outlined in this section plus the following specific requirements:

1. The bottom area must be sized using the applicable sizing factor or equation.
2. It is preferred that the bottom area is flat, but up to 3 percent slope is permitted.
3. The bioretention soil depth must be a minimum of 12 inches for flow control and 18 inches for water quality treatment.
4. The average ponding depth for the bioretention cell must be no less than the selected ponding depth.
5. If the soil cell bioretention includes a tree, additional tree planting area is required. Refer to *Sections 5.2.5.2* and *5.4.4.5* for more information about tree planting area, depth, and volume sizing. Equations to calculate the facility size is included after Table 5.30 in *Section 5.4.10.6*.

The bottom area for the bioretention cell portion of the soil cell bioretention is calculated as a function of the hard surface area routed to it. All area values must be in square feet.

Modeling Approach for On-site Performance Standard, Flow Control, and Water Quality Treatment

When using continuous simulation hydrologic modeling to size non-infiltrating soil cell bioretention, the assumptions listed for infiltrating soil cell bioretention BMPs in Table 5.33 must be applied, with the following exceptions:

- No infiltration to underlying soil
- No underdrain
- Required liner (excludes from the infiltration area)

Refer to the *Approval Status of Continuous Simulation Models* section of the SWMMWW for a list of currently approved models. When using currently available modeling methods, non-infiltrating soil cell bioretention cannot meet the Pre-developed Forested or Pre-developed Pasture Standard.

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VOLUME 4

SOURCE CONTROL

City of Seattle | Stormwater Manual

July 2026

City of Seattle

Note:

Some pages in this document have been purposely skipped or blank pages inserted so that this document will copy correctly when duplexed.

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CHAPTER 1 – Introduction

1.1. What Is the Purpose of This Volume?

This volume is designed to help businesses, individuals, responsible parties, and public entities in Seattle implement best management practices (BMPs) for source control to prevent pollutants from contaminating stormwater runoff and entering receiving waters, such as rivers, lakes, streams, and Puget Sound. Polluted stormwater can pose risks to the health, safety, and welfare of humans and the environment. Source control is the practice of preventing pollution at its source.

This chapter provides a worksheet for use in determining which BMPs are required for specific activities, including activities planned for proposed development sites. As required by the Seattle Municipal Code (SMC), Chapters 22.800 through 22.808 (Stormwater Code), BMPs from this volume must be implemented to minimize contamination and discharge of stormwater from pollution-generating activities.

Refer to Appendix A for definitions of technical terms used in this volume.

1.2. How Does this Volume Apply to Businesses and Properties?

Some BMPs are required for all real property in Seattle (refer to *Chapter 2, BMPs 1 through 16*). The implementation of additional BMPs for specific pollution-generating activities applies to all businesses and public entities in Seattle except those that drain to the public combined sewer system (refer to *Chapter 3, BMPs 17 through 56*).

The BMPs in this volume have been compiled from many documents, programs, and regulations, including the following:

- Federal Clean Water Act
- Federal Coastal Zone Management Act
- Phase I National Pollutant Discharge Elimination System (NPDES) Municipal Stormwater General Permit
- Washington State Department of Ecology (Ecology) Stormwater Management Manual for Western Washington (SWMMWW)
- Puget Sound Action Agenda
- The City's Stormwater Code (SMC, Chapters 22.800 through 22.808)

Owners, operators, and occupants of property, and anyone causing or contributing to a violation of the City Code are each considered a "responsible party" for purposes of a Code violation (SMC, Section 22.801.190).

If a commercial property is owned, leased, or rented to tenants, the owner is also responsible for any pollution from the property and can be held responsible for water quality problems caused by tenants. Make sure tenants are informed of their responsibilities.

1.3. Which Pollutants Are Targeted in This Volume?

The following provides descriptions of typical pollutants (or measures of potential pollution in the case of pH) targeted by the source control BMPs outlined in this manual, including explanations of why the pollutants can be harmful and some of the common sources of these pollutants.

1.3.1. pH

The pH value of a substance is a measurement of its acidity or alkalinity. The pH of a body of water is vitally important because most aquatic life survives within a relatively narrow range of pH values (6.5 to 8.5). A pH that is lower than 6.5 can be too acidic to support aquatic life. A pH that is higher than 8.5 can be too alkaline to support aquatic life. Some sources that can contribute to a change in the pH of stormwater and receiving waters are:

- Cement in poured concrete
- Cement dust
- Materials used in paving and recycling operations
- Solutions used in metal plating operations
- Chemicals from printing and other industrial processes
- Common cleaners such as bleaches and deck cleaners
- Calcium chloride

1.3.2. Total Suspended Solids

Total suspended solids can include particles such as sand, silt, soil, iron precipitates, and biological solids, all of which can increase the turbidity in receiving waters (make the water cloudy) and can settle out in streams as sediment. This can destroy fish habitat and other aquatic life because excess sediment has the potential to smother aquatic organisms, including developing fish eggs, and also coat them with toxic substances such as petroleum and metals, which can adhere to the sediment in receiving waters.

1.3.3. Chemical and Biological Oxygen Demanding Substances

Chemical wastes and degradable organic matter (such as landscaping waste and food waste) can drastically affect water quality if allowed to enter stormwater. As these substances are broken down by bacteria, the oxygen in the water is depleted. The resulting decrease in oxygen supply can stress or eventually kill fish and other aquatic species. Chemical oxygen demand (COD) and biological oxygen demand (BOD) are two parameters that indicate the amount of oxygen that is used up by various pollutants.

1.3.4. Metals

Metals are used in many products and include copper, lead, zinc, and arsenic. Certain metals wear off vehicle brakes, tires, and galvanized surfaces and are released from paint, scrap metal, and protective coatings used on buildings. Metals such as zinc can also be a component in products such as moss killers. These metals can be carried by stormwater runoff into receiving waters where they have been linked to severe health and reproductive problems in fish and other aquatic animals.

1.3.5. Bacteria and Viruses

Bacteria and viruses from animal wastes, wildlife, illicit connections, and leaking sewer lines can contaminate receiving waters and result in the closure of swimming and shellfish areas. Concentrations of bacteria called fecal coliform—enterococci in marine water and *Escherichia coli* in fresh water—are typically used as indicators of pollution.

1.3.6. Nutrients

In the context of water quality, the nutrients of concern are primarily compounds that contain nitrogen and phosphorus. Excess nutrients allowed to enter receiving waters can lead to overgrowth of algae, depletion of oxygen in the water, and channel clogging due to the overgrowth of vegetation. The water can also become unattractive for recreational use and unsuitable for fish and wildlife. Sources of nutrients include fertilizers, leaking trash containers, leaking sewer lines, yard waste, and animal waste.

1.3.7. Toxic Organic Compounds

A number of organic compounds are toxic to the aquatic environment. Many pesticides, herbicides, rodenticides, and fungicides contain organic compounds that can be deadly to aquatic life. The same is true of organic compounds included in antifreeze, wood preservatives, cleansers, and a host of other more exotic organic compounds that result from industrial operations or past industrial practices (such as phthalates, polychlorinated biphenyls [PCBs], dioxins, and chlordane). These toxic organic compounds can remain in the sediment for a long time.

1.3.7.1. Per- and Polyfluoroalkyl Substances (PFAS)

Per- and Polyfluoroalkyl Substances (PFAS) are manufactured, synthetic substances that include thousands of chemicals. These chemicals have been used in many industry and consumer products since the 1940s. PFAS can enter soil, water, and air from various sources and is being detected in many samples including municipal and industrial stormwater effluent. Specifically, PFAS have been detected in the stormwater of urban industrial areas and these discharges are considered to be a pathway for the uncontrolled release of PFAS into surface waters, both fresh and marine.

The science is still evolving on the toxic effects of PFAS exposure to aquatic life. Monitoring data from multiple sources statewide, such as monitoring studies of surface waters, stormwater outfalls, and PFAS testing of groundwater, for example, will help Ecology have a clearer understanding of how much PFAS is being discharged via stormwater runoff vs other pathways, and evaluate the possible effects of PFAS on aquatic life as well as human health in receiving waterbodies.

1.3.7.2. Pollutants from Rubber Preservatives (Including 6PPD-q)

6PPD-q is one of several identified organic contaminants originating from rubber manufactured products, primarily vehicle tires (Klöckner et al. 2021 and Zhao et al. 2023) that can lead to stormwater pollution and possible severe impacts to aquatic life in Washington's surface waters. The parent compound 6PPD has been added to tires as a chemical antioxidant preservative for decades.

Currently, a great deal of effort is underway worldwide to better understand the chemical properties of 6PPD-q and other transformation products and the fate and transport in human-made and natural water systems. In addition to Source Control studies, Ecology has multiple studies underway to characterize concentrations of 6PPD in stormwater and determine the effectiveness of Runoff Treatment BMPs to reduce those concentrations.

Best professional judgment of professional scientists and engineers is primarily based on EPA's chemical behavior models and a small handful of published studies. Multiple studies are underway locally and this highly toxic compound has received worldwide attention. Fortunately, two studies conducted locally, before 6PPD-q was identified, found that filtering highway runoff through the default bioretention soil mix made it no longer toxic to coho (McIntyre et al. 2015) and these researchers theorized the lethal toxicant was bound to organic matter (Spromberg et al. 2016). Current studies are evaluating the potential treatment effectiveness of sorption and other filtration techniques using a variety of media and BMPs. Implementing a wide range of stormwater management strategies, including source control, runoff treatment, and flow control, across the myriad landscapes with existing urban and roadway development without stormwater management may help to prevent 6PPD-q toxicity to salmon and trout in nearby receiving waters. Recently, a review based on best available science and professional judgment was published that ranked over 170 stormwater BMPs on likelihood of reducing concentrations of tire wear particles containing 6PPD and 6PPD-q in stormwater runoff (Navickis-Brasch et al. 2022). The literature review suggested that stormwater source control BMPs, such as street sweeping and cleaning roadside ditches, may have potential to prevent some 6PPD and 6PPD-q from entering stormwater. Source control BMPs aim to separate and prevent sources of pollutants from stormwater runoff. Flow control and runoff treatment BMPs that utilize infiltration, sorption, filtration, and sedimentation may have potential to reduce some 6PPD and 6PPD-q from stormwater. The review indicated that our understanding of the science is continuing to evolve, and our scientific understanding of 6PPD-q behavior in natural and built environments will continue to become clearer.

1.3.7.3. Polycyclic Aromatic Hydrocarbons (PAHs)

PAHs are a class of chemicals that occur naturally and result from burning of natural and manufactured fuels such as wood, gasoline, coal, or wastes. PAHs are considered 'ubiquitous' with concentrations always present in stormwater but the concentrations and rates of detection in stormwater samples vary widely. PAHs were monitored by the Phase I Western Washington municipal stormwater permittees under the 2007 permit and summarized by (Ecology 2015a). The lower molecular weight compounds are often not found in stormwater. PAHs are more commonly detected in stormwater sediments. Both water and sediment samples show land use differences with higher concentrations in commercial and industrial areas as compared to residential areas.

1.3.7.4. Polychlorinated Biphenyls (PCBs)

PCBs are persistent bioaccumulative chemicals considered one of the most significant toxic chemicals in Puget Sound, impacting fish, shellfish, and mammal populations. Between 1929 and 1979, PCBs were added to a range of building materials used on the exterior of industrial, commercial, institutional, and large multi-family/unit residential buildings to increase the material's longevity. Such materials include some paints, caulking and other joint materials,

sealants, roofing, and siding. PCBs are also known to be found in pigments currently manufactured for use in inks, paper, and other printing-related materials. More information about sources of PCBs can be found in Ecology's PCB Chemical Action Plan (Ecology 2015b).

PCBs in building materials can be released into the environment during demolition and renovation, routine maintenance (such as cleaning and pressure washing), and contaminated site remediation. Although PCBs are continually released into the environment from exterior PCB-containing building materials exposed to weather, PCBs are likely to be released from buildings in higher quantities when materials are disturbed or degraded. Stormwater is a primary way that PCBs from exterior building materials enter surface waters where they contaminate fish and shellfish (Ecology 2024). Several BMPs in this Volume (and Volume 2, BMPs C1.25 and C1.30) contain PCB-specific requirements to help prevent PCBs from entering stormwater, stormwater drainage systems, and downstream waterbodies.

1.3.8. Other Chemicals and Substances

There are many other chemicals and substances that can cause problems if they are allowed to enter the aquatic environment. Even compounds classified as "biodegradable" or "environmentally friendly" can have devastating effects on aquatic life. Some of the most common chemicals and substances that pollute stormwater are oils, greases, soaps, and detergents.

1.3.9. Oils and Greases

Oil and grease can be generated from either petroleum-based or food-based sources. Oils and greases conveyed in stormwater can accumulate in receiving waters and contaminate soil. Petroleum-based oils and greases can be immediately toxic to fish and wildlife. Food-based oils and greases can coat insects and fish gills, leading to suffocation.

1.3.10. Soaps and Detergents

Vehicles and structures are commonly washed with soaps and other detergents mixed with water. If not managed properly, the resulting washwater can flow to an inlet, catch basin, or ditch, which discharges the polluted water directly to the nearest stream, lake, or to Puget Sound. Soaps and detergents, even the biodegradable ones, can have immediate and long-term effects on aquatic life. Sediment and oil released when vehicles and structures are washed with soaps and detergents can also collect in the washwater, causing further harm to fish and other aquatic wildlife. Soaps used on roofs to treat moss can also result in soaps being discharged via roof drains to receiving waters.

The term "biodegradable" on a product label does not mean that the product is safe or environmentally friendly. The product may degrade faster than alternative products but can still be harmful to the environment.

1.4. What Are BMPs?

BMPs for managing stormwater are divided into two broad categories: source-control BMPs and treatment BMPs.

1.4.1. Source Control BMPs

Source control BMPs prevent contaminants from entering stormwater runoff by controlling them at their source. Source control can include operational changes (such as sweeping or process changes) or structural changes (such as extending a roof or installing a treatment facility).

Source control requirements are based on the following goals:

1. Prevent stormwater pollution by eliminating pathways that may introduce pollutants into stormwater.
2. Protect soil, groundwater, and receiving waters by capturing acute releases, such as spills, to reduce chronic contamination of the environment.
3. Separate stormwater and wastewater flows.
4. Direct wastewater discharges and areas with the potential for wastewater discharge (such as vehicle washing facilities) to the sanitary or combined sewer system.
5. Provide an approved method of containment and discharge for areas that have the potential for spills and are not expected to regularly receive stormwater flow or require water use (such as covered fuel islands or covered containment areas).
6. Create a combination of structural controls and operational procedures to ensure sustainability of the BMPs.

1.4.2. Treatment BMPs

This volume also identifies specific treatment BMPs that apply to particular pollutant sources such as fueling stations, railroad yards, and the outdoor storage and transfer of materials, byproducts, or finished products. Examples of treatment BMPs are oil/water separators, wet vaults, and biofilters. After identifying the required treatment BMPs, refer to *Volume 3 — Project Stormwater Control* for additional information about treatment BMPs.

1.5. Already Implementing Best Management Practices?

Property owners and operators may already be implementing BMPs in accordance with other federal, state, or local requirements (e.g., businesses that have a National Pollutant Discharge Elimination System [NPDES] permit from Ecology). In some cases, the City's requirements may be in addition to or more stringent than other applicable requirements. Anyone with questions about how to meet all of the source control requirements for stormwater should contact the City of Seattle Stormwater Source Control Team via the Water Quality Complaints/Reporting Line at (206) 684-7587. City inspectors will work with responsible parties to determine the applicable BMPs.

If it is determined that the BMPs being implemented are not effectively addressing the discharge of contaminants, additional BMPs may be required, including treatment and structural BMPs.

Entities that conduct specific industrial activities are required to obtain an Industrial NPDES Permit for their stormwater discharges. For more information about whether an entity needs an NPDES permit, refer to Ecology's website (https://ecology.wa.gov/Water-Shorelines/Water-quality/Runoff-pollution/Stormwater) or call Ecology at (360) 407-6000.

1.6. Getting Started

To understand the source control requirements addressed by this volume, the first step is to determine if the property discharges to the combined sewer, stormwater drainage system, or receiving water. If the answer is not clear, call the Water Quality Complaints/Reporting Line at (206) 684-7587.

All real property in Seattle must implement BMP 1 through BMP 8 for all real property outlined in *Section 2.1 (see also Table 1a, below)*. BMP 9 through BMP 16 also apply to all real property but are related to specific activities that may occur at a property (*Section 2.2*).

In addition, businesses and public entities, except those that discharge only to the public combined sewer, must implement the additional BMPs pertinent to site-specific activities outlined in *Chapter 3*.

The worksheets provided below (Tables 1b through 1h) are designed to help identify the appropriate BMPs required. The worksheets contain BMPs organized by the different activities that businesses and public entities perform. If the listed activity is performed indoors and all discharges (e.g., process water, washwater, lubricants, solvents, fugitive dust, granular material, and blowdown waste) are controlled such that there is no exposure of stormwater to pollutants, then additional BMPs do not have to be implemented for that activity.

1. Complete all sections of the worksheets, checking the appropriate boxes for all activities that occur at the workplace.
2. If any of the activities were checked as being performed outdoors (or indoors in areas that might spill or flow outdoors), additional BMPs are required for that activity. Refer to the subsection of this volume identified in the first column of the worksheet for a description of the required BMPs.

Questions can be answered by leaving a message on the Water Quality Complaints/Reporting Line at (206) 684-7587 or contacting the SPU Green Business Program at (206) 343-8505 or viewing the City's website (https://www.seattle.gov/utilities/protecting-our-environment/sustainability-tips/green-business-program).

Table 1a. Best Management Practices for All Real Property

Section Reference	BMP Number and Name
2.1.1	BMP 1: Eliminate Illicit Connections and Illicit Discharges
2.1.2	BMP 2: Perform Routine Maintenance
2.1.3	BMP 3: Dispose of Fluids and Wastes Properly
2.1.4	BMP 4: Proper Storage of Solid Wastes
2.1.5	BMP 5: Spill Prevention and Cleanup
2.1.6	BMP 6: Provide Oversight and Training for Staff
2.1.7	BMP 7: Property Maintenance
2.1.8	BMP 8: Constructed Dog Runs

Table 1b. Worksheet for Identifying Applicable BMPs: Business and Public Entity Best Management Practices for Specific Activities[a]

Section Reference	BMP Number and Name	Is Activity Conducted on the Site?
2.2.1	BMP 9: Fueling at Dedicated Stations ● Applies to gas stations, pumps at fleet vehicle yards or shops, and other privately owned pumps, including construction sites	
2.2.2	BMP 10: Mobile Fueling of Vehicles and Heavy Equipment ● Applies to fleet fueling, wet fueling, and wet hosing	
2.2.3	BMP 11: In-Water and Over-Water Fueling	
2.2.4	BMP 12: Maintenance and Repair of Vehicles and Equipment ● Applies to vehicle maintenance operations and activities where fluids from vehicles and equipment are removed and replaced at permanent or temporary sites	
2.2.5	BMP 13: Concrete and Asphalt Mixing and Production ● Applies to the mixing of raw materials on the site to produce concrete or asphalt or the making of concrete or asphalt products	
2.2.6	BMP 14: Concrete Pouring, Concrete/Asphalt Cutting, and Asphalt Application ● Applies to construction site, driveway, and parking lot resurfacing and cutting	
2.2.7	BMP 15: Recycling, Wrecking Yard, and Scrapyard Operations ● Applies to scrapped equipment, vehicles, construction materials, and assorted recyclables	
2.2.8	BMP 16: Storage of Liquids in Aboveground Tanks ● Applies to all liquids in aboveground tanks	

[a] BMP 9 through BMP 16 apply to All Real Property but are related to specific activities that may occur at businesses or be performed by public entities.

Does site drain only to the public combined sewer?

- If yes, only Chapter 2 BMPs are required.
- If no, fill out the remainder of the worksheet to determine applicable BMPs for site activities per SMC, Section 22.803.040.

If unsure where the site discharges to, call the Water Quality Hotline Complaints/Reporting Line at (206) 684-7587 for assistance.

Table 1c. Worksheet for Identifying Applicable BMPs: Section 3.1 – Cleaning or Washing

Section Reference	BMP Number and Name	Is Activity Conducted in an Area That Could Impact the Drainage System or Receiving Waters?
3.1.1	BMP 17: Cleaning or Washing ● Applies to all outdoor washing activities, including the following: ● Cleaning or washing of tools, engines, manufacturing equipment, vents, filters, pots and pans, grills, floor mats, graffiti-covered surfaces, and artificial turf ● Fleet vehicle yards, car dealerships, car washes, and maintenance facilities ● Mobile washing, including carpet cleaning, pressure washing, truck washing, etc. ● Buildings that are confirmed or suspected of containing PCBs on exterior materials.	

Table 1d. Worksheet for Identifying Applicable BMPs: Section 3.2 – Transfer of Liquid or Solid Materials

Section Reference	BMP Number and Name	Is Activity Conducted in an Area That Could Impact the Drainage System or Receiving Waters?
3.2.1	BMP 18: Loading and Unloading of Liquid or Solid Material ● Applies to loading and unloading of liquid or solid materials	

Table 1e. Worksheet for Identifying Applicable BMPs: Section 3.3 – Production and Application

Section Reference	BMP Number and Name	Is Activity Conducted in an Area That Could Impact the Drainage System or Receiving Waters?
3.3.1	BMP 19: Manufacturing and Post-processing of Metal Products ● Applies to machining, grinding, soldering, cutting, welding, quenching, rinsing, etc.	
3.3.2	BMP 20: Processing of Treated Wood ● Applies to chemical preservative treatment of wood as well as outdoor storage	
3.3.3	BMP 21: Commercial Composting ● Applies to commercial composting facilities that operate outdoors without cover	
3.3.4	BMP 22: Landscaping and Vegetation Management ● Applies to grading, storage of landscape materials, soil transfer, vegetation removal, pesticide and fertilizer applications, and watering	

Table 1e (continued). Worksheet for Identifying Applicable BMPs: Section 3.3 – Production and Application

Section Reference	BMP Number and Name	Is Activity Conducted in an Area That Could Impact the Drainage System or Receiving Waters?
3.3.5	BMP 23: Painting, Finishing, and Coating Activities ● Applies to surface preparation and the application of paints, finishes, and/or coatings	
3.3.6	BMP 24: Commercial Printing Operations ● Applies to materials used in the printing process and waste printing equipment	
3.3.7	BMP 25: Manufacturing Activities ● Applies to manufacturing activities in outdoor areas	

Table 1f. Worksheet for Identifying Applicable BMPs: Section 3.4 – Storage and Stockpiling

Section Reference	BMP Number and Name	Is Activity Conducted in an Area That Could Impact the Drainage System or Receiving Waters?
3.4.1	BMP 26: Storage of Leachable or Erodible Materials ● Includes sand, topsoil, lumber, and other products	
3.4.2	BMP 27: Temporary Storage or Processing of Fruits, Vegetables, or Grains ● Applies to storage of fruits, vegetables, or grains; and processing activities at: wineries; breweries; fresh and frozen juice makers; and other food and beverage processing operations	
3.4.3	BMP 28: Portable Container Storage ● Applies to containers used for temporary and permanent storage	

Table 1g. Worksheet for Identifying Applicable BMPs: Section 3.5 – Dust, Soil Erosion, and Sediment Control

Section Reference	BMP Number and Name	Is Activity Conducted in an Area That Could Impact the Drainage System or Receiving Waters?
3.5.1	BMP 29: Dust Control in Disturbed Land Areas and on Unpaved Roadways and Parking Lots ● Applies to dust control measures in disturbed land areas or on unpaved roadways and parking lots	
3.5.2	BMP 30: Dust Control at Manufacturing Sites ● Applies to grain dust, sawdust, coal, gravel, crushed rock, cement, boiler fly ash, and other airborne polluting materials	
3.5.3	BMP 31: Soil Erosion and Sediment Control at Industrial Sites ● Applies to industrial activities that take place on soil	

Table 1h. Worksheet for Identifying Applicable BMPs: Section 3.6 – Other Activities

Section Reference	BMP Number and Name	Is Activity Conducted in an Area That Could Impact the Drainage System or Receiving Waters?
3.6.1	BMP 32: Commercial Animal Care and Handling ● Applies to operations at boarding and day-use kennels, fenced pens, daycares, grooming facilities, shelter and adoption facilities, veterinary clinics, and businesses and public entities that store animals.	
3.6.2	BMP 33: Log Sorting and Handling ● Applies to log yards	
3.6.3	BMP 34: Boat Building, Maintenance, and Repair ● Applies to all types of maintenance, repair, and building operations at shipyards, ports, and marinas	
3.6.4	BMP 35: Cleaning and Maintenance of Pools, Spas, Hot Tubs, and Fountains ● Applies to cleaning and maintenance of pools, spas, hot tubs, and fountains, including all commercial pool cleaners	
3.6.5	BMP 36: Deicing and Anti-icing Operations for Airports and Streets ● Applies to highways, aircraft, runways and taxiways, and streets	

Table 1h (continued). Worksheet for Identifying Applicable BMPs: Section 3.6 – Other Activities

Section Reference	BMP Number and Name	Is Activity Conducted in an Area That Could Impact the Drainage System or Receiving Waters?
3.6.6	BMP 37: Maintenance and Management of Roof/Building Surfaces at Manufacturing and Commercial Buildings ● Applies to maintenance and management of roofs and sides of manufacturing and commercial buildings	
3.6.7	BMP 38: Maintenance and Operation of Railroad Yards ● Applies to cleaning, maintenance, and repair of equipment and engines; fueling; waste disposal; and all other yard maintenance activities	
3.6.8	BMP 39: Maintenance of Public and Private Utility Corridors and Facilities ● Applies to maintenance activities related to public and private utilities, including pipelines, pump stations, rights-of-way, and transmission corridors	
3.6.9	BMP 40: Maintenance of Roadside Ditches ● Applies to activities related to the maintenance of roadside ditches	
3.6.10	BMP 41: Potable Water Line Flushing, Water Tank Maintenance, and Hydrant Testing	
3.6.11	BMP 42: Urban Streets	
3.6.12	BMP 43: Nurseries and Greenhouses	
3.6.13	BMP 44: Color Events	
3.6.14	BMP 45: Pet Waste	
3.6.15	BMP 46: Labeling Storm Drain Inlets on Your Property	
3.6.16	BMP 47: Well, Utility, Directional, and Geotechnical Drilling	
3.6.17	BMP 48: Goose Waste	
3.6.18	BMP 49: Pesticides and an Integrated Pest Management Program	
3.6.19	BMP 50: Storage of Dry Pesticides and Fertilizers	
3.6.20	BMP 51: Irrigation	
3.6.21	BMP 52: Dock Washing	
3.6.22	BMP 53: Roof Vents	
3.6.23	BMP 54: Streets and Highways	
3.6.24	BMP 55: Fertilizer Application	
3.6.25	BMP 56: Light Rail Washing	

Notes:

If this activity could impact stormwater or receiving waters, refer to the corresponding section of this volume (identified in the first column) for BMP descriptions.

CHAPTER 2 – Best Management Practices for All Real Property

2.1. Required Best Management Practices

All real property must implement and maintain the following source control best management practices (BMPs) to prevent or reduce the amount of pollutants from leaving a site or property (SMC, Section 22.803.030):

- BMP 1: Eliminate Illicit Connections and Illicit Discharges
- BMP 2: Perform Routine Maintenance
- BMP 3: Dispose of Fluids and Wastes Properly
- BMP 4: Proper Storage of Solid Wastes
- BMP 5: Spill Prevention and Cleanup
- BMP 6: Provide Oversight and Training for Staff
- BMP 7: Property Maintenance
- BMP 8: Constructed Dog Runs

Stormwater Code Language	References
SMC, Section 22.803.030 – *For all discharges, responsible parties shall implement and maintain source controls to prevent or minimize pollutants from leaving a site or property.*	• None provided
SMC. Section 22.801.190 – *"Responsible party" means all of the following persons:* 1. *Owners, operators, and occupants of property; and* 2. *Any person causing or contributing to a violation of the provisions of this subtitle.*	• None provided

2.1.1. BMP 1: Eliminate Illicit Connections and Illicit Discharges

Illicit connections and discharges include sanitary or process wastewater connections and unpermitted discharges of pollutants that are improperly affecting a drainage system or receiving water. Illicit connections are infrastructure, such as pipes, that convey pollutants directly into the drainage system or local waters. Illicit discharges can include flow through pipes, overland flow, spills, or dumping of prohibited material into drainage systems or local waters. A variety of pollutants can flow directly to receiving waters instead of sanitary sewer systems through illicit connections and discharges. Frequently, such connections and discharges are not intentional but can harm the environment and must be removed or stopped.

Unpermitted discharges to the public combined sewer system can also affect wastewater treatment systems and infrastructure. Refer to *Volume 1, Section 3.11* for the minimum requirements to comply with the Seattle Side Sewer Code (SMC, Chapter 21.16). See SMC 21.16.300 for the list of prohibited discharges of certain substances to the public sewer system (or storm drain system or receiving water).

Illicit discharges can include chlorinated/brominated water (e.g., from swimming pools and hot tubs), cleaning solutions/washwater, sewage overflows, greywater, blackwater, cooling water, cooking oils, dirt/sand/silt, etc. Lists of prohibited and permissible substances can be found in SMC, Chapter 22.802.

Required elements of this BMP include:

- For all real properties, responsible parties must examine their plumbing systems to identify any potentially illicit connections. First examine the site plans because remodeling and tenant improvement projects are particularly susceptible to inadvertent illicit connections. If an illicit connection is suspected, examine the conveyance system using closed-circuit television inspection (CCTV), dye test with a nontoxic dye, smoke testing, flow test, or visual reconnaissance. These tests are typically best performed by qualified personnel such as a plumbing contractor. Notify the Washington State Department of Ecology (Ecology) Northwest Regional Office at (206) 594-0000 *and* Seattle Public Utilities (SPU) at (206) 386-1800 prior to performing a dye test that may result in a discharge to the public drainage system, public sewer system, or a receiving water.
- If illicit connections are found, permanently plug or disconnect the connections.
- Obtain all necessary permits for altering, repairing, or capping side sewers and plumbing fixtures. Restrictions on certain types of discharges, particularly industrial process waters, may require pretreatment of discharges before they enter the sanitary sewer. It is the responsibility of the property owner or business operator to obtain the necessary permits and to correct the connection.
- The Stormwater Code allows the Director to require a responsible party to provide or create site drainage and sewer system laterals and plumbing maps with verified discharge points to aid in identifying illicit connections and/or to verify that illicit connections are eliminated.

- A discharge from an illicit connection or illicit discharge is considered a spill and requires immediate and proper notification to SPU at (206) 386-1800 and possibly other state and federal agencies. See BMP 5 (Spill Prevention and Cleanup).
- Illicit discharges to drainage systems and receiving waters must be stopped and reported (see BMP 5). If these discharges are redirected to the sanitary sewer, consult King County Industrial Waste to ensure the material will not harm the sewage treatment system and confirm if permits, authorizations, or pre-treatment are necessary.

2.1.2. BMP 2: Perform Routine Maintenance

Sediment and pollutants can accumulate over time in various parts of drainage collection, conveyance, and treatment systems, such as inlets, catch basins, ditches, storm drains, detention structures, and oil/water separators. When a storm event occurs, debris that includes trash and leaves, solids/sediment, and pollutants can be carried into receiving waters, the public drainage system, or a public combined sewer. Performing routine maintenance is required and helps prevent debris, sediment and pollutants from discharging downstream.

Required elements of this BMP include:

- Comply with the maintenance requirements found in *Appendix G—Stormwater Control Operations and Maintenance Requirements*.
- Inspect all drainage collection, conveyance, flow control, and treatment systems at least annually, and clean or repair structures whenever the maintenance thresholds described in *Appendix G* are exceeded. Systems in industrial areas or areas that receive excessive solids, leaves, or other debris may require more frequent inspection and maintenance.
- Remove leaves or woody debris that has accumulated on catch basins and inlets to prevent localized flooding. Drainage systems must be kept in continuous working order.
- All catch basins are required to have outlet traps (downturned elbows). Outlet traps help keep oil and other floatables from discharging to the public drainage system, public combined sewer, or receiving waters. Replace or repair missing or damaged outlet traps. When catch basins lack sufficient depth or room to install an outlet trap, evaluate the drainage system to determine if an appropriate downstream location exists and install an outlet trap at that location.
- Clean catch basins when the sump is greater than 60 percent full of solids (sediment, leaves, trash, and other debris), when the solids accumulation in the sump is within 6 inches of the bottom of the lowest pipe, or any time there are obvious signs of pollution visible. When the catch basin sump is greater than 60 percent full, there is not enough settling space to remove heavier materials from stormwater and the catch basins cease to function as designed. At greater than 60 percent full, solids can block the outlet pipe, which can lead to flooding and greater maintenance costs.
- Properly dispose of all solids, polluted material, and stagnant water collected through system cleaning. Do not decant water back into the drainage system from eductor trucks or vacuum equipment because there may be residual contaminants in the cleaning equipment. Do not jet/hose material downstream into the system. In all systems, known or suspected contaminated material may need to be tested for additional disposal requirements.
- It is the property owner's responsibility to ensure access points to stormwater facility structures are accessible for inspection.

Recommended elements of this BMP and additional information:

- Consider placing "Dump No Waste" or other warning signs or labels adjacent to inlets/catch basins where possible.

- A long rod can be used to determine the level of solids in your catch basin sumps, detention systems, or treatment system facilities. Insert the rod into the catch basin or maintenance hole until it rests on the bottom of the sump. Grasp the rod at the top of the grate or lid and lift the rod slowly. Try to swing the rod side to side until it feels free of any solids and measure the depth of solids (the distance between your grip on the rod and the top of the grate or lid). Compare this measurement with the depth of the overall sump beneath the lowest pipe in or out.
- If these maintenance requirements noted in this BMP and in Appendix G are beyond your capabilities (i.e., knowledge, skill, experience level), seek support from a more experienced individual. This may be someone from within your business or public entity, or it may necessitate hiring an outside professional contractor. If contracting services are used, keep in mind that you are responsible for the resulting effects on the stormwater infrastructure to ensure they comply with City code and rules. Several contractors offer cleaning services for drainage systems. A list of contractors can be found on the SPU website or search tools (e.g., internet, Yellow Pages) under entries such as “Drainage System Maintenance Contractors.”

2.1.3. BMP 3: Dispose of Fluids and Wastes Properly

For all real properties, responsible parties must properly dispose of accumulated solid and liquid wastes, contaminated stormwater, and street waste solids. There are five disposal options, depending on the type of waste:

1. Sanitary sewer or combined sewer (liquid wastes only)
2. Recycling facilities
3. Permitted centralized waste treatment facilities
4. Municipal solid waste disposal facilities
5. Hazardous waste treatment, storage, and disposal facilities

Some liquid wastes and contaminated stormwater (depending on the pollutants and associated concentrations) may be discharged to the sanitary sewer system but are subject to approval by the City of Seattle and King County. Restrictions on certain types of discharges may require pretreatment before they enter the sanitary sewer system.

If wastes cannot be legally discharged to a sanitary sewer, one of the other disposal options must be used. Sumps (with plugged outlets) or holding tanks may be useful for storing liquid wastes temporarily, but the contents must be disposed of properly.

Contaminated street waste solids (e.g., solids removed from roads and catch basins that have elevated levels of hydrocarbons or other chemicals) must be handled by following either the guidance in Management of Street Waste Solids and Liquids in Appendix IV-B of the *Stormwater Management Manual for Western Washington* (SWMMWW) (Ecology 2024) or the Dangerous Waste Regulations (Washington Administrative Code [WAC], Chapter 173-303), if applicable.

For assistance with finding recycling facilities, refer to the King County Green Tools web page (https://kingcounty.gov/depts/dnrp/solid-waste/programs/green-building.aspx).

For assistance in determining where to take motor oil, pesticides, smoke alarms, fluorescent bulbs, and other hazardous materials, refer to the Local Hazardous Waste Management Program website (https://kingcounty.gov/en/dept/dnrp/waste-services/hazardous-waste-program?Go+to+Haz+Waste+Program+website=).

Required elements of this BMP include:

- Do not dispose of prohibited wastes or substances into the drainage system, sewer system, or into local waters. Only clean stormwater and permissible discharges are allowed into the stormwater drainage system. See SMC, Chapter 22.802 for permissible and prohibited discharges. Also refer to SMC 22.803.020.D related to requirements for disposal of waste from maintenance of drainage control facilities and SMC 22.803.030.C for disposal of fluids and wastes.
- In the non-combined sewer areas of the City, follow the procedures described in Appendix 6 of the Phase I NPDES Municipal Stormwater Permit to dispose of liquids from street waste collection and from stormwater treatment/flow control facilities and BMPs.

Recommended BMPs include:

- Dispose of wastes in accordance with applicable solid waste, dangerous waste, industrial waste, and other regulations in a manner that minimizes the risk of contaminating stormwater. Failure to comply with rules and regulations enforced by other entities can result in violations and penalties issued by those entities.

2.1.4. BMP 4: Proper Storage of Solid Wastes

This BMP applies to properties that store solid waste outside. Examples of solid waste include garbage, recyclables, compostable materials, and used cooking oil (UCO). Specific requirements in this BMP also apply to empty containers previously used to store solid waste. If improperly stored, these wastes or containers can contribute a variety of pollutants to stormwater.

Related BMPs and Permits:

Facilities that handle, process, and treat various types of solid wastes may require a Solid Waste Handling Permit. Piled material that is permitted, will be managed under BMP 26: Storage or Transfer of Leachable or Erodible Materials. Numerous activities associated with recycling or commercial solid waste handling require permit coverage through Seattle & King County Public Health.

Definitions:

Required elements of this BMP are pursuant to SMC sections:

SMC 21.36.016 – Definitions R -Z

- 12. “Solid waste” means putrescible and nonputrescible solid, semisolid, and liquid wastes. which are not the primary products of public, private, industrial, commercial, mining and agricultural operations.
- 13. "Solid waste container" is a *secure, rigid, watertight container(s) with a tight-fitting lid*.

SMC 22.802.020.A.29 – Prohibited Discharges.

- Prohibited Discharges. The following common substances are prohibited to enter, either directly or indirectly, a public drainage system, a private drainage system, or a receiving water within or contiguous to Seattle city limits, including but not limited to when entering via a service drain, overland flow, or as a result of a spill or deliberate dumping:
  - solid waste;

22.803.020.B - Minimum requirements for all discharges and real property

- Requirement to report spills, releases, or dumping. A responsible party is required to, at the earliest possible time, but in any case within 24 hours of discovery, report to the Director of SPU a spill, release, dumping, or other situation that has contributed or is likely to contribute pollutants to a public drainage system, a private drainage system, or a receiving water. This reporting requirement is in addition to, and not instead of, any other reporting requirements under federal, state or local laws. https://www.seattle.gov/utilities/protecting-our-environment/sustainability-tips/green-business-program

Required elements of this BMP include:

- Suitable containers and lids:
  - Store all solid wastes in a designated area in suitable containers (examples in Figure 1) which are durable, corrosion-resistant, non-absorbent, non-leaking, and equipped with a solid cover or screen to prevent littering. If covered with a screen, the container must be stored under a roof or other form of adequate cover to prevent rainwater intrusion.
  - All waste, recycle, and compost containers must use a secure and functional lid, and the lid must be closed at all times except when waste is actively being added to the container. Also refer to "empty containers" sub-section in this BMP.
- **Inspect and maintain:**
  - Inspect the waste storage area at least weekly, checking the storage containers and trash compactors for damage. Replace containers, compactors, lids, and secondary containment if they are leaking, corroded, or otherwise deteriorating. Discontinue use of damaged containers until they are replaced or repaired.
  - Clean the waste storage area frequently to collect all loose solids for proper disposal.
- **Printing equipment**:
  - Waste printing equipment (including ink and other cartridges) must not be stored outdoors. Pigments and dyes used in print production can be a source of inadvertent polychlorinated biphenyls (iPCBs); therefore, the equipment must not be exposed to rain, stormwater run-on, or potentially leak fluids to outdoor ground surfaces. Also see BMP 24.
- **Batteries**:
  - Store lead acid or other liquid state batteries upright in a secure location, even when staged for recycling. Cover all stored batteries. Check to ensure batteries are not damaged or leaking. Store damaged or leaking batteries in a non-leaking, container with a secondary containment system. Keep an appropriate battery acid spill kit, including neutralizing materials, such as baking soda, available near the used battery storage area.

Figure 1. Covered Outdoor Storage of Solid Wastes in Suitable Containers.

- Illicit Discharges:
  - Any spills and leaks from solid waste containers should be treated as a spill and cleaned up immediately. See BMP 5 for more requirements on spill preparedness, response, and reporting.
  - Contain and properly dispose of washwater pursuant to BMP 17 (Cleaning or Washing) when washing solid waste containers or container storage areas. Solid waste washwater is considered process water and must not be discharged to the stormwater drainage system.
- **Siting:**
  - If feasible and when in accordance with Fire and other local codes, keep solid waste containers inside a building. If not feasible, the containers may be stored outdoors following all the requirements in this BMP.
  - Trash compactor drain hoses must be connected to the sanitary sewer.
  - If a dumpster area is plumbed to the sanitary sewer, only up to 200 square feet of a dumpster area (and other solid waste storage areas at the site) may drain to the sanitary sewer. Any portion of a dumpster area over 200 square feet requires a roof canopy, and the roof runoff from the covered area must be diverted to the stormwater drainage system. This is to prevent excess stormwater from entering the sanitary sewer and impacting its capacity.
  - If the dumpster area is not plumbed to the sanitary sewer, then all of the following requirements apply at all times:

        - All other components of this BMP under the sections "Suitable containers and lids", "Inspect and maintain", "Printing equipment", "Batteries", "Illicit Discharges", "Siting" and "Requirements for Used Cooking Oil" are followed.
        - City Departments retain the right to require additional source controls (operational or structural) if BMPs are not implemented and/or effective. The additional controls could include, among other requirements, covering the dumpster area or connecting to the sanitary sewer.
    - If the dumpster area is covered and secondary containment is used, slope the containment to drain into a dead-end sump to collect leaks and small spills. In this situation, ensure the sump is monitored and cleaned out regularly to prevent overflows.

- **Requirements for Used Cooking Oil:**
    - Store used cooking oil (UCO) containers indoors and on private property when feasible. Containers can be stored in the right-of-way (ROW) only if no appropriate space is available on private property; contact Seattle's Department of Transportation (SDOT) prior to placing any UCO containers in the ROW so that the City can verify the lack of private storage options. However, if UCO containers are placed in the ROW, City Departments (including but not limited to SDOT, SPU, Seattle City Light [SCL]) retain the right to require immediate removal of the container, and the containers must always meet the following requirements:
        - UCO containers must be located on a flat, level surface to prevent tipping.
        - UCO containers must not be on top of, or within 5 feet of, grated metal lids/covers, including but not limited to electrical/utility vaults and storm drain inlets/catch basins.
        - UCO containers must not impede movement in the ROW.
        - The area around UCO containers must be kept clean and free of spilled grease, oils, food waste, and debris.
        - UCO containers not meeting the above requirements or with any recurrent issues, including spills, will be required to be stored on private property only.
    - Used cooking oil containers must be inherently tip-proof and must be located and positioned to prevent tipping, spillage, vandalism and vehicle impacts. Barrels are not tip-resistant.
    - Spills resulting from over-filling or improperly transferring used cooking oil, and the cleanup of those spills, are the responsibility of the **entity conducting the transfer of the oil.**
    - Spill response and cleanup resulting from damage, tipping, vandalism, and leaks from UCO containers are the **responsibility of the owner of the container.**
    - ***Owners of used cooking oil collection/storage containers (oftentimes the waste hauler/recycler) must implement the following:***
        - Label each UCO collection container with the following:
            - Name and phone number of container owner
            - The words "Contains used cooking oil"

- ♦ Name and phone number of the renter/user of the used cooking oil collection container
- ♦ The words "Report spills by calling SPU at (206) 386-1800"

- Record all authorized users specific to each container. Make this information available to Seattle Public Utilities upon request.
- Place and maintain tight-fitting and leak-resistant lids on UCO storage containers to prevent rainwater intrusion and leaks.
- Properly empty and replace or repair leaking, damaged, or open (e.g., without a lid) containers immediately.
- Place used cooking oil containers on a level surface or secure them to prevent tipping, as stated in the requirements above.

- ***Generators of used cooking oil (e.g., restaurants) must implement the following:***
  - Identify a location for UCO containers that is either on private property or meets all the requirements for storage in the ROW as identified above. Communicate the secure location to the UCO container owner (waste hauler) during delivery/pickup.
  - Operate in a manner that minimizes the potential to spill UCO when moving containers and transferring oil from one container to another.
  - Use appropriately sized containers when transferring UCO from the kitchen to the UCO container to prevent overfilling.
  - Do not fill storage containers beyond 75 percent of their capacity. If accumulated UCO exceeds 75 percent of the capacity of the storage container, obtain and use another suitable storage container. Call the UCO hauler/recycler immediately to arrange collection.
  - Close lids/covers immediately after use. Lock the lid after every use with a hauler-approved lock.
  - Ensure that screens are kept clean and clear of debris.
  - Report spills by calling SPU at (206) 386-1800.
  - Refer to BMP 5 for a spill plan and spill kits.
  - Assign a specific employee the responsibility for UCO management and train all staff with duties and responsibilities related to UCO management. See BMP 6 for additional training requirements.
- **Spills from UCO containers must be responded to immediately, by the generator and/or the owner.**

Figure 2. Example of a Labeled Used Cooking Oil Container Located on a Level Surface with a Secure Lid.

- **Empty containers:**
  - Empty containers with residues should be stored to prevent stormwater from entering the empty container. Ensure a functional lid is secured and closed on the empty container. If the lid cannot be securely closed at all times, cover the container to prevent stormwater from accumulating within the container.

Recommended BMPs:

- It's preferred that dumpsters with food or liquid bearing waste (including ordinary garbage) be placed on a pad with a drain to the sanitary sewer system.

- Solid waste containers should be located on a paved surface and, where feasible, placed undercover or covered with a roof or canopy.
- Hydraulic fluid leaks are fairly common occurrences with trash compactors, so place a spill kit in close proximity to the compactor in case the line leaks or ruptures.
- Where feasible, UCO containers should be located and positioned to prevent vandalism, unauthorized use, and vehicle impact. Examples include storage within a building, within a locked and fenced waste storage area, or behind bollards or other physical barriers.
- Transfer UCO between kitchens and UCO collection containers in small transfer containers of less than 3 gallons. Anything larger may be too heavy to lift to chest height. Leave several inches of room within the transfer container and use a lid while transporting the oil from the kitchen to the UCO collection container.
- Schedule appropriate recurrent UCO pick-ups to ensure containers are not overfilled.
- Individuals and businesses should contact their waste hauler immediately if the container delivered/replaced is unsuitable (e.g. if a lid is missing or malfunctioning, or if the container is damaged) and arrange for a replacement.
- If there is adequate space, consider storing used cooking oil inside with an external port/valve that used oil haulers may connect to. This will eliminate the need for outdoor storage of used cooking oil and reduce the potential for stormwater pollution.

Additional Information:

- SPU's Green Business Program can provide information about the best practices for managing used cooking oil. They can be reached by calling (206) 343 8505 or on the City's website (https://www.seattle.gov/utilities/protecting-our-environment/sustainability-tips/green-business-program).
- Leaking solid waste containers are considered a spill, and cleanup should be managed under BMP 5. Failure to manage and report spills that enter the drainage system, sewer system, or local waters promptly and properly may result in a Notice of Violation and penalty.
- Secondary containment can help make spills less severe, particularly when transferring UCO from small containers (e.g., generated by a restaurant) to a larger UCO container (e.g., owned and serviced by a hauler/recycler). If secondary containment is used, cover it to prevent rainwater accumulation within the secondary containment.
- Consider installing an oil/water separator (or other treatment device capable of containing a spill) ahead of any stormwater drainage features like catch basins, inlets or pipes.

2.1.5. BMP 5: Spill Prevention and Cleanup

Leaks and spills can damage public infrastructure, interfere with sewage treatment, and cause a threat to human health or the environment. Spills are often preventable if appropriate chemical and waste handling techniques are practiced effectively and the spill response plan is immediately implemented. Additional spill control requirements may be needed based on the specific activity occurring on site.

A spill can be a one-time event, a continuous leak, or frequent small spills. All types must be addressed. Spills resulting from vandalism or inadequate waste management are the responsibility of the waste owner.

Businesses and real properties that load, unload, store, and manage liquids or other erodible materials must implement this BMP.

2.1.5.1. Spill Prevention

Implement the following practices and provide spill cleanup kits (*Section 2.1.5.3*) at activity locations where spills may occur:

- Clearly label, with content descriptions, all containers that contain potential pollutants.
- Store and transport liquid materials in appropriate containers with tight-fitting lids.
- Place drip pans underneath all containers, fittings, valves, and where materials are likely to spill or leak. Check drip pans periodically to prevent overflow, especially during rain events.
- Use tarpaulins, ground cloths, or drip pans in areas where materials are mixed, carried, and applied to capture any spilled materials.
- Train employees on the safe methods for handling the materials used onsite and to check for leaks and spills.

2.1.5.2. Spill Plan

- Develop and implement a spill plan and update it annually or whenever there is a change in activities or staff responsible for spill cleanup.
- Post a written summary of the plan at areas with a high potential for spills, such as loading docks, outside of product storage areas, outside of waste storage areas, and near a phone (Figure 3). The spill plan may need to be posted at multiple locations at the same facility.
- The spill plan must:
    - describe the facility, including the owner's name, address, and telephone number; the nature of the facility activity; and the general types of chemicals used at the facility.
    - provide a site plan showing the locations of storage areas for chemicals, inlets and catch basins, surface drainage flow directions, spill kits, and other relevant infrastructure or materials information.
    - describe the emergency cleanup and disposal procedures.

- list the names and telephone numbers of public agencies to contact in the event of a spill. Refer to *Section 2.1.5.4* for more information.

- For high-risk activities, designate spill response employees to be on the site during business activities. Provide a current list of the names and telephone numbers (office and home) of designated spill response employee(s) who are responsible for implementing the spill plan.

Figure 3. Waste Storage Area with Spill Kit and Posted Spill Plan.

2.1.5.3. Spill Kit or Spill Cleanup Kit

Store spill cleanup kits near areas with a high potential for spills so they are easily accessible in the event of a spill. The contents of the spill kit must be appropriate to the types and quantities of materials stored or otherwise used at the facility and refilled when the materials are used.

Spill kits must be located within 25 feet of all fueling/fuel transfer areas, including onboard mobile fuel trucks.

A spill kit, contained in a watertight container, may include the following items:

- Absorbent pads
- Sorbent booms or socks

- Absorbent granular material (such as kitty litter)
- Protective clothing (such as latex gloves and safety goggles)
- Thick plastic garbage bags
- Drain cover
- Drain lid removal tool (e.g., metal hook)
- Shovel
- Broom

2.1.5.4. Spill Cleanup and Proper Disposal of Material

In the event of a spill, implement the following procedures:

- Stop, contain, and clean up all spills immediately upon discovery.
- Start the spill plan immediately.
- Contact the designated spill response employee(s).
- Block off and seal nearby inlets and catch basins to prevent materials from entering the drainage system or combined sewer.
- At the earliest possible time, but always within 24 hours, **report all spills, discharges, or releases that have impacted or could impact a drainage system, a combined sewer, a sanitary sewer, or a receiving water to the SPU Operations Response Center at (206) 386-1800.** This reporting requirement *is in addition to*, and not instead of, any other reporting requirements under federal, state, or local laws. Spill reporting should take priority over the collection of supporting information.
  - **In case of emergency, dial 911.**
  - Other agencies you may need to report to include:
    - Seattle Fire Department (206) 386-1400
    - Ecology (206) 594-0000
    - National Response Center (800) 424-8802.
- Use an appropriate material to clean up spills. Do not use emulsifiers or dispersants such as liquid detergents or degreasers, unless they are cleaned up afterward, because those chemicals themselves cannot enter the stormwater drainage system or a receiving waterbody.
- Do not wash absorbent materials into interior floor drains or inlets and catch basins. Pick up all absorbent materials for proper disposal after application. Spill cleanup is incomplete until all absorbent materials have been recovered.
- Dispose of used spill control materials in accordance with the Seattle Solid Waste Collection Code (SMC, Chapter 21.36), Dangerous Waste Regulations (WAC, Chapter 173-303), and applicable laws.

The SPU Green Business Program is a free conservation program funded by SPU. The program offers free technical assistance, free spill kits, and assistance with developing a spill plan. SPU can be found on the City's website (https://www.seattle.gov/utilities/protecting-our-environment/sustainability-tips/green-business-program) or reached by phone at 206-343-8505.

2.1.5.5. Discharges Associated with Firefighting Activities

- Discharges from emergency firefighting activities to the public drainage system are considered permissible discharges (SMC 22.802.030.B.11); however, those discharges must be reported to Seattle Public Utilities at (206) 386-1800 immediately after the emergency has ceased. Emergency responders are responsible for determining when an emergency has ceased.
    - Individuals and entities must implement procedures to minimize discharges to the public drainage system or receiving waters during post-emergency cleanup and disposal activities. Examples of procedures, among others, may include timely cleanup actions especially during wet weather, covering nearby catch basins in close proximity to the cleanup effort, plugging catch basin outlets, employing vactor services to remove foam and debris from drainage structures and roadway surfaces, and installing a containment berm around debris to prevent migration.
- Discharges of firefighting materials (foam, liquids, other types) to drainage system structures (e.g., catch basins, inlets, pipes, ditches) during training activities and equipment testing, or discharges released accidentally or as part of any non-emergency situation are not permissible discharges; these discharges must be prevented from entering drainage structures. All firefighting materials that impact, or have a likelihood of impacting, drainage system structures under non-emergency circumstances must be collected and properly disposed of or directed to the sanitary sewer, and reported to Seattle Public Utilities at (206) 386-1800 immediately but no later than within 24 hours of the release.
- Public and private entities that store and/or use PFAS-containing aqueous film-forming foam (AFFF) in areas that do, or that could, discharge to the public drainage system or receiving waters:
    - must notify Seattle Public Utilities in accordance with the Seattle Stormwater Code.
    - must report PFAS-containing AFFF use (emergency or non-emergency situations) to Seattle Public Utilities at (206) 386-1800 no later than 24 hours after use.

2.1.6. BMP 6: Provide Oversight and Training for Staff

The key to sustaining pollution prevention (Source Control) BMPs is to ensure that staff are properly trained in their purpose and maintenance requirements. Assign pollution prevention as a job responsibility for staff.

Some businesses or facilities require only a single employee who will implement and maintain strong pollution prevention best management practices while other businesses or facilities will need a team to manage this task. It is important that every involved employee feels confident in performing their part, and this requires proper training.

For all businesses and public entities, required elements of this BMP include:

- Assign an employee to oversee implementation and management of stormwater source control BMPs.
- Train all team members annually in their job-appropriate and expected level of contribution to the operation, maintenance, and inspection of stormwater protection BMPs. Keep training records for a minimum of 5 years and make them available to Seattle Public Utilities on request.
- Train all spill prevention and cleanup team members annually in how to safely implement the spill plan and other topics, including:
  - Identifying the Pollution Prevention team members and team leader
  - Identifying pollutant sources
  - Understanding the pollutant control measures
  - Implementing material handling practices, such as those related to vehicle and equipment liquids.
- When commercial, industrial, institutional, and multi-family/unit buildings[1] built or renovated between 1950 and 1980 are suspected or confirmed to contain PCBs on their exterior in a manner consistent with *Ecology's How to Find and Address PCBs in Building Materials (Ecology, 2024, Publication No. 22-04-024),* the building owner must ensure that facility maintenance staff are notified of the likely or actual presence of PCB-containing materials and any operational BMPs to prevent PCBs from entering the stormwater system.

The SPU Green Business Program is a free conservation program funded by SPU. The program offers free technical assistance and can assist with employee training. They can be -found on the City's website (https://www.seattle.gov/utilities/protecting-our-environment/sustainability-tips/green-business-program) or reached by phone at 206-343-8505.

[1] For the purposes of this Volume, multi-family/unit residential buildings could include, but are not limited to, apartment complexes, condos, hotels, motels. These may have been built using PCB-containing materials because they're designed for longevity and often are built using types of structures known to be associated with PCB-containing caulk, sealants, and other materials (like concrete panel-style exteriors).

2.1.7. BMP 7: Property Maintenance

Preventive maintenance and good housekeeping practices reduce the potential for stormwater to come into contact with pollutants and can reduce maintenance intervals for the drainage system and sewer system.

Public and commercial parking lots, such as those used for retail stores, fleet vehicles (including rent-a-car lots and car dealerships), and equipment sale and rental businesses; paved equipment storage yards; parking lot driveways; and restaurant drive-throughs can be sources of pollution. Potential pollutants can include, but are not limited to, hydrocarbons and other organic compounds, including oils and greases, metals, and suspended solids.

Parking lots are *not* considered streets; see BMP 54 for streets and highways. For cleaning or washing maintenance of buildings, see BMP 17. For maintenance of roof and building drains at industrial and commercial buildings, see BMP 37.

Property maintenance begins with periodic inspections. Take time to walk the property and note signs of possible pollution: stains under equipment; ponding stormwater around drains; excessive surface dirt, leaves, or trash; equipment not stored properly; full spill containment devices; unusual odors; missing spill kits; full or overflowing trash containers; or oil sheens when it rains. Follow up your inspections with spill clean-up (see BMP 5) and/or employee training (BMP 6) to re-establish good housekeeping practices.

For all businesses and public entities, required elements of this BMP include:

- Prevent the discharge of unpermitted liquid or solid wastes, process wastewater, and sewage to groundwater or surface water, to storm drains that discharge to surface water, or to the ground.
- Perform pollution-generating activities away from stormwater pathways, such as inlets and catch basins, conveyance pipes, and ditches. Work under cover or use drop cloths or plastic sheeting to make cleanup quicker. Clean these areas after the activity is completed or before the next rain event.
- Sweep or vacuum paved areas used for loading and unloading of materials, outdoor production and manufacturing, driveways, parking lots, sidewalks, and storage areas quarterly, or more frequently as needed, to remove debris that could contaminate stormwater. Mechanical or hand sweeping may be necessary for areas that a vacuum sweeper cannot reach.
- Do not hose down or otherwise transport pollutants from any area to the ground, drainage system, combined sewer, or receiving water except where permissible per SMC, Section 22.802.030.
    - Discharges of street and sidewalk washwater may be permitted when surfaces are swept prior to washing, detergents are not used, and water use is minimized. See BMP 17 for more information.
- Promptly contain and clean up solid and liquid leaks and spills (refer to BMP 5 for specific information on spill prevention and cleanup).

- Inspect areas used for loading and unloading, material and waste storage, and vehicle parking as needed to prevent pollutant transport off site or to the drainage system.
    - Take immediate action to correct the problem(s) noted in the inspection.
    - Check your spill supplies when you inspect your property. Make sure spill kits are kept stocked and are undamaged. See BMP 5.
    - Inspect and clean areas around waste storage or fence lines. Keeping your property tidy can help prevent others from dumping their waste on your property.
    - Look for equipment or containers out of place, uncovered, or leaking. Keep pollution-generating parts or containers properly stored under cover and off the ground. Empty containers should be disposed of and containers of liquids in use should be secured or placed into spill containment.
- Place drip pans, absorbent pads, or other containment vessels below leaking vehicles and equipment (including inoperable vehicles and equipment) in a manner that catches leaks or spills. Drip pans or other containment measures must be managed to prevent overfilling and the contents disposed of properly. Absorbent pads must be weighted down so they do not blow away and must be inspected, changed out, and disposed of properly before becoming fully saturated.
- Where exposed to stormwater, use containers, piping, tubing, pumps, fittings, and valves that are appropriate for their intended use and for the contained liquid.
- For properties other than those that drain only to the combined sewer, an oil removal system, such as an American Petroleum Institute (API) oil/water separator, coalescing plate oil/water separator, catch basin filter sock, or equivalent BMP that is approved by SPU, is required for parking lots that meet the threshold for vehicle traffic intensity of a "high-use site." Refer to SMC, Section 22.801.090 for the definition of "high-use site."

Recommended BMPs:

- Spot clean outdoor surfaces like parking lots and other areas with stains prior to, or instead of, washing to minimize the area washed and amount of washwater generated.
- Minimize use of toxic cleaning solvents, such as chlorinated solvents, and other toxic chemicals.
- Use environmentally safe raw materials, products, additives, etc., such as substitutes for zinc used in rubber production.
- Stencil warning signs at catch basins and drains; e.g., "Dump no waste—Drains to stream." See BMP 46.
- Use solid absorbents; e.g., clay and peat absorbents and rags for cleanup of liquid spills and leaks, where practical.
- Promptly repair, replace, or reseal damaged paved areas at industrial facilities.
- Recycle materials, such as oils, solvents, and wood waste, to the maximum extent practical.
- Encourage employees to repair leaking personal vehicles.
- When watering landscaped areas and lawn, practice Natural Yard/Lawn Care methods such as watering lawn deeply, infrequently, and when it's cool. This can help minimize

water use and reduce irrigation runoff to the drainage system and downstream waterbodies. Simple tips and guidance can be found at the following City-supported websites:

- https://www.seattle.gov/utilities/protecting-our-environment/sustainability-tips/landscaping/for-residents/smart-watering
- https://www.seattle.gov/utilities/protecting-our-environment/sustainability-tips/pollution-prevention/yard-care
- https://www.savingwater.org/lawn-garden/

Additional Information:

Evidence of stormwater pollution can include the presence of visible sheen, color, or turbidity (cloudiness) in the runoff, or current or historical operational problems at the facility. Operators can use simple pH tests, such as litmus or pH paper to screen for high or low pH levels (anything outside the 6.5 to 8.5 range) which can be an indicator of stormwater pollution.

2.1.8. BMP 8: Constructed Dog Runs

Dog runs are increasingly being constructed as an amenity at residential and commercial properties.

- **Rooftop and above-grade plaza-level dog runs** on residential or commercial buildings are typically constructed with artificial turf and often have automatic sprinklers to wash and disinfect the area.
- **At-grade dog runs** can include a variety of ground covers, such as natural or artificial turf, pavement, gravel, or a layer of wood chips.

While dog runs are a pet-friendly amenity valued by pet owners, the accumulated pet waste must be properly managed.

Pet waste that washes into lakes, streams, or Puget Sound begins to decay, depleting oxygen and releasing ammonia. Low oxygen concentrations and ammonia combined with warm water can kill fish. Pet waste also contains nutrients that encourage the growth of weeds and algae and contribute to low oxygen concentrations and high pH in waters we use for swimming, boating, and fishing. Most importantly, pet waste can carry viruses and bacteria that could cause disease and lead to beach closures or shellfish harvesting bans.

For commercial pet facilities and businesses (e.g., doggy daycares), see BMP 32.

The following required elements of this BMP apply to all **dog runs on rooftops and above-grade plazas:**

- Prevent stormwater discharge from the dog run from flowing directly or indirectly to a public drainage system, private drainage system, drainage/flow control facility, groundwater, or receiving water body.
- Drainage from rooftop and above-grade plaza-level dog runs, including overflow drainage, must be plumbed to the building's sanitary sewer.
- No more than 200 square feet of uncovered dog run area may discharge to the sanitary sewer. This is to prevent excess stormwater from entering the public sanitary sewer system. The portion of a dog run area draining to sanitary sewer that is greater than 200 square feet must be covered. The cover must be a roof or canopy that prevents stormwater from coming in contact with the dog run area and directs uncontaminated stormwater runoff to the building's drainage system per the requirements of the Seattle Plumbing Code.
    - In combined sewer areas, dog runs greater than 200 square feet do not require a cover, but all drainage from dog run areas on building rooftops and above-grade plazas must be directed to the building's sanitary sewer system. However, this contaminated stormwater runoff must not be connected to a combined side sewer *until downstream of the entire building drainage system*, including all drainage collection and control facilities such as detention vaults. (Note: If the dog run is part of a construction project that requires flow control (refer to Volume 1), the uncovered dog run area must be modeled as an uncontrolled bypass area that connects to the point of compliance and the flow control BMPs must be oversized to account for this bypass area.)

The following required elements of this BMP apply to **dog runs at-grade (at ground level):**

- Prevent stormwater runoff from the dog run from discharging to a public drainage system, private drainage system, drainage control facility, groundwater, or receiving water.
- Runoff over hard surfaces at-grade must evenly disperse across a minimum of 10 feet of vegetated area prior to discharging to a drainage system. If this is not feasible, the area must discharge to the sanitary sewer.
- No more than 200 square feet of uncovered dog run area may discharge to the sanitary sewer. The 200 square-foot limit does not apply in combined sewer service areas.
- Washing the area with water is not allowed unless the area discharges to the sanitary sewer or the runoff will evenly disperse across a minimum of 10 feet of vegetated area.
- Washing the area with disinfectant is not allowed unless the area discharges to the sanitary sewer. Disinfectants must not be allowed to enter drainage systems, groundwater, or receiving waters, even if disinfection is a Public Health agency operational requirement.
- Additional requirements for commercial pet facilities (e.g., doggy daycares), are in BMP 32.

2.2. Required Best Management Practices for Specific Activities

For business and public entities with specific pollution-generating activities, the following BMPs must be implemented to prevent or minimize pollutants from leaving a site or property, regardless of whether the discharge flows to the stormwater drainage system, combined sewer system, or directly into receiving waters:

- BMP 9: Fueling at Dedicated Stations
- BMP 10: Mobile Fueling of Vehicles and Heavy Equipment
- BMP 11: In-water and Over-water Fueling
- BMP 12: Maintenance and Repair of Vehicles and Equipment
- BMP 13: Concrete and Asphalt Mixing and Production
- BMP 14: Concrete Pouring, Concrete/Asphalt Cutting, and Asphalt Application
- BMP 15: Recycling, Wrecking Yard, and Scrapyard Operations
- BMP 16: Storage of Liquids in Aboveground Tanks

Stormwater Code Language	References
SMC, Section 22.803.040: *For all discharges, source controls shall be implemented, to extent allowed by law, by businesses and public entities for the following specific pollution-generating activities as specified in the joint SPU/SDCI Directors' Rule titled "Seattle Stormwater Manual" at "Volume 4 – Source Control," to the extent necessary to prevent prohibited discharges as described in Section22.802.020, and to prevent contaminants from coming in contact with drainage water or being discharged to the drainage system, public combined sewer, or directly into receiving waters:* *1. Fueling at dedicated stations, for new or substantially altered fueling stations.* *2. Mobile fueling of vehicles and heavy equipment.* *3. In-water and over-water fueling.* *4. Maintenance and repair of vehicles and equipment.* *5. Concrete and asphalt mixing and production.* *6. Concrete pouring, concrete/asphalt cutting, and asphalt application.* *7. Recycling, wrecking yard, and scrapyard operations.* *8. Storage of liquids in aboveground tanks.*	• None provided

2.2.1. BMP 9: Fueling at Dedicated Stations

This BMP applies to businesses and public entities that operate a facility used exclusively for the transfer of fuels from a stationary pumping station to vehicles or equipment. This type of fueling station includes aboveground or underground fuel storage facilities, which may be permanent or temporary. Fueling stations include facilities such as, but not limited to, commercial gasoline stations, 24-hour convenience stores, car washes, warehouses, manufacturing establishments, maintenance yards, port facilities, marinas and boatyards, construction sites, and fleet fueling stations.

Description of Pollutants

Typically, stormwater contamination at fueling stations is caused by leaks or spills of fuels, lubrication oils, radiator coolants, fuel additives, and vehicle washwater. These materials contain organic compounds, oils and greases, and metals that can be harmful to humans and aquatic life. These pollutants must not be discharged to the drainage system or directly into receiving waters.

A spill can be a one-time event, a continuous leak, or frequent small spills. All types must be addressed.

Required BMP Elements

All BMPs related to fueling at dedicated stations must be consistent with the requirements of the Seattle Fire Code (SMC, Chapter 22.600). The water quality requirements presented in this manual are separate from, and in addition to, the requirements of the Seattle Fire Code. These water quality requirements relate to fuel storage tanks, fuel dispensing equipment, area lighting, spill control and secondary containment, signage, maintenance, and operations. For current requirements, refer to the Seattle Fire Code.

New or substantially altered stations* require the following (refer to Figure 4):

*Substantial alteration of fueling stations includes removing or replacing the canopy or relocating, replacing, or adding one or more fuel dispensers in such a way that the portland cement concrete (or equivalent) paving in the fueling area is modified. Addition of fuel tanks to a site also triggers implementation of source control BMPs.

- Construct fueling stations on an impervious concrete pad under a roof to keep out rainfall and to prevent stormwater run-on. Pave the fueling island and containment pad with portland cement concrete or equivalent. Asphalt is not considered an equivalent material.
- Design the fueling island (Figure 5) to minimize stormwater contamination, to control and contain spills, and to collect and direct contaminated stormwater or wastewater to an oil/water separator. The oil/water separator must be sized to provide fuel containment in case of spills, as described below, as well as to provide oil control treatment. The fueling island must be designed in compliance with all applicable codes.

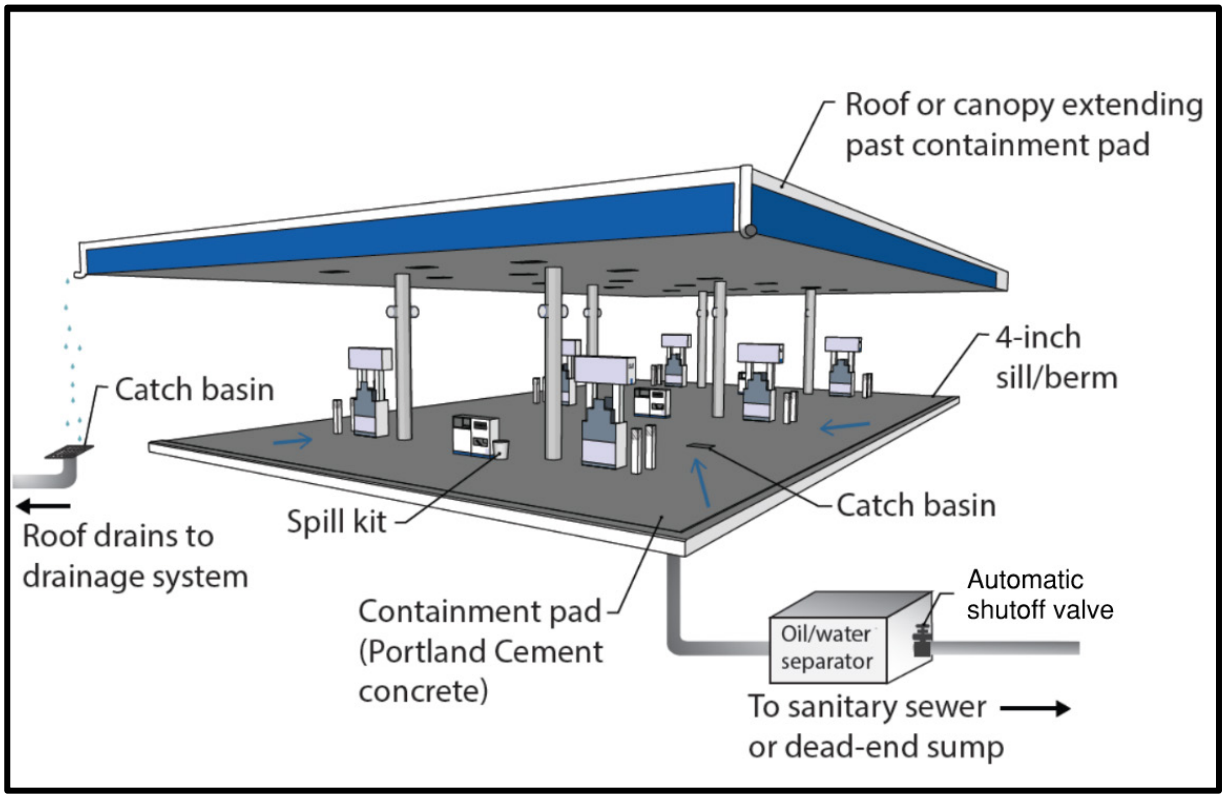

Figure 4. Fueling Island Schematic.

Figure 5. Roof at Fueling Island to Prevent Contact with Rain.

- The fueling island spill containment pad must be designed with the following:
  - A sill or berm (or equivalent control) raised to a minimum of 4 inches to contain spilled liquids and to prevent the run-on of stormwater from the surrounding area. Raised sills are not required at open-grate trenches that connect to an approved drainage control system.
  - A concrete containment pad around the fueling island that is sloped toward the fuel containment pad drains. The slope of the drains must not be less than 1 percent. Drains from the fueling island containment pad must discharge to the sanitary sewer, combined sewer, or a dead-end sump. Provide drainage using trench drains or catch basins to collect spilled liquids and any contaminated stormwater runoff from the fuel island containment pad and convey it to either (1) the sanitary sewer—if approved by SPU and King County—through an approved pretreatment system such as an oil/water separator or (2) a dead-end sump so that it can be held for proper off-site disposal.
    - For discharges to the sanitary sewer, a catch basin must be installed upstream of the oil/water separator.
    - If a dead-end sump is used, it must be easily inspected.
  - Collected runoff from the fuel island containment pad discharged to the sanitary sewer must comply with SMC, Section 21.16.300 — Prohibited discharge of certain substances. The fueling facility must comply with pretreatment regulations prohibiting discharges that could cause a fire or explosion (WAC, Section 173-216-060).
  - The minimum spill retention volume of the oil/water separator or dead-end sump (i.e., volume of spilled fuel contained before the structure overflows) must be sized as follows:
    - For a covered fuel pad: 15 minutes for the flow rate of the dispensing mechanism with the highest through-put rate, with a minimum of 50 gallons.
    - For an uncovered area or an area that receives run-on from an uncovered area: size the oil/water separator for the online water quality flowrate per the requirements in Volume 3, Section 5.8.10 for the contributary area, then check to ensure that the fuel spill retention volume required for a covered fuel pad will be met in the case of a spill. Note: when establishing the size based on the water quality flowrate, account for the head loss through the oil stop valve per the recommendations of the oil stop valve manufacturer.

    The spill retention and containment volume of the oil/water separator must retain the required spill volume when the oil/water separator is full of water. Dead-end sumps must not be used when the fuel containment area is uncovered or will receive run-on from other areas, unless approved by the Director of SPU.

    Note: To calculate the fuel spill retention capacity, first determine the retained water volume in the bottom of the oil/water separator bottom below the elevation at which the oil stop valve closes in contact with fuel. The spill retention volume is equal to the total volume of the oil/water separator less the retained water volume at the bottom and less the freeboard volume at the top (see Figure 6).

  - For further requirements and guidance related to the storage of fuel-contaminated stormwater, refer to BMP 16.

- For discharges to the sanitary sewer or combined sewer, an automatic shutoff valve is required at the discharge point of the oil/water separator. The shutoff valve at the discharge point must automatically close when a spill occurs. When an oil-stop valve or resin plug valve is used, it must be engineered to be at least as protective as an automatic shutoff valve.
  - An overflow riser is not allowed in an oil/water separator, vaults, etc. with an oil-stop valve or other shutoff valve. No fuel may discharge from the structure.
- Construct a roof or canopy over the fueling island to prevent rain/snow from falling directly onto the spill containment pad (Figure 5). Removing a canopy without replacement is prohibited. The roof or canopy must:
  - At a minimum, cover the spill containment pad (within the grade break or fuel dispensing area) and preferably extend several additional feet to reduce the introduction of windblown rain.
  - Roofs and canopies 10 feet high or less must have an overhang of at least 3 feet on each side. The overhang must be measured relative to the berm or other hydraulic grade break.
  - Roofs or canopies greater than 10 feet high must have an overhang of at least 5 feet on each side.
- Convey runoff collected in roof or canopy drains to a drainage system or receiving water outside the fueling containment area. This will prevent the mixing of uncontaminated runoff from the roof with contaminated runoff from the fueling island.
- A roof or canopy may not be practical at fueling stations that regularly fuel vehicles 10 feet high or more, particularly at industrial or transportation sites. Additional BMPs or equivalent measures are required. At these types of fueling facilities, the following BMPs apply as well as all other required BMPs and fire prevention requirements (Seattle Fire Code and Uniform Fire Code):
  - The concrete fueling pad must be equipped with an emergency spill control device that includes a shutoff valve for drainage from the fueling area.
  - The shutoff valve must be maintained in the closed position in the event of a spill and its associated cleanup. An automatic shutoff valve is required to minimize the time lapse between spill and containment.
- Obtain all necessary permits for installing, altering, or repairing side sewers. Restrictions on certain types of discharges may require pretreatment before they enter the sanitary sewer.

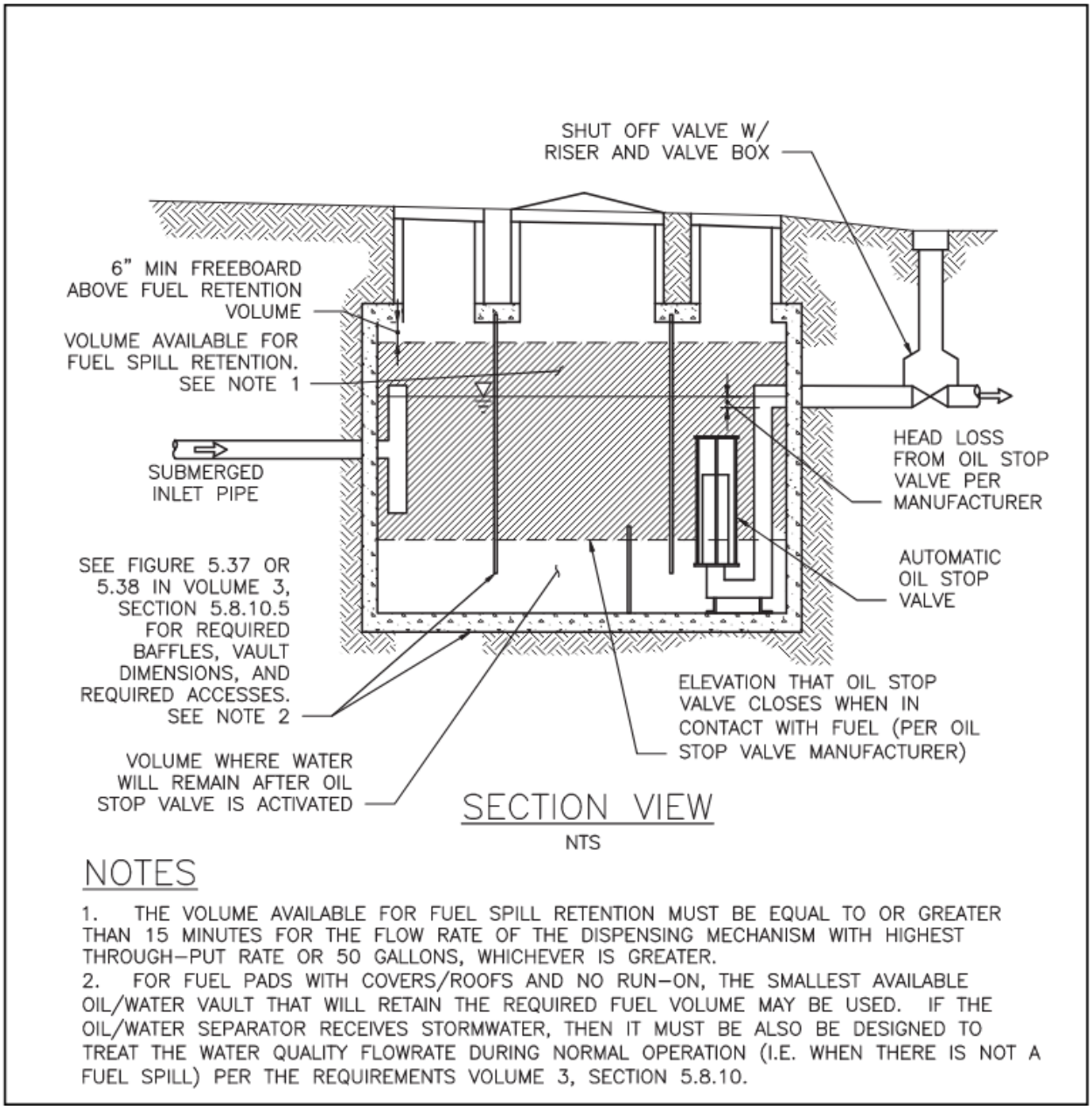

Figure 6. Oil/Water Separator with Oil Stop Valve for Spill Containment.

The following BMPs or equivalent measures are required for all fueling stations:

- Implement BMP 1 through BMP 8 for all real property (refer to *Section 2.1*).
- Train employees on the proper use of fuel dispensers and on the spill plan (required under BMP 5).
- Do not use dispersants to clean up spills or sheens unless they are cleaned up afterward. Dispersant use is prohibited for spills on water or where the dispersant may enter storm drains, sanitary sewers, treatment systems, or receiving waters.

- Post signs about the operation of fuel dispensers in accordance with the Seattle Fire Code. For example, post "No Topping Off" signs near fuel dispensers (topping off gasoline tanks results in spillage and vents gasoline fumes to the air).
- Ensure that the person conducting the fuel transfer is present at the fuel dispenser/pump during fuel transfer, particularly at unattended or self-service stations. Post "Stay with Vehicle during Fueling" signage near fuel dispensers.
- Ensure that the automatic shutoff on the fuel nozzle is functioning properly.
- Ensure that at least one designated trained person is always available either on site or on call to promptly and properly implement spill prevention and cleanup. If the fueling station is unattended by a trained person during operating hours, the spill plan must be visible to all customers and untrained employees using the station, and the spill kit must also be accessible and always stocked.
- Keep suitable cleanup materials, such as dry absorbent materials, on site to enable employees to promptly clean up spills. Have proper waste accumulation containers, with a tight-fitting lid, to store used/spent absorbents until they can be properly disposed of.
- Transfer the fuel from the delivery tank trucks to the fuel storage tank in impervious contained areas and ensure that appropriate overflow protection is used. Cover nearby inlets and catch basins during the filling process and use drip pans under all hose connections.
- Immediately remove and properly dispose of fuel-contaminated soils with visible surface contamination to prevent the spread of chemicals to groundwater or receiving waters via stormwater runoff.
- Immediately notify the Seattle Fire Department (911), the Ecology Northwest Regional Office (206) 594-0000, and SPU (206) 386-1800 in the event of a fuel spill.
    - Establish a "call down list" to ensure the rapid and proper notification of management and government officials if any significant amount of product is discharged from the site. Keep the list in a protected but readily accessible location in the mobile fueling truck.
    - The "call down list" should also identify spill response contractors available in the area to ensure the rapid removal of significant product spills into the environment. Include this bullet item in the fuel operation plan.

2.2.2. BMP 10: Mobile Fueling of Vehicles and Heavy Equipment

This BMP applies to businesses and public entities that fill fuel tanks of vehicles and equipment by means of portable fuel-dispensing systems delivered to where the vehicles to be fueled are located (also known as mobile fueling, fleet fueling, wet fueling, or wet hosing).

Description of Pollutants

Typically, stormwater contamination at mobile fueling locations is caused by leaks or spills of fuels and vehicle fluids. These materials contain organic compounds, oils and greases, and metals that can be harmful to humans and to the aquatic environment. These pollutants must not be discharged to the drainage system, sanitary sewer or combined sewer systems, pervious ground, or directly into receiving waters.

Required BMP Elements

The following BMPs or equivalent measures are required of all businesses (organizations or individuals) and public entities that conduct mobile fueling of vehicles and heavy equipment:

- Implement BMP 1 through BMP 8 for all real property (refer to *Section 2.1*).
- Mobile fueling operations must be permitted by the Seattle Fire Department (SFD). The fuel delivery company as well as the site of activity is required to have an SFD permit for mobile fueling.
- In fueling locations near sensitive aquifers, designated wetlands, wetland buffers, or other receiving water, compliance with additional local requirements may be required.
- Train the driver or operator annually in spill prevention and cleanup. Make all delivery employees aware of the significant liability associated with fuel spills. New employees must be trained upon hiring. Document and retain all training records.
- Develop and follow a written fuel operation plan that is:
    - properly signed and dated by the responsible fuel delivery manager.
    - retained at headquarters and given to all delivery operators along with the spill plan.
    - made available when an authorized government agency requests a review.
- Ensure that the driver or operator is present and constantly observing and monitoring the fuel transfer location during fuel transfer. Carry out the following procedures at fuel transfer locations:
    - To the extent practical, locate the point of fueling at least 25 feet from the nearest inlet or catch basin, or inside an impervious containment area with a volume equal to or greater than 110 percent of the fueling tank volume, or cover the inlet or catch basin with an impervious material to ensure there is no inflow of spilled or leaked fuel. Before removing the drain cover, check for sheen. Do not remove the drain cover if sheen or product is present, until the sheen/product is cleaned up and the contaminated materials are properly disposed of.
    - Place a drip pan or absorbent materials under each fueling connection before and during all dispensing operations. The pan must be watertight and must have a

minimum capacity of 5 gallons. There is no need to report spills retained in the drip pan.

- Handle and operate fuel transfer hoses and nozzles, drip pan(s), and absorbent pads to prevent fuel spills and leaks from reaching the ground, receiving waters, and inlets and catch basins.
- Avoid extending the fueling hoses across a traffic lane without a cone barrier and do not allow vehicles to drive over fuel hoses.
- Remove the fill nozzle and cease filling the tank when the automatic shut-off valve engages. Do not lock automatic shutoff fueling nozzles in the open position.
- Do not "top off" fuel tanks.

- Use automatic shutoff nozzles for dispensing the fuel. Replace automatic shutoff nozzles as recommended by the manufacturer.
- Inspect, maintain, and replace equipment on fueling vehicles, particularly hoses and nozzles, at established intervals to prevent failures. Document and keep all inspection records on file.
- Use an adequate lighting system at the filling point so that the driver or operator of the fueling vehicle can properly observe the transfer.
- At a minimum, maintain the following spill cleanup materials in a readily accessible location in all fueling vehicles:
  - Non-water-absorbent materials capable of absorbing 15 gallons of diesel fuel.
  - An inlet or catch basin plug or cover.
  - A non-water-absorbent containment boom at least 10 feet long with a 12-gallon absorbent capacity.
  - A non-spark-generating shovel.
  - Adequate means to hold spent absorbents generated by a 15-gallon spill for disposal.
- Immediately remove and properly dispose of fuel-contaminated soils with visible surface contamination to prevent the spread of chemicals to groundwater or receiving waters via stormwater runoff.
- Immediately notify the Seattle Fire Department (911), the Ecology Northwest Regional Office (206) 594-0000, and SPU (206) 386-1800 in the event of a fuel spill.
  - Establish a "call down list" to ensure the rapid and proper notification of management and government officials if any significant amount of product is discharged from the site. Keep the list in a protected but readily accessible location in the mobile fueling truck.
  - The "call down list" should also identify spill response contractors available in the area to ensure the rapid removal of significant product spills into the environment. Include this bullet item in the fuel operation plan.
- Do not use dispersants to clean up spills or sheens unless they are cleaned up promptly afterward. Dispersant use is prohibited for spills on water or where the dispersant may enter storm drains, sanitary sewers, treatment systems, or receiving waters.

2.2.3. BMP 11: In-Water and Over-Water Fueling

This BMP applies to businesses and public entities that operate a facility used for the transfer of fuels from a stationary station to vehicles or equipment in water. This type of fueling station includes aboveground or underground fuel storage facilities, which may be permanent or temporary. Fueling stations include facilities such as, but not limited to, commercial gasoline stations, port facilities, marinas, private fleet fueling stations, and boatyards.

Spills from water and over-water fueling are reportable to federal and state agencies—immediately report a spill of fuel or oil to water to the National Response Center at 1-800-424-8802 and the Washington Emergency Management Division at 1-800-258-5990.

See Ecology's spill reporting web page for more information: https://ecology.wa.gov/footer-pages/report-an-environmental-issue/report-a-spill

Description of Pollutants

In-water and over-water fueling can result in leaks or spills of fuels and associated petroleum products that can be harmful to humans and aquatic life.

Required BMP Elements

Required BMP elements are contained in *S439 — BMPs In-Water and Over-Water Fueling* in Volume IV of the SWMMWW (Ecology 2024).

2.2.4. BMP 12: Maintenance and Repair of Vehicles and Equipment

This BMP applies to businesses and public entities on whose premises oil, fuel, engine oil, and other fluids, such as battery acid, coolants, and transmission and brake fluids, are removed and replaced in vehicles and equipment. It also applies to mobile vehicle maintenance operations.

Description of Pollutants

Pollutants of concern are total petroleum hydrocarbons, toxic organic compounds, oils and greases, oxygen demanding substances (e.g., antifreeze), sediments, high acidity or alkalinity, and metals. These pollutants must not be discharged to the stormwater drainage system, sanitary or combined sewer systems, or directly to receiving waters.

Required BMP Elements

The following BMPs or equivalent measures are required of all businesses and public entities engaged in vehicle and equipment repair and maintenance activities:

- Implement BMP 1 through BMP 8 for all real property (refer to *Section 2.1*).
- The business conducting repair or maintenance is responsible for the condition of all customer vehicles in their care. Spills from customer vehicles awaiting service are the responsibility of the business whether parked on private or public property.
- Inspect all incoming vehicles and equipment for leaks and spills. Clean up all leaks and spills as they occur. Contain leaks with drip pans or other spill capture equipment. Drain all fluids that have the potential to leak from wrecked vehicles and from damaged equipment, into a leak-free container, when they arrive. Empty oil and fuel filters before disposal. Store and dispose of, or recycle, fluids properly.

A spill can be a one-time event, a continuous leak, or frequent small spills. All types must be addressed as prescribed in BMP 5 (Spill Prevention and Cleanup).

- Maintenance and repair activities must be conducted inside a building or other covered impervious containment area that is sloped to prevent rain, stormwater runoff (contaminated or not), or spilled materials from entering the work area. If an emergency requires immediate repair outside the building or covered containment area, spill containment equipment (e.g., spill containment pool) must be used under the vehicle or equipment needing repair, in order to contain automotive fluids and chemicals.
- Cover, contain, and mark containers of used oil, antifreeze, and other fluids. Each container must be marked with the name of the contents.
- Remove batteries and liquids from vehicles and equipment in designated areas designed to prevent stormwater contamination. Store batteries upright in a secure, contained, and covered location (not outdoors on the ground). Check to ensure batteries are not damaged or leaking. Store damaged or leaking batteries in a covered, non-leaking secondary containment system. Keep battery acid neutralizing materials, such as baking soda, available near the storage area.
- Ensure that employees are familiar with the site's spill cleanup plans and are trained in the proper handling, storage, and disposal of all fluids.

- Store and maintain appropriate spill cleanup materials in an easily accessible location.
- Make sure all outdoor materials that have the potential to leach or spill to the drainage system are covered and contained or moved to an indoor location. Indoor locations that are incapable of preventing spills from reaching outside will not be considered covered and contained.
- Inspect parking and outdoor storage areas daily for leaks and drips or inappropriately stored wastes or materials.
- Sweep paved work areas as needed. Soak up spilled vehicle fluids with rags or other absorbent material immediately. Never wash paved areas that drain to the stormwater drainage system or the street.
- Frequently inspect drains (indoors and outdoors) for evidence of spills or accumulation of pollutants. Clean these drains when pollutants are observed.
- Maintenance and repair areas cannot be washed down. Use dry methods for cleaning up, such as sweeping.
- Wastes, including but not limited to washwater, may not be discharged to the stormwater system or receiving waters except as conditionally allowed in SMC, Section 22.802.030. Do not dump or discharge vehicle fluids to storm drains; they can affect the drainage system, sanitary sewer, and receiving waters.
- Maintenance and repair shop floor drains must discharge to the sanitary sewer. Do not allow drains inside maintenance buildings to connect to the sanitary sewer without prior approval by SPU and King County.
- If extensive staining and oily sheen are present, absorbent pillows or booms must be used in and/or around catch basins and properly maintained to prevent petroleum products from entering the drainage system. If operational BMPs are insufficient to prevent and manage recurrent prohibited discharges of pollutants, then structural source control measures may be required.
- The secondary containment requirements found in *BMP 28 (Portable Container Storage)* apply to the maintenance and repair of vehicles and equipment that is conducted in any drainage area, including areas with stormwater discharge to the sanitary or combined sewer systems.

2.2.5. BMP 13: Concrete and Asphalt Mixing and Production

This BMP applies to businesses and public entities that mix raw materials on site to produce concrete or asphalt. See BMP 14 for mobile concrete pouring and asphalt applications.

Description of Pollutants

Pollutants of concern include petroleum hydrocarbons, toxic organic compounds, oils and greases, metals, and high acidity or alkalinity. Not only can concrete pouring activities severely alter the pH of stormwater runoff, but slurry from aggregate washing can harden in stormwater pipes, thereby reducing capacity that can result in flooding. These pollutants must not be discharged to the stormwater drainage system, sanitary or combined sewer, or directly into receiving waters.

Required BMP Elements

Activities associated with concrete and asphalt mixing and production may require an NPDES permit from Ecology. Refer to Ecology's website (https://ecology.wa.gov/Regulations-Permits/Permits-certifications/Stormwater-general-permits) or call Ecology at (360) 407-6000 to determine if the site activities trigger permit coverage.

The following BMPs or equivalent measures are required of all businesses and public entities engaged in activities related to concrete and asphalt mixing and production at stationary sites:

- Implement BMP 1 through BMP 8 for all real property (refer to *Section 2.1*).
- Cover production areas to protect them from contact with rain and stormwater run-on.
- Recycle all production process water or discharge it to a dead-end sump, process water treatment system and the sanitary sewer. Obtain all necessary permits for discharge to the sanitary sewer.
- Never discharge process water into streets, sidewalks, storm drains, or receiving waters.
- Separate production areas from anywhere exposed to rain or stormwater flows. Any stormwater that mixes with production areas is considered process water and cannot be discharged to streets, sidewalks, the public drainage system, or receiving waters. Obtain all necessary permits for discharge to the sanitary sewer.
- Establish a BMP maintenance schedule and train employees annually about the need to prevent stormwater contamination through regular BMP maintenance. Document and keep all maintenance training records on hand.
- Use absorbent materials or catch basin filter socks (Figure 7) in and around inlets and catch basins to help filter out solids. If catch basin filter socks are used, maintain the filters regularly (weekly or as needed) to prevent plugging. Stormwater contaminated with concrete or asphalt must not enter the stormwater drainage system.

Catch basin filter socks only remove solids and do not provide treatment for other pollutants associated with concrete and asphalt mixing and production.

- Sweep the production area, driveways, gutters, and all other outdoor areas as necessary to collect fine particles and aggregate for recycling or proper disposal.

Figure 7. Commercially Available Catch Basin Filter Sock.

- Do not wash or hose down areas that flow to the drainage system.
- Make sure all outdoor materials that have the potential to leach or spill to the drainage system are covered, contained, or moved to an indoor location.
- Collect, treat, and properly dispose of runoff that comes in contact with release agents.
- If operational controls do not prevent stormwater contamination, treatment BMPs may be necessary.

For information about water quality treatment BMPs for activities related to concrete and asphalt mixing and production at stationary sites, refer to *Volume 3 — Project Stormwater Control*. For a current list of proprietary and emerging water quality treatment technologies, refer to Ecology's website (https://ecology.wa.gov/Regulations-Permits/Guidance-technical-assistance/Stormwater-permittee-guidance-resources/Emerging-stormwater-treatment-technologies).

Recommended BMPs

Although not required, the following BMPs are recommended to further prevent and minimize the contamination of stormwater from concrete and asphalt mixing and production activities:

- Pave the mixing and production areas. A sump drain in these areas is not recommended due to potential clogging problems. Sweep these areas to remove loose aggregate and recycle or properly dispose of the aggregate.
- Use catch basin covers or similarly effective containment devices to prevent runoff from entering the drainage system.

2.2.6. BMP 14: Concrete Pouring, Concrete/Asphalt Cutting, and Asphalt Application

This BMP applies to businesses and public entities that apply asphalt or pour or cut concrete or asphalt for building construction and remodeling; road construction; repair and construction of sidewalks, curbs, and gutters; sealing of driveways and roofs; and other applications.

Description of Pollutants

Pollutants of concern include petroleum hydrocarbons, toxic organic compounds, oils and greases, metals, suspended solids, and high acidity or alkalinity. Not only can concrete pouring activities severely alter the pH of stormwater runoff, but slurry from aggregate washing can harden in stormwater pipes, thereby reducing capacity that can result in flooding. These pollutants must not be discharged to the drainage system, sanitary or combined sewers, or directly into receiving waters.

Required BMP Elements

The following BMPs or equivalent measures are required of all businesses and public entities engaged in activities related to concrete pouring and cutting and asphalt application:

- Implement BMP 1 through BMP 8 for all real property (refer to *Section 2.1*).
- Use drip pans, ground cloths, heavy cardboard, or plywood wherever concrete, asphalt, or asphalt emulsion are likely to spill, such as beneath discharge points from equipment.
- Sweep or shovel and collect loose materials, waste, and dust for recycling or proper disposal at the end of each workday or as needed, especially at work sites such as streets, driveways, parking lots, sidewalks, curbs, and gutters where rain can readily pick up the loose material. Never hose down concrete or asphalt waste materials to a public or private drainage system (including inlets, catch basins, and ditches), sanitary or combined sewer, or receiving waters.
- Place catch basin covers or similarly effective containment devices over all nearby drains at the beginning of each workday.
- Shovel or vacuum all waste slurry and remove from the site. All contaminated runoff and solids must be collected and properly disposed of at the end of each workday, or more often if necessary.
- Make sure all outdoor materials that have the potential to leach or spill are covered, contained, or moved to an indoor location.
- Use a mechanism for containment and collection of the discarded concrete slurry when performing exposed aggregate washing, where the top layer of unhardened concrete is hosed or scraped off to leave a rough finish. Dispose of the slurry properly.
- Use a catch basin filter sock to remove solid materials from inlets and catch basins (Figure 7). This is not meant as a treatment substitute for keeping pollutants out of the drain but is intended to be an emergency precaution only. Maintain the filter regularly to prevent plugging. Stormwater contaminated with concrete or asphalt must not enter the drainage system.

- Perform cleaning of concrete application and mixing equipment or concrete delivery vehicles in a designated area where the rinse water can be controlled, contained, and properly disposed of.
- Collect, treat, and properly dispose of stormwater that comes in contact with diesel or coatings used in asphalt applications, cleanup, or transportation. Once stormwater comes into contact with those materials, it becomes process water and is not allowed to enter drains or streets or other locations where it can enter the drainage system.
- Collect, treat, and properly dispose of wastes from cutting activities.

Recommended BMPs

Although not required, the following BMPs are recommended to further prevent and minimize the contamination of stormwater from concrete pouring and cutting and asphalt application at temporary sites:

- Avoid the activity when rain is falling or expected.
- If possible, portable asphalt mixing equipment should be covered by an awning, a lean-to, or other simple structure to avoid contact with rain.
- Recycle broken concrete and asphalt. Search for “Recycling Services” online to find a local recycler.

2.2.7. BMP 15: Recycling, Wrecking Yard, and Scrapyard Operations

This BMP applies to businesses and public entities that reclaim various materials for resale, salvage of parts, or for scrap, such as vehicles, parts of vehicles, equipment, construction materials, metals, beverage containers, electronic waste, and papers. Activities that can generate pollutants include the following: transfer, dismantling, and crushing of vehicles and scrap metal; transfer and removal of fluids; maintenance and cleaning of vehicles, parts, and equipment; and storage of fluids, parts for resale, solid wastes, scrap parts, materials that are contaminated or contain fluids, equipment, and vehicles that contain fluids.

Description of Pollutants

Potential sources of pollutants include paper, plastic, metal scrap debris, engines, transmissions, radiators, batteries, printing equipment, and other materials that contain fluids or are contaminated with fluids. Other pollutant sources include leachate from metal components, contaminated soil, and eroded soil.

Potential pollutants typically found at recycling and scrapyards include oils and greases, ethylene glycol, propylene glycol, suspended solids, polychlorinated biphenyls (PCBs), phthalates, substances that increase biological oxygen demand (BOD), metals (including mercury and lead), and high acidity (low pH). PCB sources can include lamp ballasts, capacitors from white goods, transformers, other electrical equipment, printing equipment (associated with the pigments and dyes), and PCB-contaminated building materials such as concrete, masonry, siding, and roofing.

Required BMP Elements

Recycling, wrecking yard, or scrapyard activities may require an NPDES permit from Ecology. Refer to Ecology's website (https://ecology.wa.gov/Water-Shorelines/Water-quality/Runoff-pollution/Stormwater) or call Ecology at (360) 407-6000 to determine- if the site activities trigger permit coverage. If the permit is required, refer to Publication 94-146, Vehicle and Metal Recyclers: A Guide for Implementing the Industrial Stormwater General National Pollutant Discharge Elimination System Permit Requirements (Ecology 2011), for the selection of BMPs.

At a minimum, the following BMPs or equivalent measures are required for activities related to recycling, wrecking yard, and scrapyard operations. Additional BMPs may be required for businesses and public entities subject to Ecology's Industrial Stormwater General Permit.

- Implement BMP 1 through BMP 8 for all real property (refer to *Section 2.1*).
- Drain all fluids upon arrival, prior to storage or disposal, into leak-proof containers.
- Inspect all items for leakage or potential leaks. Use drip pans or other spill containment equipment where necessary to prevent leaks from reaching the ground or drainage systems. Do not wash pollutants from any area to the ground or into drainage systems. Manage collected wastes to prevent stormwater contamination.
- Check incoming scrap materials, vehicles, and equipment for batteries, mercury switches, liquid tanks, containers, ballasts, capacitors, switches, or transformers. Remove these items before the incoming materials are processed, crushed, co-mingled with other materials, and dispose of them properly.

- Remove batteries and store them in a safe condition in a leakproof container and under cover.
- Make sure all outdoor materials that have the potential to leach or spill pollutants to the drainage system are covered, contained, or moved to an indoor location.
- Cover and raise above the ground surface any materials that may contaminate stormwater. A tarpaulin and pallet are acceptable.
- Keep all containers, including dumpsters and scrap collection bins, under cover or fit them with lids that must be kept closed when the container is not in use. Empty bins may have residual pollutants from previous contents and must be covered when stored outdoors.
- Areas used for processing material to be recycled or for draining or transferring fluids should be designed to prevent run-on and to contain all fluids that may be spilled or released. Use cover and containment options, such as an enclosed building or roof and berms or dikes. If there is a sump, dispose of waste properly or recycle accordingly. Prevent any run-off from the property to nearby properties or to the public right-of-way or drainage system. Maintain this containment in constant working order.
- For fluids stored in containers, the containers must be rigid, durable, resistant to corrosion due to the weather and fluid contents, watertight, and equipped with a tight-fitting lid able to retain the contents in the event of tipping. Place containers in covered impervious secondary containment areas.
- Label or mark all containers and tanks with their contents and identify the hazard they pose. Handle all dangerous and hazardous materials and waste in accordance with SPU, King County, and Ecology's requirements.
- Prevent track-out from the site onto the adjacent roadway.
- If operational BMPs are not sufficient to prevent stormwater contamination, structural controls must be implemented, including treatment or structural containment. Structural controls must be used for new or redeveloped facilities to prevent prohibited discharges to the public drainage system, the private drainage system, receiving waters (refer to SMC, Section 22.802.020), or the public sewer system (refer to SMC, Section 21.16.300).
- For facilities subject to Ecology's Industrial Stormwater General Permit, refer to *Vehicle and Metal Recyclers: A Guide for Implementing the Industrial Stormwater General National Pollutant Discharge Elimination System Permit Requirements* (Ecology 2011). Apply the Guide's BMPs to scrap material recycling facilities, depending on the pollutant sources at those facilities.
- Storage of flammable and combustible materials must comply with the appropriate fire codes.
- Develop and implement a BMP inspection log to be used daily. Keep all records on file.
- Promptly clean up any leaks, spills, or contamination.
- Sweep paved storage areas daily or more often as needed to remove accumulated dust, debris, trash, and pollutants. Inspect storage areas often and maintain good housekeeping.

- Keep spill cleanup materials in a central location. Ensure that employees are familiar with the site's spill control plan and proper spill cleanup procedures. Restock spill cleanup supplies after each use.
- PCB-contaminated materials must not be re-used. Keep this waste separate from other materials and dispose of PCB-contaminated materials, including, but not limited to, concrete, masonry, and roofing and siding, in accordance with EPA's Toxic Substances Control Act (TSCA) regulations and Washington State waste regulations. Also, see Volume 2 BMPs C1.25 and C1.30.

Recommended BMPs

- If your site discharges process water or contaminated stormwater to the sanitary sewer or combined sewer systems, contact the King County Industrial Waste Program to complete an Industrial Waste Program Survey to obtain discharge approval.

2.2.8. BMP 16: Storage of Liquids in Aboveground Tanks

This BMP applies to businesses and public entities that have on their property aboveground tanks that contain liquids (excluding uncontaminated water). These tanks may be equipped with a valved drain, vent, pump, and bottom hose connection. These include, but are not limited to, commercial aboveground heating oil tanks, gasoline and diesel tanks, food products, fertilizer, stormwater treatment, or process water. Tanks that are mobile but designed to be moved only when empty *are covered* by this BMP.

This BMP is *not required* for the following equipment: Equipment containing fuel tanks or oil reservoirs are not considered liquid storage tanks if the tanks or reservoirs are integral to the equipment function. This equipment may include backup electrical generators, transformers, hydraulic lifts, or boilers. This BMP would also not apply to liquified gases held in pressurized or cryogenic tanks. Though not considered tanks, this BMP can be used as *recommended* controls for this equipment.

For oil containment systems required for transformers that are mounted at-grade or on a pad in the Seattle City Light (SCL) distribution system, refer to SCL Construction Standard 0735.50 (https://web8.seattle.gov/city-light-engineering-standards).

Description of Pollutants

Potential sources of pollutants from leaks and spills that can occur at connections and during liquid transfer include oils and greases, organic compounds, acids, alkalis, turbidity, and dissolved metals, which can result in stormwater contamination.

Required BMP Elements

The following BMPs or equivalent measures are required for activities related to the storage of liquids in aboveground tanks:

- Implement BMP 1 through BMP 8 for all real property (refer to *Section 2.1*).
- Provide secondary containment or use a double-walled tank.
- Do not discharge contaminated stormwater that may collect within the secondary containment area to the drainage system. Evidence of contamination can include the presence of visible sheen, smell, color or turbidity in the runoff, or existing or historical operational problems at the facility. Check for acceptable pH ranges for areas subject to acid or alkaline contamination. Develop appropriate screening techniques for contaminants that easily mix with water (e.g., alcohols or ketones), such as test strips or laboratory testing.
- Implement the following maintenance activities to prevent and minimize stormwater contamination:
    - Inspect tank containment areas regularly to identify problems (e.g., cracks, corrosion, leaks, open valves, or missing plugs) with components such as fittings, pipe connections, and valves.
    - Replace or repair tanks that are leaking, corroded, or otherwise deteriorating. Document and keep all inspection records. A soundness evaluation by a Professional Engineer may be requested to confirm tank stability.

- Vacuum sweep and clean the tank storage area regularly, if paved.

- For new and redeveloped sites, locate and design tanks to prevent and minimize stormwater contamination:
  - Locate permanent tanks on an impervious (portland cement concrete or equivalent) spill containment pad. All exposed containment surfaces within the containment area must be impervious to all materials in the tanks.
  - Surround the spill containment pad with dikes or walls or provide double-walled tanks approved by the Underwriters Laboratory (UL). Design the dike to be of sufficient height to provide a containment volume of either 10 percent of the total volume of the enclosed tanks or 110 percent of the volume of the largest tank, whichever is greater. If only a single tank is present, the dike must be able to hold 110 percent of the volume of that tank.
  - Slope all covered secondary containment pads so they will drain to a dead-end sump or equivalent for the collection of small spills.
  - If the tank containment area is not covered, equip the outlet from the spill-containment sump with a shutoff valve. The valve should only be opened to convey contaminated stormwater to an approved treatment system or disposal facility, or to convey uncontaminated stormwater to the drainage system.
  - Place adequately sized drip pans beneath all mounted taps and locations where drips and spills might occur during the filling and draining of tanks.
  - Include a tank overfill protection system to decrease the risk of spillage during loading.
  - In areas with petroleum product storage tanks (e.g., petroleum tank farms), convey stormwater contaminated with floating oil or debris that has collected in the contained area to the sanitary sewer (with the sewer authority's approval) or through an American Petroleum Institute (API) oil/water separator, coalescing plate oil/water separator, or other approved treatment system with an automatic shutoff valve (or similar design) or oil stop valve, prior to discharge to the drainage system. Oil stop valves must be selected on the basis of the type of petroleum product stored in the tank(s).

CHAPTER 3 – Business and Public Entity Best Management Practices for Specific Activities

In addition to BMP 1 through BMP 8 for all real property (*Section 2.1)* and BMP 9 through BMP 16 for specific activities for all real property (*Section 2.2)*, many additional source control BMPs may be required depending on the specific activities that occur or will occur at a business or a public entity, except those that drain only to the combined sewer. Source control requirements are outlined in SMC, Section 22.803.040 (Minimum Source Controls for Specific Activities) and SMC, Section 22.805.020.I (Install Source Control BMPs).

Before reading this chapter, fill out the worksheet in *Section 1.6* to identify which site-specific activities require BMPs.

3.1. Cleaning or Washing

The cleaning or washing of vehicles, aircraft, vessels, engines, tools, cooking equipment, manufacturing equipment, and buildings are pollution-generating activities when not performed properly. When these activities occur, the resulting washwater usually contains soap or detergents, and can contain a variety of pollutants that contaminate stormwater. The specific BMPs that apply to cleaning and washing are presented in this section.

The discharge from some maintenance activities may be allowed, such as street and sidewalk washing, but only when those activities meet the specific conditions outlined in the Stormwater Code. Refer to the required provisions and conditions outlined in the Stormwater Code (SMC, Chapters 22.800 through 22.808). Refer to Chapter 23.84A of the Seattle Land Use Code for the definitions of street, sidewalk (which is part of the street), and other terms.

Remember to also implement BMP 1 through BMP 8 for all real property (refer to *Section 2.1*), and BMP 9 through BMP 16 for other specific activities (refer to *Section 2.2*).

3.1.1. BMP 17: Cleaning or Washing

This BMP applies to cleaning, washing, and rinsing activities, including but not limited to pressure washing and steam cleaning, whether it involves hand cleaning/scrubbing/sanding/washing or uses mechanically assisted tools. The purpose of cleaning and washing activities is to remove pollutants from equipment, vehicles, boats, buildings and other structures, and other surfaces where cleaning may dislodge pollutants; these pollutants should not be discharged to the public drainage system (also known as the municipal stormwater system) or receiving waters (surface water or groundwater). Disposal of washwater to the sanitary sewer may be allowed if authorized by the local sewer authority, however, there are limits on certain pollutants; consultation with the King County Industrial Waste Program is advised for large discharges or washwater exceeding limits found in SMC 21.16.300 - Prohibited Discharge of Certain Substances.

The 2024 Phase I Municipal Stormwater Permit prohibits the discharge of building washdown water to municipal stormwater systems from structures suspected or confirmed to have PCB-containing materials on their exterior. Commercial, industrial, institutional, and multi-family/unit residential structures that were constructed or renovated between the years 1950-1980, inclusive, are broadly considered to be most likely to have PCB-containing building materials. The PCB-related BMP elements, below, apply to private and public buildings and are designed to prevent PCBs from entering the stormwater system and local waterbodies.

Description of Pollutants

Source pollutants include surfactants; petroleum hydrocarbons; toxic organic compounds; fats, oils, and grease; soaps; detergents; nutrients; metals; polychlorinated biphenyls (PCBs); high acidity or alkalinity; suspended solids; paint (e.g., spray-paint as graffiti), solids from artificial turf (e.g., crumb rubber, turf blades), debris, substances that increase biological oxygen demand (BOD); and substances that increase chemical oxygen demand (COD).

Stormwater that commingles with washwater is considered process wastewater and can no longer be managed as stormwater.

Required BMP Elements

The following BMPs or equivalent measures are required of all businesses and public entities engaged in cleaning or washing activities:

- Implement all BMP 1 through BMP 8 for all real property (refer to *Section 2.1*).
- Provide training to employees regarding proper disposal of washwater. This training must be documented. Refer to BMP 6.
- Identify the type of drainage system on your property or the property you've been hired to service, including where stormwater enters the drainage system (e.g., at catch basins or inlets) and implement required BMPs accordingly.
- Depending on the location within Seattle, outdoor drains (e.g., catch basins and inlets) discharge to the combined sewer, directly to local waters, or to the public drainage system. Directing washwater into drains that discharge to the drainage system or local waters is not allowed unless specifically identified as **conditionally permissible** per SMC 22.802.030.

- The following are **conditionally permissible** discharges to the public drainage system: (1) Discharges of street and sidewalk washwater when the surfaces have been swept prior to washing, detergents are not used, and water use is minimized; (2) Discharges of water from routine external building washdown for buildings built and renovated before 1950 and after 1980, when detergents are not used and water use is minimized. These **conditions** must be met or the washing activity is prohibited. Sweep surfaces before cleaning/washing to remove excess sediment and other pollutants. Refer to "Building-Specific Requirements" later in this BMP for the washing of buildings built or renovated from 1950-1980.
    - Additionally, though the above conditions are met, cleaning that will result in washwater containing a prohibited substance listed in SMC 22.802.020 is a prohibited discharge. In other words, washing of any surface cannot cause pollution to the drainage system or receiving water (surface water or groundwater).
    - While the definition of street includes the roadway and sidewalk (see SMC 23.84A.036), it does not include parking lots. That means that washwater generated from washing parking lots is **not** a conditionally permissible discharge (i.e., the discharge is prohibited from entering the public drainage system), even when parking lots have been swept prior, detergents are not used, and water use is minimized.
    - While a woonerf (see SMC 23.84A.044) is intended and designed to prioritize pedestrian movement and safety (via slower vehicular movement), it is still used for vehicle access and must therefore be considered a roadway and street for the purposes of this BMP.
- **Potable water** (i.e., treated City-supplied water from faucets and hoses) contains a minimum amount of chlorine to maintain safe consumption and to comply with the Safe Drinking Water Act (SDWA) and Washington Administrative Code (WAC)[2]; however, chlorine can impact aquatic life. Therefore, washing with potable water requires dechlorination if discharges will enter the drainage system. Specifically, discharges of potable water to the drainage system may be conditionally allowed (see SMC, Section 22.802.030) only if they are dechlorinated to a total residual chlorine concentration of 0.1 ppm or less, pH adjusted if necessary, and volumetrically and velocity controlled to prevent resuspension of sediments in the stormwater conveyance system. Discharges of non-dechlorinated water (i.e., water with a chlorine residual greater than 0.1 ppm) that enter the City's municipal stormwater system (MS4) must be reported to Seattle Public Utilities at (206) 386-1800.
- Discharge wastewater from cleaning or washing activities into the sanitary or combined sewer if permissible, into a holding tank, or collected and hauled off-site for proper disposal in accordance with all necessary permits. Authorization for discharge to the sanitary or combined sewer may be required, and pretreatment may be necessary. If using a holding tank, ensure that it is properly sized and does not overfill. Refer to BMP 16 for tanks and BMP 28 for portable containers.

[2] Chapter 246-290 WAC requires that SPU, as the City of Seattle's drinking water utility and Group A Public Water System, provide potable water with a chlorine residual between 0.2 and 4 ppm.

- **Graffiti-impacted areas:** Collect any washwater generated from hosing down, pressure washing, scrubbing, or otherwise cleaning graffiti-impacted areas, and dispose of it according to applicable local, state, or federal waste disposal regulations, *not* into the stormwater drainage system, receiving waters or the ground.
- Label all mobile cleaning equipment as follows: "Properly dispose of all washwater. Do not discharge to an inlet/catch basin, ditch, stream, or on the ground."
- See BMP 32 for information related to commercial pet care facilities such as pet daycares/boarding facilities.
- **Building-specific requirements:**
    - Commercial, industrial, institutional and multi-family/unit residential buildings constructed or renovated from 1950 through 1980 cannot be washed down in a manner that discharges to the MS4 or a surface waterbody, **unless it has been determined that they do not contain PCBs in exterior materials**. An **assessment to inform this determination must be conducted *prior* to building washdown** and following a method consistent with Ecology's Guidance Document "*How to Find and Address PCBs in Building Materials*" (Ecology 2024). Single detached dwelling units and associated accessory structures[3], and buildings built and renovated before 1950 or after 1980, are exempt from PCB assessment prior to washdown.
        - The discharge of washwater from structures confirmed or suspected to have PCB-containing materials on their exterior to public or private stormwater drainage systems, the right-of-way and other public spaces, surrounding properties or receiving waters (including surface water and groundwater) is prohibited. All washwater from confirmed or suspected PCB containing buildings must be collected and disposed of in accordance with a discharge authorization permit. Contact King County for more information about discharge authorizations.
            - For the purposes of these requirements, unless analytical data (using EPA method 8082A or a more precise method) confirms that no PCBs are detected in samples collected from the range of materials on the exterior of the building (e.g., paint, caulk, sealants, coatings, joint material, among others), buildings are "**suspected**" of containing PCBs on their exterior **if any part of the building exterior was built or renovated between 1950 and 1980 (inclusive), and they are not single detached dwelling units (or associated accessory structures), and they are not wood-framed.**
        - Report all structures confirmed or suspected to have PCB-containing exterior building materials to Seattle Public Utilities at 206-386-1800.

[3] "Detached dwelling unit", defined in SMC 23.84A.008, means a dwelling unit that (i) occupies space from the ground to the roof of the structure in which it is located; and (ii) is not attached to any other dwelling unit. Associated accessory structure is a structure like a garage or shed on a property with a detached dwelling unit. These structures are exempt from PCB assessment and, for the purposes of Volume 4, are being used in place of the previously used common term "single-family residential".

- If roof equipment or hood vents are cleaned, ensure that no wastewater or prohibited substance (refer to SMC, Chapter 22.802) is discharged to the roof drains or drainage system.
- Contain the washing activity or wash inside a building having a floor drain that connects to the sanitary sewer.

Ecology Publication WQ-R-95-056, *Vehicle and Equipment Washwater Discharges: Best Management Practices Manual* (Ecology 2012) can be used for guidance on sumps, holding tanks, and the prevention of runoff.

For wash pads discharging directly to the sanitary sewer:

- The uncovered portion of the wash pad must be no larger than 200 square feet or must have an overhanging roof (refer to Figure 8). This is to prevent excess stormwater from entering the sanitary sewer and impacting its capacity. Covering the wash pad(s) may be required in many situations.

Figure 8. Car Wash Building with Drain to the Sanitary Sewer.

- If the uncovered wash pad (or uncovered portion of a wash pad) cannot be less than 200 square feet, a shut off valve may be installed that will direct washwater to the sanitary sewer when the wash pad is in use, and stormwater to the drainage system

when the wash pad is not in use (refer to Figure 9). The valve on the outlet may be manually operated; however, a pneumatic or electrical valve system is preferable. The valve may be on a timer circuit, where it is opened to the drainage system upon completion of a wash cycle. During washing, the valve is open to the sanitary sewer.

- The wash pad must be clearly signed as to the operation and location of the valve.
- All staff authorized to wash at the wash pad must receive annual training on operation of the valve system. Maintain training records.
- If adjacent to a building or constructed over hazardous material storage areas, other regulations, including the Seattle Fire Code, may apply.
- Obtain all necessary permits for installing, altering or repairing onsite wash pads, drainage structures, and side sewers. Restrictions on certain types of discharges may require pretreatment before they enter the sanitary sewer.

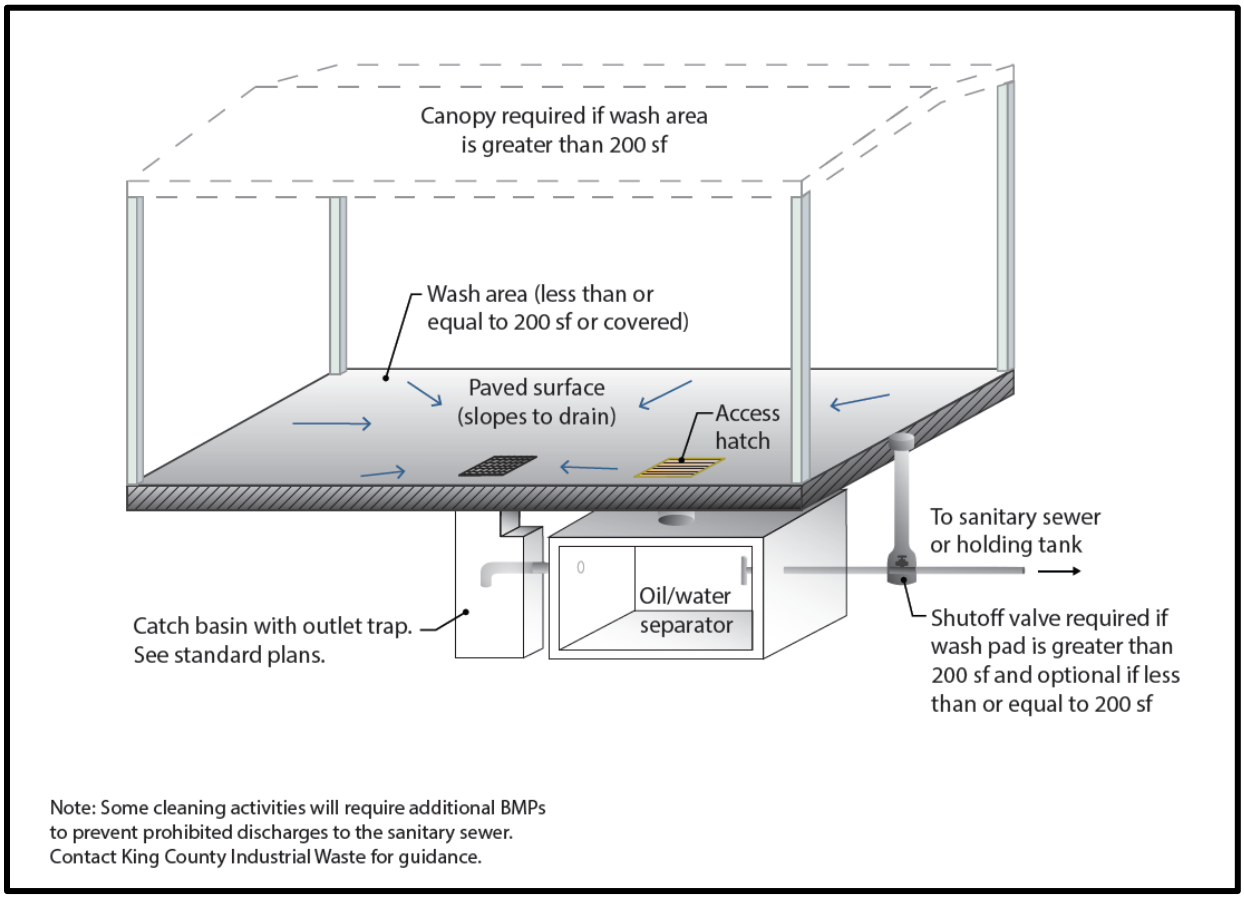

Figure 9. Schematic of Wash Pad with Sump.

Recommended BMPs

- Consider focused spot cleaning prior to, or instead of, washing to minimize the area washed and amount of washwater generated.
- **Graffiti:**
  - Painting over graffiti is preferred over washing it off.

  - Some cleaning systems are equipped with a suction and storage canister (i.e., a closed vacuum system) that removes paint/graffiti without releasing washwater. Captured washwater must not be discharged to the drainage system or ground.
  - Extra care must be taken when removing graffiti on a surface adjacent to a water body.

- **Artificial turf and athletic surfaces:**
  - When cleaning artificial turf playfields, artificial turf athletic fields, and synthetic rubber running tracks, work in a manner that prevents the dislodgment of artificial grass blades, crumb rubber, pigments, and other artificial materials. This may mean reducing the water pressure, dry sweeping, or using other means.
  - Avoid the use of chemicals to clean the surfaces, unless required by a Public Health agency; in all cases, collect materials dislodged and dispose of according to local, state, and federal waste disposal regulations, not into the drainage system.
- **Permeable pavement:**
  - Follow Appendix G for permeable pavement inspection frequencies and refer to the permeable pavement manufacturer for recommended cleaning procedures.
  - Deep cleaning and unclogging permeable pavement may be best accomplished by equipment that simultaneously washes and vacuums, such as a regenerative vacuum sweeper. Care should be taken to avoid extremely high pressures with a pressure washer, as this can degrade the bonding cement paste and increase weathering.
- **Dechlorination:**
  - When planning a street and sidewalk cleaning project (in accordance with the conditions described above and in SMC Section 22.802.030), obtain dechlorination tabs and know how to use them *before* beginning cleaning activities to prevent the discharge of chlorinated water to the stormwater drainage system.
- Although not required, the following BMPs can provide additional pollution control for washing activities that drain **to the sanitary sewer.** To reduce the potential overall pollution load to the sanitary sewer from washing operations for tools, vehicles, engines, and manufacturing equipment:
  - Minimize water and detergent use in all washing operations.
  - Use the least hazardous cleaning products available.
  - Use phosphate-free and biodegradable detergents when practical.
  - Consider recycling the washwater by installing a closed-loop water recycling system.
  - For intermittent washing of vehicles, use a car wash that recycles washwater and discharges to the sanitary sewer.
  - Install filter socks in yard drains to capture solids.

3.2. Transfer of Liquid or Solid Materials

The transfer of liquid or solid materials, including the loading and unloading of such material, fueling of vehicles or equipment at mobile or designated locations, and vehicle and equipment repair and maintenance are activities that have a high risk for spills or leaks of toxic material. Both required and recommended BMPs can help prevent, minimize, and manage the effects of accidental spills or leaks. The specific BMPs that apply to the transfer of particular types of liquid and solid materials are presented in this section.

Remember to also implement BMP 1 through BMP 8 for all real property from *Section 2.1*.

3.2.1. BMP 18: Loading and Unloading of Liquid or Solid Material

This BMP applies to businesses and public entities engaged in the loading and unloading of liquid or solid materials or the transfer of non-containerized bulk materials. Sources of pollution include loading docks, vehicles, and equipment involved in material handling. These activities are typically conducted at shipping and receiving areas, outdoor storage areas, and fueling areas.

Description of Pollutants

Leaks and spills of fuels, oils, powders, organic compounds, fertilizers metals, food products, salts, acids, alkalis, and other chemicals during transfer are potential sources of stormwater contamination. Spills from breaks in hydraulic lines and leaking forklifts are common problems at loading docks. Spilled or leaked products can negatively affect water quality and harm both people and aquatic organisms that come in contact with the contaminated water. These pollutants must not be discharged to the drainage system because many inlets and catch basins in Seattle discharge directly to receiving waters that include local streams and waterways.

Required BMP Elements

The following BMPs or equivalent measures are required in all loading and unloading areas:

- Implement BMP 1 through BMP 8 for all real property (refer to *Section 2.1*).
- Sweep as often as necessary to prevent material from coming into contact with stormwater and to remove accumulated debris and other material that could otherwise be washed off by stormwater. Do not sweep this debris into inlets, catch basins, or any other drainage system infrastructure.
- Place drip pans or other appropriate temporary containment devices in locations where leaks or spills may occur, such as hose connections, hose reels, and filler nozzles (Figure 10).
- Always use drip pans when making and breaking connections. Clean drip pans after each use to remove any residue. Dispose of any residual material in accordance with the Seattle Solid Waste Collection Code (SMC, Chapter 21.36) and the state Dangerous Waste Regulations (WAC, Chapter 173-303).
- Inspect loading and unloading areas after each delivery for leaks and spills and clean up immediately.
- Check material handling equipment such as valves, hoses, pumps, flanges, and connections regularly for leaks, and repair as needed. Document and keep all inspection records. Store contaminated equipment indoors or under cover to prevent residual material from coming into contact with stormwater.
- Provide impervious containment with berms, dikes, etc. or cover the loading and unloading areas to prevent run-on and runoff of contaminated stormwater. Create and maintain a minimum 1.5 percent slope in and around solid material storage areas to prevent pooling. Areas should be sloped to drain stormwater to the perimeter for collection or to areas where no stockpiled material is kept.

Figure 10. Temporary Containment Device Placed Under a Hose Connection.

The following BMPs or equivalent measures are required where liquid or solid materials are transferred from tanker trucks and railcars to aboveground or underground storage tanks and containers, or between transport vehicles (rail or highway):

- To reduce the risk of accidental spillage, prepare and follow an "Operations Plan" that describes procedures for loading and unloading. Train employees on the plan.
- For rail facilities, install and maintain a drip pan system within the rails to collect spills and leaks from tank cars, hose connections, hose reels, and filler nozzles.
- You may be subject to SPCC requirements (40 CFR Part 112) if transloading oil products in excess of 1,320 gallons in areas where, if spill occurred oil could reach navigable water.

The following BMPs or equivalent measures are required in areas of loading and unloading **from or to marine vessels**:

- Facilities and procedures for the loading or unloading of petroleum products must comply with U.S. Coast Guard requirements.
- For requirements related to the transfer of small quantities from tanks and containers, refer to BMP 28 for storage of portable containers of liquid or dangerous waste containers (*Section 3.4.3*) and BMP 16 for storage of liquids in aboveground tanks (*Section 2.2.8*).

Recommended BMPs

Although not required, the following BMPs can provide additional pollution protection:

- Whenever possible, conduct the loading and unloading activity indoors or under cover to reduce exposure to stormwater.
- For the transfer of liquids in areas that cannot contain a catastrophic spill, install an automatic shutoff system in case of an unanticipated interruption during off-loading (e.g., a coupling break, hose rupture, or overfill).
- Install and maintain overhangs (Figure 11) or door skirts that enclose the delivery truck's/trailer's end to prevent contact with stormwater.

Figure 11. Loading Docks with an Overhang to Prevent Contact of Material with Stormwater.

Following elements of BMP 10 (Mobile Fueling of Vehicles and Heavy Equipment) is recommended when liquid or solid materials are transferred from tanker trucks to aboveground or underground storage tanks. Key actions include:

- Pave the area on which the transfer takes place. If any transferred liquid, such as gasoline, reacts with asphalt, pave the area with portland cement concrete or equivalent.
- Construct a slope, berm, or dike to direct runoff from the transfer area to a dead-end sump, spill containment sump, spill control oil/water separator, or other spill containment device. The minimum spill retention time should be 15 minutes for the flow rate of the dispensing mechanism with the highest through-put rate, or at the peak flow rate of the 6-month, 24-hour storm event (or 91 percent of the total runoff volume for the simulation period if using continuous runoff modeling) over the surface of the containment pad, whichever is greater. The volume of the spill containment sump should be a minimum of 50 gallons with an adequate grit sedimentation volume.

3.3. Production and Application

Production and application activities are associated with a high risk for spills or leaks of toxic material. Required and recommended BMPs can help to prevent, minimize, and manage accidental spills or leaks so there are minimal environmental impacts. The specific BMPs that apply to particular types of production and application activities are presented in this section.

Remember to also implement BMP 1 through BMP 8 for all real property from *Section 2.1*.

3.3.1. BMP 19: Manufacturing and Post-Processing of Metal Products

This BMP applies to businesses and public entities such as mills, foundries, and fabricators that manufacture or process metal products. A variety of activities such as machining, grinding, soldering, cutting, welding, quenching, etching, bending, coating, cooling, and rinsing may take place.

Description of Pollutants

Pollutants of concern include toxic organic compounds, metals, oils and greases, high acidity or alkalinity, suspended solids, and substances that increase chemical oxygen demand (COD). These pollutants must not be discharged to the drainage system or directly into receiving waters.

Required BMP Elements

Activities associated with metal manufacturing and processing may require an NPDES permit from Ecology. Refer to Ecology's website (https://ecology.wa.gov/Water-Shorelines/Water-quality/Runoff-pollution/Stormwater) or call Ecology at (360) 407-6000 to determine if the site activities trigger permit coverage.

The following BMPs or equivalent measures are required of all businesses and public entities engaged in activities related to manufacturing and processing of metal products:

- Implement BMP 1 through BMP 8 for all real property (refer to *Section 2.1*).
- Process wastewater (including contact cooling water, filter backwash, or cooling tower blowdown) from this activity and stormwater runoff from processing or production areas must be discharged to the sanitary sewer or a holding tank. If a holding tank is used for the storage of wastewater, the contents must be pumped out before the tank is full and disposed of appropriately to the sanitary sewer or hauled off site. Obtain all necessary permits for discharge to the sanitary sewer.
- Cover the activity area with a roof or canopy to prevent rain from contacting the manufacturing or processing area and to reduce the amount of runoff that may require treatment.
- Make sure all outdoor materials that have the potential to leach or spill to the drainage system are covered, contained, or moved to an indoor location.
- Sweep the activity area at the end of each workday or more often as needed to collect and properly dispose of metal fragments and product residues. Do not allow metal fragments, residues, or dust to accumulate in areas exposed to rain or stormwater.
- Educate employees about carrying out their work in a way that minimizes stormwater pollution. Document and maintain all training records.

Recommended BMPs

Although not required, the following BMPs are recommended to further prevent and minimize the stormwater contamination at metal manufacturing and processing facilities:

- Limit the amount of water used in quenching and rinsing. Recycle used water where possible.

- Use a catch basin filter to capture stray metal particles. Maintain the filter regularly (weekly or as needed) to prevent plugging.

For information about water quality treatment BMPs, refer to *Volume 3 — Project Stormwater Control*. For a current list of proprietary and emerging water quality treatment technologies, refer to Ecology's website (https://ecology.wa.gov/Regulations-Permits/Guidance-technical-assistance/Stormwater-permittee-guidance-resources/Emerging-stormwater-treatment-technologies).

3.3.2. BMP 20: Processing of Treated Wood

This BMP applies to businesses and public entities that perform wood treatment activities, including both anti-staining and preserving using pressure processes, dipping, or spraying. It also applies to businesses and public entities that cut treated wood outdoors.

Description of Pollutants

Pollutant sources include drips of condensate or preservative after pressurized treatment, product washwater (in the treatment or storage areas), spills and leaks from process equipment and preservative tanks, fugitive emissions from vapors in the process, blowouts and emergency pressure releases, and kick-back from lumber (leakage of preservative as it returns to normal pressure).

Potential pollutants typically include wood-treating chemicals, substances that increase biological oxygen demand (BOD), suspended solids, oils and greases, benzene, toluene, ethylbenzene, phenol, chlorophenols, nitrophenols, metals such as chromium and zinc, and polycyclic aromatic hydrocarbons (PAHs). Potential pollutants depend on the chemical additive used. Wood preservatives are registered with the U.S. EPA and include oil-borne and water-borne preservatives. Some wood preservatives and anti-staining chemical additives include creosote, coal tar, pentachlorophenol, copper naphthenate, arsenic trioxide, and other inorganic arsenicals. These pollutants must not be discharged to the drainage system or directly into receiving waters.

Required BMP Elements

Activities associated with processing treated wood may require an NPDES permit from Ecology. Refer to Ecology's website (https://ecology.wa.gov/Water-Shorelines/Water-quality/Runoff-pollution/Stormwater) or call Ecology at (360) 407-6000 to determine if the site activities trigger permit coverage.

The following BMPs or equivalent measures are required of all businesses and public entities engaged in activities related to wood treatment:

- Implement BMP 1 through BMP 8 for all real property (refer to *Section 2.1*).

Production Areas:

- Cover or enclose the following and contain them on impervious surfaces:
  - All wood treatment areas
  - All treated wood
  - All associated wastes
- Separate clean stormwater from process water. Convey all process water to an approved treatment system and discharge to the sanitary sewer or haul off site. Obtain all necessary permits for discharge to the sanitary sewer.
- To prevent tracking treatment chemicals from one area to another, use equipment dedicated to each treatment activity or chemical type.

- For areas around dip tanks, spray booths, and retorts:
  - Eliminate non-process traffic on the drip pad.
  - Clean non-dedicated lift trucks on the drip pad.
  - Construct a slope and direct the drainage in a manner that allows treatment chemicals to flow back to the wood treatment process.
  - Seal any holes or cracks in the asphalt areas subject to contamination with wood treatment chemicals.

Storage Areas:

- Cover or enclose storage areas for treated wood and contain them with impervious surfaces.
  - Alternatively, if stored in uncovered areas, dry treated lumber stacks must be thoroughly wrapped in plastic and elevated to prevent contact with rain and stormwater.
- Immediately remove and properly dispose of soils with visible surface contamination to prevent stormwater runoff from transporting or spreading chemicals to drainage systems, groundwater or surface receiving water.

Treated Wood Products:

- Freshly treated wood is defined as wood that has not been removed from the drip pad immediately following treatment.
- Elevate treated wood products to prevent contact with stormwater run-on and runoff.
- Place treated wood products over the dip tank or on an inclined ramp for at least 30 minutes to allow excess chemicals to drip back to the dip tank.
- Install a structure or cover over freshly treated wood that has not ceased dripping, including over the drip pads, to prevent contact of treated wood products with stormwater.
- Bulk storage of treated wood is permitted outdoors only when the units are protected from contact with stormwater by tarpaulins or wraps.
- Ensure the wood is drip free and dry on the surface before it is moved.
- When cutting treated wood, collect all dust and debris for proper disposal.

3.3.3. BMP 21: Commercial Composting

This BMP applies to commercial composting facilities that operate outdoors without cover. These facilities require large areas for the decomposition of waste and other feedstock.

Description of Pollutants

When stormwater is allowed to seep through active composting areas—including waste receiving and processing areas—it becomes leachate. Pollutants in leachate include nutrients, substances that increase biological oxygen demand (BOD) and lower pH levels, organic compounds, coliform bacteria, and suspended solids. Runoff from areas at a composting facility not associated with active processing and curing, such as product storage areas, vehicle maintenance areas, and access roads, can also contain contaminants. These pollutants must not be discharged to the drainage system or directly into receiving waters.

Required BMP Elements

Activities associated with commercial composting may require an NPDES permit from Ecology as well as other permits. Refer to Ecology's website (https://ecology.wa.gov/Water-Shorelines/Water-quality/Runoff-pollution/Stormwater) or call Ecology at (360) 407-6000 to determine if the site activities trigger permit coverage. For state regulations related to composting facilities, refer to WAC, Section 173-350-220.

The following BMPs or equivalent measures are required of all businesses and public entities engaged in commercial composting activities:

- Implement BMP 1 through BMP 8 for all real property (refer to *Section 2.1*).
- Screen incoming wastes for dangerous materials and solid wastes. These materials will not be accepted for composting and must be properly disposed of.
- Clean up and sweep debris from yard areas daily and more often as needed.
- Store finished compost on an impervious surface and in a manner that prevents contamination of stormwater.
- Convey all leachate to the sanitary sewer, a holding tank, or a permitted onsite treatment system that is designed to treat the leachate and remove suspended solids. If a holding tank is used for the storage of leachate, the contents must be pumped out before the tank is full and disposed of appropriately to a sanitary sewer or wastewater treatment system.
- For new and redeveloped facilities, prevent and reduce stormwater contamination by storing finished compost on a concrete pad that is:
  - curbed to separate leachate from uncontaminated stormwater.
  - sloped sufficiently to direct leachate to the collection device.
  - Designed with one or more sumps or catch basins capable of collecting all leachate generated by the design storm (the intensity of rainfall used to design the drainage infrastructure) and conveying it to the leachate holding structure.
- Line all ponds used to collect, store, or treat leachate and other contaminated waters associated with the composting process to prevent groundwater contamination. Apply

All Known Available and Reasonable Methods of Prevention, Control, and Treatment (AKART) technologies to all pond liners, regardless of the construction materials.

Recommended BMPs

Although not required, the following BMPs are recommended to further prevent and reduce the contamination of stormwater resulting from commercial composting activities:

- Locate stored residues in areas designed to collect leachate and limit storage times to prevent degradation and generation of leachate.

3.3.4. BMP 22: Landscaping and Vegetation Management

This BMP applies to businesses and public entities that perform landscaping, including grading, storage of landscape materials, soil transfer, vegetation removal, pesticide and fertilizer applications, and watering. Landscaping and vegetation management can include control of objectionable weeds, insects, mold, bacteria, and other pests by means of chemical pesticides and is conducted commercially at commercial, industrial, and residential sites. Examples of landscaping and lawn and vegetation management include weed control on golf courses, access roads, and utility corridors; treatment or removal of moss from rooftops, sidewalks, or driveways; killing of nuisance rodents; application of fungicides on patio decks; and residential lawn and plant care.

Description of Pollutants

Stormwater contaminants from landscaping and vegetation management activities include toxic organic compounds, metals, oils, suspended solids, high acidity or alkalinity, coliform bacteria, fertilizers, pesticides, and detergents.

Pesticides such as pentachlorophenol, carbamates, and organometallics can be released to the environment as a result of leaching and dripping from treated plants, container leaks, product misuse, and outdoor storage of pesticide-contaminated materials and equipment. Inappropriate management of vegetation and improper application of pesticides or fertilizers can result in stormwater contamination. These pollutants must not be discharged to the drainage system or directly into receiving waters, except as permitted by Ecology.

The Washington State Department of Agriculture regulates pesticide use and application.

Required BMP Elements

The following BMPs or equivalent measures are required of all businesses and public entities engaged in landscaping and vegetation management activities:

- Implement BMP 1 through BMP 8 for all real property (refer to *Section 2.1*).

Landscaping:

- Do not dispose of or store collected vegetation in drainage systems, waterways, receiving waters, or public spaces. Take care to avoid contamination or site disturbance.
- Use mulch or other erosion control measures when soils or erodible materials are exposed for more than 1 week during the dry season (May 1 to September 30) or 2 days during the rainy season (October 1 to April 30).
- Comply with *Appendix I* of this manual and *S435 — BMPs for Pesticides and an Integrated Pest Management Program* in Volume IV of the SWMMWW (Ecology 2024) (referenced in BMP 49 and BMP 50) for more information.
- Implement the landscaping principles in *Volume 1, Section 2.4.8*, when planning, constructing, and maintaining landscaped areas.
- Comply with all landscape management plans that apply to the site (refer to *Appendix I* of this manual).

Vegetation Management:

- Fertilizer:
  - Apply all fertilizers using properly trained personnel. Document and keep all training records.
  - For commercial and industrial facilities, do not apply fertilizers to grass swales, filter strips, or buffer areas that drain to receiving waters.
  - Refer to *S443 — BMPs for Fertilizer Application* in Volume IV of the SWMMWW (Ecology 2024) for additional information (referenced in BMP 55).

Recommended BMPs

Although not required, the following BMPs are recommended to further prevent and reduce the contamination of stormwater resulting from landscaping and lawn and vegetation management activities:

- Follow other regulations, including the Seattle Fire Code, as applicable.
- Install engineered soil and landscape systems to improve the infiltration and regulation of stormwater in landscaped areas.
- Mulch and mow whenever practical.
- Dispose of grass clippings, leaves, sticks, and other collected vegetation by composting, where feasible.
- Till fertilizers into the soil where practical rather than dumping or applying them onto the surface. Determine the proper fertilizer application for the types of soil and vegetation encountered.
- Till a topsoil mix or composted organic material into the soil to create a well-mixed transition layer that encourages deeper root systems and greater drought-tolerance.
- Use manual or mechanical methods of vegetation removal rather than applying herbicides, where practical.

An amended soil and landscape system can preserve both the plant system and the soil system more effectively. This approach can provide a soil and landscape system with adequate depth, permeability, and organic matter to sustain itself and continue working to effectively infiltrate stormwater and provide a sustainable nutrient cycle.

Vegetation Management:

- Material:
  - Use a topsoil layer that is at least 8 inches thick and consists of at least 8 percent organic matter to provide a sufficient growing medium for the vegetation.
  - Select the appropriate turfgrass mixture for the applicable climate and soil type.

- Fertilizer:
  - Use slow-release fertilizer and organic materials.
  - Time the fertilizer application to periods of maximum plant uptake. Fertilizers should be applied in amounts appropriate for the target vegetation and at the time of year that reduces loss to surface water and groundwater.
  - Do not fertilize during a drought or when the soil is dry.
  - Refer to the *S443 — BMPs for Fertilizer Application* in the SWMMWW (Ecology 2024) for additional information (referenced in BMP 55).

3.3.5. BMP 23: Painting, Finishing, and Coating Activities

This BMP applies to businesses and public entities that perform outdoor surface preparation and application of paints, finishes, and coatings to vehicles, boats, buildings, and equipment.

Description of Pollutants

Potential pollutants include organic compounds (including PCBs in some paints), oils and greases, metals, and suspended solids. These pollutants must not be discharged to the drainage system or directly into receiving waters.

Required BMP Elements

Activities associated with boatyard and shipyard operations may require an NPDES permit from Ecology. Refer to Ecology's website (https://ecology.wa.gov/Water-Shorelines/Water-quality/Runoff-pollution/Stormwater) or call Ecology at (360) 407-6000 to determine if the site activities trigger permit coverage.

The following BMPs or equivalent measures are required of all businesses and public entities engaged in activities related to the painting, finishing, and coating of vehicles, boats, buildings, and equipment outdoors.

- Implement BMP 1 through BMP 8 for all real property (refer to *Section 2.1*).

Preparation and Application:

- Train employees in the application and cleanup of paints, finishes, and coatings to reduce misuse and overspray. Document and keep all training records.
- Implement BMP 17 (Cleaning or Washing) during surface preparation activities to prevent PCB-containing solids (e.g., paint chips) from entering stormwater and the drainage system. When working with surfaces suspected or known to contain PCBs:
  - follow Ecology's Guidance Document "How to Find and Address PCBs in Building Materials" (Ecology, 2024);
  - avoid working in high wind conditions and construct a wind screen around the surface preparation areas;
  - use a HEPA vacuum below suspected and confirmed PCB-containing walls, seams, windows, doors, downspouts, or other exterior features being worked on; and
  - educate staff about the need to control the release of PCB-contaminated dust and solids during surface preparation activities.
- Use ground cloths or drop cloths underneath outdoor painting, scraping, and sandblasting work, and properly clean and temporarily store collected debris after each use.
- Use a catch basin cover, filter sock (see Figure 7), or similarly effective runoff control device if dust, sediment, or other pollutants may escape the work area. If catch basin filter socks are used on site, maintain the filter regularly to prevent plugging. Stormwater contaminated with pollutants must not enter the drainage system.

Catch basin filter socks only remove solids and do not provide treatment for other pollutants associated with painting, finishing, and coating activities.

- Do not conduct spraying, blasting, or sanding activities over open water or where wind may blow paint into water. If windy conditions are present, use a curtain to contain the activity.
- While using a spray gun or conducting sand blasting, enclose and contain all work in compliance with applicable air pollution control requirements and those of the Occupational Safety and Health Administration (OSHA), the Washington Industrial Safety and Health Act, and the Puget Sound Clean Air Agency.

Cleanup:

- Wipe up spills with rags and other absorbent materials immediately. Do not hose down the area.
- On marine dock areas, sweep to collect debris. Do not hose down debris.
- Use a ground cloth, pail, drum, drip pan, tarpaulin, or other protective device for activities such as paint mixing and tool cleaning outdoors or where spills can contaminate stormwater. Whenever possible, conduct these activities indoors or in an enclosed area.
- Clean paintbrushes and tools covered with water-based paints into drains connected to the sanitary sewer. Verify the discharge point before discharging.
- Collect solvents used to clean brushes and tools covered with non-water-based paints, finishes, or other materials. Safely and properly recycle or dispose of used solvents (e.g., paint thinner, turpentine, and xylol).

Material Storage and Disposal:

- Dispose of all waste properly and prevent uncontrolled releases to the air, ground, or water.
- Store all paints, finishes, or solvents inside a building or in covered secondary containment.
- All containers must have tight-fitting lids able to retain the contents in the event of tipping.

Recommended BMPs

Although not required, the following BMPs are recommended to further prevent and reduce the contamination of stormwater resulting from activities related to the painting, finishing, and coating of vehicles, boats, buildings, and equipment:

- Dispose of water-based paints by drying them and then placing them in the garbage. Do not dump pollutants collected in portable containers into any stormwater drain, combined sewer system, sanitary sewer drain, or receiving waters.
- Recycle paints, paint thinner, solvents, washwater from pressure washers, and any other recyclable materials.
- Use efficient spray equipment such as electrostatic, air-atomized, high-volume and low-pressure, or gravity-feed spray equipment.
- Purchase recycled paints, paint thinner, solvents, and other products where feasible.
- Dispose of unused paint promptly.

3.3.6. BMP 24: Commercial Printing Operations

This BMP applies to businesses and public entities that perform commercial printing. Materials used in the printing process include inorganic and organic acids, resins, solvents, polyester film, developers, alcohol, vinyl lacquer, dyes, acetates, and polymers.

Description of Pollutants

Waste products from commercial printing processes may include waste inks and ink sludge, resins, photographic chemicals, solvents, acid and alkaline solutions, chlorides, chromium, zinc, lead, PCBs, formaldehyde, silver, plasticizers, paper, dust, and used lubricating oils. These pollutants must not be discharged to the drainage system or directly into receiving waters.

Printing operations are conducted indoors; therefore, the likely points of potential contact with stormwater are outdoor storage areas and the external loading bays where chemicals are offloaded.

Required BMP Elements

The following BMPs or equivalent measures are required of all businesses and public entities engaged in commercial printing activities:

- Implement BMP 1 through BMP 8 for all real property (refer to *Section 2.1*).
- Sweep outdoor areas as necessary to prevent accumulation of dust and debris.
- Discharge process wastewater to the sanitary sewer if approved by SPU and King County (as applicable), or to an approved process wastewater treatment system.
- Determine whether any generated wastes are dangerous wastes and manage and dispose of them accordingly.
- Store materials inside a building or in covered secondary containment.
    - Waste printing equipment (including ink and other cartridges) must not be stored outdoors. Pigments and dyes used in print production are a source of inadvertent polychlorinated biphenyls (iPCBs); therefore, the equipment must not be exposed to rain, run-on, or potentially leak fluids to outdoor ground surfaces.

3.3.7. BMP 25: Manufacturing Activities

This BMP applies to businesses and public entities that perform any type of outdoor processing, fabrication, mixing, milling, or refining. This also includes areas where historical contamination may currently be contaminating stormwater.

Description of Pollutants

Pollutant sources from outdoor manufacturing operations include outdoor process areas, air pollution control equipment, and areas of historical manufacturing activity. Pollutants can include suspended solids, high acidity or alkalinity, metals, oils and greases, a variety of organic compounds, and substances that increase chemical oxygen demand (COD). These pollutants must not be discharged to the drainage system or directly into receiving waters.

Required BMP Elements

Outdoor activities associated with industrial manufacturing may require an NPDES permit from Ecology. Refer to Ecology's website (https://ecology.wa.gov/Water-Shorelines/Water-quality/Runoff-pollution/Stormwater) or call Ecology at (360) 407-6000 to determine if the site activities trigger permit coverage.

The following BMPs or equivalent measures are required of all businesses and public entities engaged in outdoor manufacturing activities:

- Implement BMP 1 through BMP 8 for all real property (refer to *Section 2.1*).
- Move all or parts of the manufacturing activity into a building or under cover (Figure 12), contain the activity, and connect floor drains to the sanitary sewer. Obtain all necessary permits for installing, altering, or repairing side sewers. Restrictions on certain types of discharges may require pretreatment of discharges before they enter the sanitary sewer. Construct a berm or a sloped floor as needed to prevent drainage of pollutants to outdoor areas and to prevent run-on of uncontaminated stormwater.
- Make sure all outdoor materials that have the potential to leach or spill to the drainage system are covered, contained, or moved to an indoor location. The cover must not contribute pollutants to the drainage system.
- Sweep paved areas daily or more often as needed to prevent contamination of stormwater.
- Isolate and separate polluted materials, such as washwater and process water, and convey it to a sanitary sewer, process treatment, or dead-end sump, depending on the available methods and applicable permit requirements.
- If operational BMPs are not sufficient to prevent stormwater contamination, structural controls must be used, including treatment or structural containment.

Recommended BMPs

Although not required, the following BMPs are recommended to further prevent and reduce the contamination of stormwater resulting from manufacturing activities:

- Consider modifying the activity to eliminate or reduce the contamination of stormwater.

Figure 12. Structure Used to Cover Manufacturing Activities.

3.4. Storage and Stockpiling

Activities related to the storage and stockpiling of liquid or solid materials are potentially associated with a high risk for spillage, leakage, erosion, or leaching of pollutants. Both required and recommended BMPs can help to prevent, minimize, and manage the effects of accidental spills and leaks. The specific BMPs that apply to various types of storage and stockpiling activities are presented below.

Remember to also implement BMP 1 through BMP 8 for all real property (refer to *Section 2.1*).

3.4.1. BMP 26: Storage of Leachable or Erodible Materials

This BMP applies to businesses and public entities where there is storage of leachable and erodible materials, including but not limited to gravel, sand, salts, topsoil, compost, logs, sawdust, wood chips, lumber and other building materials, concrete, and non-coated galvanized metal or other leachable metal. This BMP applies regardless of the stockpile size (volume).

Description of Pollutants

If rain or stormwater run-on comes in contact with stockpiled materials, pollutants may wash away with the stormwater. Though these materials are typically destined for use outdoors, storage of large quantities of these materials awaiting sale or use can contribute high levels of localized pollutant loading. Potential pollutants include suspended solids, substances that increase biological oxygen demand (BOD), organic compounds, dissolved salts (e.g., sodium chloride, calcium chloride, and magnesium chloride), metals, and oils that may be attached to metal parts. These pollutants must not be discharged to the drainage system or directly into receiving waters. Even low levels of metals such as copper and zinc can have detrimental effects on aquatic life.

Required BMP Elements

The following BMPs or equivalent measures are required of all businesses and public entities engaged in the storage of leachable or erodible materials This includes all (i) stockpiles of erodible or water-soluble material (such as soil, road de-icing salt, compost, unwashed sand and gravel, and sawdust) regardless of size, and (ii) outdoor storage areas for solid materials (such as logs, bark, lumber, and non-coated galvanized metal products).

- Implement BMP 1 through BMP 8 for all real property (refer to *Section 2.1*).
- Store materials indoors (see Figure 13) **or** in a **paved, covered, and bermed area designed to contain the material** (Figure 14). Cover options and requirements include:
    - The cover may be a roof, canopy, or impermeable (e.g., plastic) sheeting but must be constructed and maintained to fully prevent wind and weather contact with the polluting material. Common types of plastic sheeting include polyethylene, polypropylene, Hypalon, or equivalent material.
    - The cover must not contribute pollutants to the drainage system.
    - Covers must be in place at all times when the stockpile is not in active use (i.e., being added to or removed from).
    - If plastic sheeting is used, it must be anchored and re-positioned as needed to prevent contact with rainfall.
- Maintain drainage areas in and around storage areas for solid materials with a minimum slope of 1.5 percent to prevent pooling and minimize leachate formation. Slope storage areas to drain stormwater to a collection area at the perimeter of the storage area or to internal drainage “alleyways” between storage areas where material is not stockpiled.
- Sweep paved storage areas daily or more often as necessary to collect and dispose of loose solid materials.

- Place cleanup materials, such as brooms, dustpans, and vacuum sweepers, near the storage area for quick access.
- Do not hose down the contained stockpile area to an inlet or catch basin, ditch, street, or to receiving water.
- For new or modified areas, pave and install a drainage system:
  - Place curbs or berms along the perimeter of the area to prevent the run-on of uncontaminated stormwater and to collect and convey contaminated runoff to a treatment system.
  - Slope the paved area in a manner that minimizes the contact between stormwater (e.g., pooling) and leachable materials.

Figure 13. Covered, Paved, and Secured Storage Area for Bulk Solids.

Figure 14. Covered Storage Area for Erodible Material (e.g., gravel).

- If large stockpiles cannot be covered, **all of the following apply:**
  - **Install containment devices** such as a berm or a low wall around the perimeter of the site and at any catch basins as needed to prevent erosion of the stockpiled material and to prevent discharge of leachate from the stockpiled material off site.
  - Ensure that contaminated stormwater is not discharged directly to the drainage system or receiving waters without being conveyed **through a treatment BMP**. *Volume 3 — Project Stormwater Control* presents approved methods, requirements, criteria, details, and general guidance for analysis and design of on-site stormwater management, flow control, and water quality treatment per SMC, Chapter 22.800 through 22.808 (Stormwater Code).
  - Inspect and maintain catch basins on a regular basis (at least weekly). Stormwater contaminated with pollutants must not enter the drainage system or receiving waters.

Recommended BMPs

The following BMPs are recommended to further prevent and reduce the contamination of stormwater resulting from activities related to the storage or transfer of leachable and erodible materials:

- Raise solid material (i.e., erodible or water-soluble material) off the ground if possible to prevent stormwater contact beneath the material. Pallets or racks are a good way to keep those materials away from stormwater flow.

- If and when feasible, collect and recycle materials and leachate to the stockpile.
- Keep the smallest necessary amount of stockpiled materials on site. Smaller piles reduce the loss of materials due to wind and rain and will make the piles more manageable to cover.

3.4.2. BMP 27: Temporary Storage or Processing of Fruits, Vegetables, or Grains

This BMP applies to businesses and public entities that temporarily store fruits, vegetables, and grains outdoors before processing or sale, or that crush, cut, or shred them for wines, beers, frozen juices, or other food and beverage products.

Description of Pollutants

Activities involving the storage or processing of fruits, vegetables, and grains can potentially result in the delivery of pollutants to stormwater. Potential pollutants of concern from all fruit and vegetable storage and processing activities include nutrients, suspended solids, substances that increase biological oxygen demand (BOD), and color. These pollutants must not be discharged to the drainage system or directly into receiving waters.

Required BMP Elements

Outdoor activities associated with food processing (examples include brewing activities, grape crushing at wineries, and fresh fruit packing) may require an NPDES permit from Ecology. Refer to Ecology's website (https://ecology.wa.gov/Water-Shorelines/Water-quality/Runoff-pollution/Stormwater) or call Ecology at (360) 407-6000 to determine if the site activities trigger permit coverage.

The following BMPs or equivalent measures are required of all businesses and public entities engaged in the temporary storage or processing of fruits, vegetables, and grains:

- Implement BMP 1 through BMP 8 for all real property (refer to *Section 2.1*).
- Do not allow water used to clean produce to enter the drainage system.
- Sweep paved storage areas daily or more often as needed. Inspect storage areas often and maintain good housekeeping.
- Make sure all outdoor materials that have the potential to leach or spill to the drainage system are covered, contained, or moved to an indoor location.
- Enclose the processing area in a building or shed, or cover the area with provisions for stormwater run-on prevention. If less than 200 square feet, pave and slope the area to drain to the sanitary sewer, a holding tank, or a process treatment system collection drain. Prevent stormwater run-on from entering the processing area. If a holding tank is used for the storage of wastewater, pump out the contents before the tank is full and dispose of it properly.
- Keep cleanup materials, such as brooms and dustpans, near the storage area.

3.4.3. BMP 28: Portable Container Storage

This BMP applies to businesses and public entities that keep containers (e.g., jugs, pails, drums, totes, and others) outdoors on their premises that may include, but are not limited to, used automotive fluids, liquid feedstock, cleaning compounds, chemicals, dangerous wastes (liquid or solid), and contaminated stormwater. For outdoor storage of used cooking oil containers, refer to BMP 4. Responsible parties must also comply with all requirements of the State's Dangerous Waste Regulations, as applicable.

Description of Pollutants

Leaks and spills during handling and storage of portable containers are the primary sources of pollutants. Potential pollutant constituents are oils and greases, high acidity (low pH) or alkalinity (high pH), surfactants, substances that increase biological oxygen demand (BOD), substances that increase chemical oxygen demand (COD), and toxic organic compounds.

Required BMP Elements

The following required BMPs apply to all portable containers:

- Implement BMP 1 through BMP 8 for all real property (refer to *Section 2.1*).
- Store materials in a leakproof container with a tight-fitting lid able to contain the material in the event of tipping.
    - For the storage of liquids, use containers, such as steel and plastic drums, that are rigid and durable, corrosion resistant to the weather and fluid content, non-absorbent, watertight, and rodent-proof.
- Label or mark all containers to identify their contents. Position containers so that labels or markings are clearly visible.
- Place drip pans beneath all taps on mounted containers and at all potential drip and spill locations during the filling and draining of containers. Maintain this spill control routinely to keep it functional.
- Inspect container storage areas regularly for corrosion, structural failure, spills, leaks, and overfills. Check containers daily for leaks and spills. Replace containers and replace and tighten bungs in drums as needed.
- Store and secure containers in a manner that prevents accidental spillage, pilferage, or any unauthorized use (Figure 15 and Figure 16).

The following BMPs or equivalent measures are required for activities related **to outdoor storage of containers of hazardous or dangerous material or wastes and liquids** (except potable water):

- Store containers in a designated area. Provide covered secondary containment that is able to hold a volume of either 10 percent of the total volume of the enclosed containers or 110 percent of the volume of the largest container, whichever is greater. Provide a portable secondary containment unit or cover and pave the storage area with an impervious surface and install a berm or dike to surround the area. Slope the area to drain into a dead-end sump for the collection of leaks and small spills.

- Store containers that do not contain free liquids in a designated sloped area with the containers elevated or otherwise protected from stormwater run-on.
- Elevate metal drums to prevent corrosion from trapped moisture.
- Ensure the storage of hazardous, reactive, ignitable, or flammable liquids complies with the Seattle Fire Code and Washington State Fire Code.

Figure 15. Covered and Secured Storage Area for Containers.

Figure 16. Containers Surrounded by a Berm in an Enclosed Area.

Recommended BMP Elements

- Wherever possible, store containers on a paved surface under a roof or other appropriate cover or in a building. Storage indoors must prevent all possible exposure to the outdoors from spills to qualify as covered under this BMP.

3.5. Dust, Soil Erosion, and Sediment Control

Construction, manufacturing, and industrial activities have the potential to generate significant amounts of dust, soil, and sediment, which can pollute both air and stormwater. Control measures for dust, soil, and sediment are necessary to prevent pollution, but BMPs that are not properly applied can be harmful to stormwater and the environment.

The required and recommended BMPs for these activities are presented below. First, prevent the production of dust, soil, and sediment. Then, apply BMPs to reduce their production. Finally, manage dust, soil, and sediment so that contaminated stormwater is not conveyed to the drainage system or receiving waters.

Remember to also implement BMP 1 through BMP 8 for all real property (refer to *Section 2.1*).

3.5.1. BMP 29: Dust Control in Disturbed Land Areas and on Unpaved Roadways and Parking Lots

This BMP applies to businesses and public entities that apply dust control measures in disturbed land areas or on unpaved roadways and parking lots. All land-disturbing activity must comply with the erosion and sediment controls described in the Stormwater Code (SMC, Chapters 22.800 through 22.808).

Description of Pollutants

Dust can result in air and water pollution, particularly at demolition sites, in disturbed land areas, and on unpaved roadways and parking lots. Chemicals applied to dust-prone areas to reduce dust production also have the potential to pollute stormwater and receiving waters if they are not properly selected or applied.

Required BMP Elements

The following BMPs or equivalent measures are required of all businesses and public entities engaged in activities that generate dust:

- Implement BMP 1 through BMP 8 for all real property (refer to *Section 2.1*).
- Protect inlets and catch basins during application of dust suppressants. Prevent liquid dust suppressants from flowing into the drainage system during application.
- Sprinkle or wet down soil or dust with water as long as it does not result in a discharge to inlets and catch basins or receiving waters.
- Only use local or state government approved dust suppressant chemicals, such as those listed in Publication No. 96-433, *Methods for Dust Control* (Ecology 2016a).
- Avoid excessive and repeated application of dust suppression chemicals. Time the application of dust suppressants to avoid or reduce their wash off by rainfall or human activity (such as irrigation).
- Street gutters, sidewalks, driveways, and other paved surfaces in the immediate area of the activity must be swept regularly to collect and properly dispose of dust, dirt, loose debris, and garbage.
- Install catch basin filter socks on site and in surrounding catch basins to collect sediment and debris. Maintain the filters regularly to prevent plugging.

BMPs required for construction dust control, such as dust suppression by water spray, are provided in *Volume 2 — Construction Stormwater Control*.

3.5.2. BMP 30: Dust Control at Manufacturing Sites

This BMP applies to all businesses and public entities, but particularly to industrial and manufacturing facilities that have the potential to generate dust, including gravel, crushed rock, cement, fly ash, and other airborne pollutants.

Description of Pollutants

Industrial material handling activities can generate a considerable amount of dust, which is typically removed by use of exhaust systems. The exhaust systems can generate air emissions and can contaminate stormwater. Dust can be generated by mixing cement and concrete products and handling powdered materials. Particulate materials that can cause air pollution are sawdust, coal, boiler fly ash, and dust from grain, coal, gravel, crushed rock, and cement. Air emissions can contaminate stormwater if not properly managed and controlled.

Required BMP Elements

The following BMPs or equivalent measures are required of all businesses and public entities engaged in activities that can generate dust:

- Implement BMP 1 through BMP 8 for all real property (refer to *Section 2.1*).
- Clean accumulated dust and residue from powdered material handling equipment and vehicles as needed.
- Maintain onsite controls so that no vehicle track-out occurs.
- Regularly sweep areas of accumulated dust that can contaminate stormwater. Sweeping should be conducted with vacuum-filter equipment to minimize dust generation and ensure optimal dust removal.
- Maintain dust collection devices on a regular basis.
- Where feasible, regularly clean surfaces, such as roofs and yards, to prevent buildup. Discharge washwater to the sanitary sewer, if authorized, or recover for proper off-site treatment or disposal.
- If operational BMPs are not enough to prevent stormwater contamination, structural controls must be used, including treatment or structural containment.

Facility operations that create or have the potential to create air pollution are regulated by the Puget Sound Clean Air Agency. For more information on necessary permits, contact the Puget Sound Clean Air Agency at (800) 552-3565.

3.5.3. BMP 31: Soil Erosion and Sediment Control at Industrial Facilities

This BMP applies to business and public agency industrial facilities that operate in areas with exposed or disturbed soils, areas with steep grades, or as deemed necessary to prevent sediment transport. For information on construction-related soil erosion and sediment control, refer to *Volume 2 — Construction Stormwater Control*.

Description of Pollutants

Industrial activities in areas with exposed or disturbed soils or areas with steep grades can be sources of sediment that can contaminate stormwater runoff. Pollutants include suspended solids, oils and greases, metals, and other industrial contaminants from onsite activities.

Required BMP Elements

The following BMPs or equivalent measures are required of all businesses and public entities for soil erosion and sediment control:

- Implement BMP 1 through BMP 8 for all real property (refer to *Section 2.1*).
- Limit the exposure of erodible soil.
- Stabilize or cover erodible soil to prevent erosion.
- Stabilize entrances and exits to prevent track-out.
- Install one or more of the following cover practices:
  - Vegetative cover, such as grass, trees, or shrubs, in erodible soil areas.
  - Cover with mats, such as clear plastic, jute, or synthetic fiber.
  - Preserve natural vegetation, including grass, trees, shrubs, and vines.
- If operational BMPs are not enough to prevent stormwater contamination, structural controls must be used, including treatment or structural containment, which may include paving.

Washington State Water Quality Standards have specific limits on turbidity discharges. For specific information, refer to WAC, Chapter 173-201A.

3.6. Other Activities

Several activities that do not fall into the previously described categories have a high risk for generating pollutants and contaminating stormwater and receiving waters. The required and recommended BMPs for these activities are presented according to the type of activity and the potential pollutants. Regardless of the activity, an overall approach to pollutant control should first emphasize pollution prevention, then the minimization of pollution, followed by pollution management.

Remember to also implement BMP 1 through BMP 8 for all real property (refer to *Section 2.1*).

3.6.1. BMP 32: Commercial Animal Care and Handling

This BMP applies to businesses and public entities that perform animal care and handling, including, but not limited to, the management of animals at racetracks, kennels, day kennels, fenced pens, and veterinary offices and hospitals. It encompasses businesses or public entities that provide services such as boarding, daycare, grooming, shelter and adoption services, and health services for horses, dogs, cats, and other animals. For non-commercial constructed dog runs, including those on rooftops or above grade, refer to BMP 8.

Refer to Seattle & King County Public Health's (Public Health's) Pet Business Program for their requirements (https://kingcounty.gov/en/dept/dph/health-safety/environmental-health/pet-business). Following Public Health's requirements are in addition to, but not in place of, Seattle's Stormwater Code and the BMPs contained in this Manual.

Description of Pollutants

Examples of animal handling activities that can generate pollutants are the cleanup of manure deposits, animal washing, and outdoor exercise area washing and maintenance. Potential pollutants include fecal coliform bacteria, nutrients, soap, disinfectants, substances that increase biological oxygen demand (BOD), hair, and suspended solids.

Required BMP Elements

The following source control BMPs or equivalent measures are required for all commercial animal handling activities:

- Implement BMP 1 through BMP 8 for all real property (refer to *Section 2.1*).
- Regularly sweep and clean outdoor animal-keeping areas to collect and properly dispose of droppings, uneaten food, and other potential stormwater contaminants. Do not discharge pollutants associated with these activities to the drainage system or receiving waters.
    - Check with Seattle & King County Public Health regarding required maintenance for this outdoor activity.
- Runoff from uncovered outdoor areas with hard surfaces subject to animal access must not be allowed to enter the stormwater drainage system or receiving waters.
    - New connections to the sanitary or combined sewers require City side sewer permits. Contact Seattle Department of Construction and Inspections (SDCI) for more information (sidesewerinfo@seattle.gov).
- No more than 200 square feet of uncovered outdoor animal-keeping areas may discharge to the sanitary sewer. This is to prevent excess stormwater from entering the public sanitary sewer system. The portion of outdoor area that is greater than 200 square feet that drains to the sanitary sewer must be covered. The cover must be an impermeable roof or canopy that prevents rain and stormwater from coming in contact with the animal-keeping area and directs uncontaminated stormwater runoff to the drainage system.
- In combined sewer areas, outdoor animal-keeping areas greater than 200 square feet do not require a cover.

- Do not wash or disinfect outdoor areas that contain potential stormwater contaminants if the water will drain to a public drainage system, a private drainage system, or receiving waters.
    - Although disinfection and washing of outdoor animal handling areas may be required by Seattle & King County Public Health, it would be in violation of Seattle's Stormwater Code to allow any of the washwater to discharge to anything other than the sanitary sewer system.
    - Washwater containing disinfectant is never allowed to infiltrate, since it can affect groundwater.
    - Check with the Seattle Department of Construction and Inspection (SDCI) for permit requirements before changing drainage or sewer connections or installing infiltration improvements. Contact SDCI at sidesewerinfo@seattle.gov or call 206-684-5362.
- If animals are not leashed or in cages, the animal-keeping area must be surrounded by a fence or other means of preventing animals from moving out of the controlled area where BMPs are used.
- Do not stockpile manure in areas where runoff is allowed to flow into a storm drain or to nearby receiving waters or wetlands.

Recommended BMPs

- For outdoor surface areas that must be disinfected, use an unsaturated mop to spot clean the area, thus reducing the amount of washwater that would carry pollutants to the sanitary sewer system. (The required BMP prohibiting wastewater runoff from entering the drainage system still applies).

3.6.2. BMP 33: Log Sorting and Handling

This BMP applies to businesses and public entities with paved or unpaved areas where logs are transferred, sorted, debarked, cut, and stored to prepare them for shipment, or for the production of dimensional lumber, plywood, chips, poles, or other products. Log yards are generally maintained at sawmills, shipping ports, and pulp mills.

Log sorting and handling activities may require an NPDES permit from Ecology. Refer to Ecology's website (https://ecology.wa.gov/Water-Shorelines/Water-quality/Runoff-pollution/Stormwater) or call Ecology at (360) 407-6000 to determine- if the site activities trigger permit coverage. Required and recommended source control and treatment BMPs are described in detail in Publication No. 04-10-031, *Industrial Stormwater General Permit Implementation Manual for Log Yards* (Ecology 2016b).

Refer to *S413 — BMPs for Log Sorting and Handling* in Volume IV of the SWMMWW (Ecology 2024) for a description of the pollutants associated with this activity and the required BMP elements.

3.6.3. BMP 34: Boat Building, Maintenance, and Repair

This BMP applies to businesses and public entities that perform activities related to boat and shipbuilding and their repair and maintenance at boatyards, shipyards, ports, and marinas. Activities that can generate pollutants include pressure washing, surface preparation, paint removal, sanding, painting, engine maintenance and repairs, and material handling and storage. If conducted outdoors, all of these activities are associated with a high risk for contaminating receiving water.

Description of Pollutants

Potential pollutants include spent abrasive grits, solvents, oils, ethylene glycol, washwater, paint overspray, cleaners and detergents, anticorrosion compounds, paint chips, scrap metal, welding rods, resins, glass fibers, dust, and miscellaneous trash. Pollutants could include suspended solids, oils and greases, organic compounds, copper, lead, tin, and zinc.

Required BMP Elements

Activities associated with boatyard and shipyard operations may require an NPDES permit from Ecology. Refer to Ecology's website (https://ecology.wa.gov/Water-Shorelines/Water-quality/Runoff-pollution/Stormwater) or call Ecology at (360) 407-6000 to determine if the site activities trigger permit coverage.

The following BMPs or equivalent measures are required for boat and ship **building, maintenance, and repair activities:**

- Implement BMP 1 through BMP 8 for all real property (refer to *Section 2.1*).
- In addition to the BMP 5 spill control requirements, include a marine containment boom in spill kits for shipyards, boatyards, and marinas.
- Locate spill kits on all piers or docks.
- Immediately clean up any spills on dock, boat, or ship deck areas and dispose of the wastes properly.
- Immediately repair or replace leaking connections, valves, pipes, hoses, and equipment that can result in the contamination of stormwater.
- Relocate maintenance and repair activities onshore if possible to reduce the potential for direct pollution of receiving waters.
- Perform paint and solvent mixing, fuel mixing, and similar handling of liquids onshore or in a location with proper containment so that nothing can spill directly into receiving waters.
- All liquids stored over water or on docks must have covered secondary containment.
- Store all batteries and oily parts in a covered container with a tight-fitting lid.
- Store materials such as paints, tools, and ground cloths indoors or in a covered area when not in use.
- Collect spent abrasives regularly and contain or store them under cover until they can be disposed of properly.

- Sweep and clean yard areas, docks, and boat ramps at least once each week or more often as needed. Do not hose them down. Properly dispose of the collected materials. Sweep dry docks before flooding.
- When washing, do not allow any pollutants, including soap, to enter the drainage system or receiving waters.
- Use fixed platforms with appropriate plastic or tarpaulin barriers as work surfaces and for containment when work is performed on a vessel in the water to prevent material or overspray from contacting stormwater or receiving water. Use of the platform approach should be kept to a minimum. Only work that is done in compliance with NPDES requirements should be done over water.

The following BMPs or equivalent measures are required for boat and ship **blasting and spray painting activities:**

- Move the activity indoors or enclose, cover, and contain the activity. Prohibit outdoor spray painting, blasting, or sanding activities during windy conditions that make containment ineffective.
- Store materials such as paints, tools, and ground cloths indoors or in a covered area when not in use.
- Contain blasting and spray-painting activities by hanging tarpaulins to block the wind and prevent dust and overspray from escaping. Do not perform uncontained spray painting, blasting, or sanding activities over open water without proper protection (e.g., overspray collection, drop cloths, booms).
- Use plywood or plastic sheeting to cover open areas between decks when sandblasting.
- Use ground cloths to collect drips and spills during painting and finishing operations, paint chips, and used blasting sand during sand blasting.
- Do not paint or use spray guns on or above the deck.

In the event of an accidental discharge of oil or hazardous material into receiving water or onto land if there is a potential for entry into receiving water, the responsible party must meet all notification requirements including, but not limited to, notifying the yard, port, or marina owner or manager; Ecology's Northwest Regional Office at (206) 594-0000; and the National Response Center at (800) 424-8802 (24-hour). If the spill can reach or has reached marine water, call the U.S. Coast Guard at (206) 217-6232.

Recommended BMPs

Although not required, the following BMPs are encouraged to further reduce the potential for stormwater contamination:

- Select the least toxic antifouling paint available.
- Routinely clean boat interiors and properly dispose of collected materials so that accumulated water, which must be drained from the boat, does not become contaminated.

3.6.4. BMP 35: Cleaning and Maintenance of Pools, Spas, Hot Tubs, and Fountains

This BMP applies to all public and commercial swimming pools and spas, hot tubs, and fountains that use chemicals or are heated. Pools and spas at hotels, motels, apartments, and condominium complexes are also covered.

Owners and operators of water recreation facilities must also comply with state and local Public Health agency regulations, policies, and procedures.

Description of Pollutants

Pollutants of concern include nutrients, bacteria, suspended solids, chlorine, bromine, high acidity or alkalinity, and substances that increase chemical oxygen demand (COD). Elevated temperatures found in these waters can also impact aquatic life in receiving waters.

Required BMP Elements

The following BMPs or equivalent measures are required for all pool, spa, hot tub, and fountain cleaning and maintenance activities:

- Implement BMP 1 through BMP 8 for all real property (refer to *Section 2.1*).
- Discharge wastewater from backwashing and other maintenance activities related to cleaning to the sanitary sewer. Obtain all necessary permits for discharge to the sanitary sewer.
- For pool, spa, hot tub, and fountain draining, discharging to the sanitary sewer is the preferred method. Obtain all necessary permits for discharge to the sanitary sewer.
- If discharging to the ground, the discharge must comply with Ecology's Groundwater Quality Standards (WAC, Chapter 173-200). Discharge must be moderated to allow infiltration of all water into the ground and not produce surface runoff.
- If discharge to the sanitary sewer or ground is not possible for draining a pool, spa, hot tub, or fountain, water may be discharged to a ditch or drainage system, provided that the following conditions have been met:
    - Dechlorinated and debrominated to a total residual concentration of 0.1 parts per million (ppm) or less.
    - Adjusted to a pH between 6.5 and 8.5.
    - Adjusted to a temperature and dissolved oxygen concentration that will prevent an increase in temperature or a decrease in dissolved oxygen concentration in the downstream receiving water.
    - Released at a controlled flow rate to prevent erosion and high flow impacts in the drainage ditch or downstream receiving water.
    - Free of any coloration, sodium chloride, dirt, cleaning chemicals (including, but not limited to, copper-based algaecides), algae, filter media, suds, acid cleaning wastes, or otherwise prohibited wastes.

Recommended BMPs

- Maintain proper chlorine levels, water filtration, and circulation to reduce the need to drain the structures.

Guidance on dechlorination is provided in the Department of Health's Water System Design Manual, Publication 331-123 (DOH 2020). The Department of Health manual further references the American Water Works Association (AWWA) Standard for Disinfecting Water Mains (C651) and Standard for Disinfecting Water Storage Facilities (C652). Contact AWWA for more information. Contact a pool chemical supplier to obtain the neutralizing chemicals needed.

3.6.5. BMP 36: Deicing and Anti-icing Operations for Airports and Streets

This BMP applies to businesses and public entities that perform deicing and anti-icing operations used on highways, streets, airport runways, airport taxiways, ramp and gate areas, and aircraft to control ice and snow.

Description of Pollutants

Typically, ethylene glycol and propylene glycol are used on aircraft as deicers. The deicers commonly used on highways and streets include calcium magnesium acetate, calcium chloride, magnesium chloride, sodium chloride, urea, and potassium acetate.

Deicing and anti-icing chemicals become pollutants when they are conveyed to inlets and catch basins or to receiving waters after application. Leaks and spills of these chemicals can also occur during their handling and storage. These chemicals can reduce oxygen availability for aquatic life.

Discharges of spent glycol in aircraft application areas are process wastewaters regulated under Ecology's Industrial Stormwater General Permit. (Contact Ecology at (360) 407-6000 for details.) BMPs for aircraft deicers and anti-icers must be consistent with aviation safety requirements and the operational needs of the aircraft operator.

Required BMP Elements

The following BMPs or equivalent measures are required for deicing and anti-icing activities related to **aircraft**:

- Implement BMP 1 through BMP 8 for all real property (refer to *Section 2.1*).
- Conduct aircraft deicing and anti-icing applications in impervious containment areas.
- Collect spent deicing liquids (e.g., ethylene and propylene glycols) and anti-icing chemicals (e.g., urea) that drain from aircraft in deicing or anti-icing application areas and convey them to a sanitary sewer, treatment facility, or other approved disposal or recovery method. These chemicals must not enter the drainage conveyance system. Divert runoff of deicing chemicals from paved gate areas to appropriate collection areas or conveyances for proper treatment or disposal.
- Do not allow spent deicing and anti-icing chemicals or contaminated stormwater to be discharged directly or indirectly from application areas, including gate areas, to a receiving water or groundwater.
- Transfer deicing and anti-icing chemicals on an impervious containment pad or an equivalent spill and leak containment area and store them in secondary containment areas.

The following BMPs or equivalent measures are required for deicing and anti-icing activities related to runways and taxiways:

- Avoid excessive application of deicing and anti-icing chemicals, which could contaminate stormwater.

- Store and transfer deicing and anti-icing materials on an impervious containment pad or an equivalent containment area.

The following BMPs or equivalent measures are required for deicing and anti-icing activities related to streets and highways:

- Select deicers and anti-icers that result in the least negative environmental impact, and apply the smallest quantities needed.
- Where possible and practical, use roadway deicers, such as calcium magnesium acetate, potassium acetate, or similar materials, that cause less negative environmental impact than urea and sodium chloride.
- Store and transfer deicing and anti-icing materials on an impervious containment pad.
- Clean up and dispose of accumulated deicing and anti-icing materials and grit from roads as soon as possible after the road surface clears.
- Increase the frequency of maintenance of stormwater structures in areas where deicing and anti-icing activities occur, as necessary.

Recommended BMPs

Although not required, the following BMPs are recommended to further reduce the potential for contamination of stormwater and receiving waters:

Aircraft:

- Establish a centralized aircraft deicing and anti-icing facility, if possible and practical, or conduct deicing and anti-icing in designated areas of the tarmac equipped with separate collection drains for the spent deicing liquids.
- Consider installing a recovery system for aircraft deicing and anti-icing chemicals, or contract with a chemical recycler, if practical.

Airport Runways and Taxiways:

- Include limits on toxic materials and phosphorus in the specifications for deicers and anti-icers, where applicable.
- Consider using anti-icing materials rather than deicers if they will result in less negative environmental impact.
- Select cost-effective deicers and anti-icers that cause the least negative environmental impact.

Streets and Highways:

- Sweep and clean roadways more frequently in early spring to help remove particulates from road surfaces.
- Include limits on toxic metals in the specifications for deicers and anti-icers.

3.6.6. BMP 37: Maintenance and Management of Roofs and Building Surfaces at Industrial and Commercial Buildings

This BMP applies to businesses and public entities where the roofs and sides of industrial or commercial buildings can be sources of pollutants when stormwater runoff results in the leaching of roofing materials, materials from building vents, air emissions, flashing, cleaning agents, applied moss killers, flaking paint, caulking, and other joint materials..

Description of Pollutants

Vapors and entrained liquid and solid droplets and particles have been identified as potential pollutants in roof and building runoff. The pollutants identified include metals, solvents, high acidity (low pH) and alkalinity (high pH), substances that increase biological oxygen demand (BOD), and organic compounds. Flaking paint or caulking may be a source of metals and organic compounds. PCBs may leach out of old paint, coatings, siding, roofing, and caulking materials from buildings, such as those built or renovated between 1950 and 1980, which are considered to be the years when certain building materials were most likely to have contained PCBs.

Entities that conduct specific industrial activities are required to obtain an Industrial NPDES Permit for their stormwater discharges. For more information about whether an entity needs an NPDES permit, refer to Ecology's website (https://ecology.wa.gov/Water-Shorelines/Water-quality/Runoff-pollution/Stormwater) or call Ecology at (360) 407-6000.

Required BMP Elements

The following BMPs or equivalent measures are required for all commercial and industrial buildings to prevent and reduce stormwater pollution:

- Implement BMP 1 through BMP 8 for all real property (refer to *Section 2.1*).
- If leachates or emissions from buildings are suspected sources of stormwater pollutants, sample and analyze the stormwater draining from the building and the sediment from nearby catch basins.
- PCB Assessment:
    - Before conducting exterior building maintenance activities on commercial, industrial or institutional buildings (including on roofs and other surfaces), first conduct a PCB assessment in a manner consistent with Ecology's guidance document *How to Find and Address PCBs in Building Materials* (Ecology 2024).
    - If PCBs are suspected or confirmed on external building materials after conducting the PCB assessment, apply appropriate BMPs to prevent PCB-containing materials and PCB-impacted runoff from entering the public stormwater system, right-of-way, adjacent properties, and surface waterbodies. At a minimum, install filter socks or other inserts in nearby storm drain inlets, avoid abrasive cleaning or other maintenance actions on buildings, frequently sweep adjacent hard surfaces and properly dispose of collected materials, avoid using leaf blowers around the building footprint, and direct runoff to vegetated areas where possible.
        - Do not wash exterior building surfaces suspected or confirmed to contain PCBs unless all washwater is collected and disposed of to the sanitary sewer in

accordance with a discharge authorization permit, or hauled off-site for treatment; washwater from suspected or confirmed PCB-containing buildings must not discharge to the municipal separate storm sewer system (MS4, which includes the drainage system infrastructure as well as streets with drainage features) or surface waters

- If a roof or building is identified as a source of stormwater pollutants, apply appropriate operational source-control measures, such as air pollution control equipment, selection of alternative materials, operational changes, material recycling, process changes, remediation, removal and abatement, or treatment.
- Sweep areas routinely to remove pollutant residues.
- If operational methods do not prevent or reduce zinc pollution from galvanized roofing or siding, paint or coat the galvanized surfaces as described in Publication 08-10-025, *Suggested Practices to Reduce Zinc Concentrations in Industrial Stormwater Discharges* (Ecology 2008) or treat the stormwater runoff.
- If operational BMPs are not sufficient to prevent stormwater contamination, structural controls must be applied, including treatment or containment.
    - If roofs are confirmed or suspected to contain PCBs, structural controls must address runoff directed through roof drains in a manner that prevents discharges entering a storm drain or leaving the site.

3.6.7. BMP 38: Maintenance and Operation of Railroad Yards

This BMP applies to businesses and public entities that perform activities at railroad yards not otherwise covered in this manual, including cleaning, maintenance, and repair of equipment and engines; fueling; waste disposal (including human waste); and all other yard maintenance activities (including vegetation management).

Description of Pollutants

Pollutant sources can include litter; cleaning areas for locomotives, rail cars, and equipment; fueling areas; rail cargo; human waste disposal; outdoor material storage areas; erosion and loss of soil particles from the railroad bed; maintenance and repair activities at railroad terminals, switching yards, and maintenance yards; and herbicides used for vegetation management. Potential pollutants include oils and greases, suspended solids, substances that increase biological oxygen demand (BOD), fecal coliform, organic compounds, pesticides, and metals.

Required BMP Elements

The following BMPs or equivalent measures are required for railroad yards:

- Implement BMP 1 through BMP 8 for all real property (refer to *Section 2.1*).
- Implement the applicable BMPs in this volume specific to the activity that is occurring.
- Do not allow discharge from toilets to outdoor areas. Pump-out facilities should be used to service these units.
- Use drip pans at hose and pipe connections during liquid transfer and other leak-prone areas.
- During maintenance, do not discard debris or waste liquids along the tracks or in railroad yards.
- In areas subject to leaks or spills of oils or other chemicals, direct the contaminated stormwater to an appropriate treatment system such as the sanitary sewer, if approved by SPU and King County, or to an American Petroleum Institute (API) oil/water separator, coalescing plate oil/water separator for floating oils, or an appropriate treatment BMP (refer to *Volume 3 — Project Stormwater Control*).
- Place drip pans, absorbent pads, or other containment measures below leaking vehicles (including inoperable vehicles and equipment) in a manner that catches leaks or spills. Drip pans or other containment measures must be managed to prevent overfilling or pass-through, and the contents must be disposed of properly. Absorbent pads or mats must be weighted down or secured so as not to be blown away and changed out prior to becoming fully saturated.
- During routine maintenance, discharge locomotive cooling systems only after the locomotive has stopped and at a location where the coolant can be collected, managed, and then disposed of properly.
- Handle wastes generated from large-scale equipment cleaning, such as locomotive, track equipment or axle-cleaning operations, properly to avoid harming the environment and to comply with state and federal environmental regulations.

- Store any metal scrap generated from metal punching or other mechanical operations where it will not come in contact with stormwater.
- Place track mats under each rail and flange lubricator that is in service where track mats can be safely installed and maintained without danger to rolling stock or personnel.
- Install track mats at designated engine tie-up and outdoor locomotive parking locations (e.g., service tracks) in SWPPP-permitted areas when locomotives are unattended and idle for extended periods of time.
- Inspect and replace track mats as necessary. Routinely inspect all track mats for tears or saturation and replace as necessary.
- Install spill containment pans and trays or track mats at designated locomotive and railcar maintenance facilities and fixed fueling areas to reduce environmental impacts due to potential spills under locomotives and other track equipment. Direct spill containment pans and trays to an oil/water separator where possible for treatment or collect spilled chemicals for proper disposal.
- During locomotive fueling operations use drip pans or secondary containment to capture any fuel or oil leaks.
- Select cost-effective rail and flange lubricant that provides safe and effective rail operation while considering negative environmental impacts. Consider both the chemical make-up of the lubricant and the likelihood of off-rail transfer during rain events.
- Do not conduct heavy or major locomotive engine repairs on the rail line. Conduct heavy or major engine repairs at an established railroad maintenance facility.
- Store creosote-treated railroad ties in locations that reduce the potential to impact stormwater runoff.

3.6.8. BMP 39: Maintenance of Public and Private Utility Corridors and Facilities

This BMP applies to businesses and public entities that maintain utility corridors and associated equipment at petroleum product pipelines, natural gas pipelines, water pipelines, pump stations, electrical power transmission corridors, and rights-of-way.

Description of Pollutants

Corridors and facilities can be sources of pollutants, such as herbicides used for vegetation management and eroded soil particles generated from unpaved access roads. At pump stations, waste materials generated during maintenance activities are often temporarily stored outdoors and thus can be a source of pollution into inlets and catch basins and receiving waters.

Additional potential pollutant sources include the leaching of preservatives from wood utility poles, older polychlorinated biphenyl (PCB) containing electric transformers, water that is removed from underground transformer vaults, and leaks or spills from petroleum pipelines. Potential pollutants are oils and greases, suspended solids, substances that increase biological oxygen demand (BOD), organic compounds, PCBs, pesticides, and metals.

Required BMP Elements

The following BMPs or equivalent measures are required for activities related to the maintenance of public and agency utility corridors and facilities:

- Implement BMP 1 through BMP 8 for all real property (refer to *Section 2.1*).
- Implement BMP 22 (Landscaping and Vegetation Management) in this Manual, and integrated pest management (IPM) following BMP *S435 — BMPs for Pesticides and an Integrated Pest Management Program* in Volume IV of the SWMMWW (Ecology 2024) (referenced in BMP 49). *Appendix I* of this manual contains information on developing an integrated pest management plan.
- When water or sediments are removed from electric transformer vaults, determine whether contaminants are present before disposing of the water and sediments.
    - Inspect for the presence of oil or oil sheen and determine from records or testing whether the transformers contain or previously contained polychlorinated biphenyls (PCBs).
    - If work is occurring in a vault that has an oil leak, a PCB-containing transformer, or if non-stormwater is encountered (e.g., there is evidence of foam, debris, odors, etc.), collect the water and materials removed into a leak-free container and dispose of it appropriately according to federal and state regulations; do not discharge the materials into the drainage system or a receiving water body.
    - If records or tests indicate that the sediment or water could contain PCBs, manage the sediment or water in accordance with applicable federal and state regulations, including the federal rules for polychlorinated biphenyls (Code of Federal Regulations, Title 40, Part 761) and the state Model Toxics Control Act cleanup regulations (WAC, Chapter 173-340).

  - Water removed from the vaults can be discharged in accordance with the Code of Federal Regulations, Title 40, Section 761.79, and state regulations (Washington Administrative Code, Chapters 173-201A and 173-200), or via the sanitary sewer if the requirements, including applicable permits, for such a discharge are met.

- Follow maintenance practices to prevent stormwater from accumulating and draining across or onto roadways. Stormwater should be conveyed through roadside ditches and culverts. The road should be crowned, outsloped, water barred, or otherwise left in a condition that is not conducive to erosion.
- Maintain ditches and culverts often enough to prevent plugging and flooding across the roadbed resulting in overflow erosion.
- Apply all other appropriate BMPs in this volume for the storage of waste materials that can contaminate stormwater.
- Stabilize access roads or areas of bare ground with gravel, crushed rock, or another method to prevent erosion. Use and manage vegetation to reduce bare ground and soils that may be susceptible to erosion.

Recommended BMPs

Although not required, the following BMPs can further prevent and reduce stormwater contamination:

- Maintain vegetation in roadside ditches that discharge to receiving waters to remove some pollutants associated with sediments carried by stormwater.
- When selecting utility poles for a specific location, consider the potential environmental effects of the pole or poles during their storage, handling, and end use.
- If a wood product treated with chemical preservatives is used, it should be made in accordance with generally accepted industry standards such as the American Wood Preservers Association Standards.
- If the pole or poles will be placed in or near a drinking water well or a critical area, consider alternative materials or technologies. These include poles made of material(s) other than wood, such as fiberglass composites, metal, or concrete.
- Consider using other technologies and materials, such as sleeves or caissons for wood poles, when they are determined to be practical and available.
- As soon as practical, remove all litter from wire cutting and replacement operations.

3.6.9. BMP 40: Maintenance of Roadside Ditches

This BMP applies to businesses and public entities that perform activities related to the maintenance of roadside ditches, which can present a high risk of polluting stormwater because the ditches in which work is performed flow into the drainage system. Roadside ditches also play an important role in conveying runoff and preventing localized flooding.

Ditches owned or operated by a state, city, town, county, or other public body that is designed or used for conveying stormwater are included in the definition of a Municipal Separate Storm Sewer System (MS4) (see MS4 definition in Ecology's 2024 Phase I MS4 Permit).

Description of Pollutants

Sources of stormwater pollutants from common road debris include particles from tire wear, dripped oil, and other fluids; chemicals used in deicing; pesticides; herbicides; eroded or contaminated soil; and metals.

Required BMP Elements

The following BMPs or equivalent measures are required for activities related to the maintenance of roadside ditches:

- Implement BMP 1 through BMP 8 for all real property (refer to *Section 2.1*).
- Implement BMPs for Landscaping and Vegetation Management (BMP 22) and integrated pest management (IPM) following *S435 — BMPs for Pesticides and an Integrated Pest Management Program* in Volume IV of the SWMMWW (Ecology 2024) (referenced in BMP 49).
- Inspect roadside ditches regularly to identify sediment accumulations and areas of localized erosion.
- Clean ditches on a regular basis, as needed:
    - Keep ditches free of rubbish and debris.
    - Maintain ditches (seeding, fertilizer application, and harvesting) when most effective, usually in late spring or early fall and avoid maintenance during heavy rainfall. This allows re-establishment of vegetative cover by the next wet season, thereby reducing erosion of the ditch.
    - Do not apply fertilizer unless needed to maintain vegetative growth.
    - Do not leave material from the ditch cleaning on roadway surfaces.
    - Sweep and remove dirt and debris that remains on the pavement at the completion of ditch cleaning operations.
    - Separate clean and uncontaminated roadside ditch cleaning materials from suspect or contaminated materials. Non-contaminated soils may be handled as "clean soils" and non-contaminated vegetative matter can be composted or disposed of in a municipal waste landfill, if permitted. Suspected contaminated or contaminated material removed from ditches must be tested and handled according to the Dangerous Waste Regulations (WAC, Chapter 173-303) unless testing indicates that it is not dangerous waste.

- Vegetation in ditches often prevents erosion and cleanses runoff:
  - Remove vegetation only when flow is blocked or excess sediments have accumulated.
  - Use grass vegetation, unless specified otherwise by SPU.
  - Establish vegetation from the edge of the pavement if possible or at least from the top of the slope of the ditch.
  - Use temporary erosion and sediment control measures or re-vegetate as necessary to prevent erosion during ditch reshaping.
- Diversion ditches on top of cut slopes that are constructed to prevent slope erosion by intercepting surface drainage must be maintained to retain their diversion shape and capability.
- Inspect culverts on a regular basis for scour or sedimentation at the inlet and outlet, and repair as necessary. Give priority to culverts that are conveying perennial or salmon-bearing streams and to culverts near streams in areas of high sediment load, such as those near subdivisions during construction. Maintain trash racks to avoid damage, blockage, or erosion of culverts.
- Waste generated from ditch maintenance, i.e., spoils and debris, may be contaminated and require specialized disposal. Consult Dangerous Waste Regulations found in WAC 173-303.
- Note: Work in wet areas may be regulated by local, state, or federal laws that impose obligations on the responsible party.

3.6.10. BMP 41: Potable Water Line Flushing, Water Tank Maintenance, and Hydrant Testing

This BMP applies to businesses and public entities that perform activities related to potable water line flushing, water tank maintenance, and hydrant testing.

Description of Pollutants

Improper water line flushing, water tank maintenance, and hydrant testing may result in the discharge of sediments and materials to water bodies. Chemicals associated with water line flushing and water tank maintenance, such as chlorine, may be harmful to aquatic organisms and have a negative effect on receiving water bodies.

Required BMP Elements

Required BMP elements are contained in *S441 — BMPs for Potable Water Line Flushing, Water Tank Maintenance, and Hydrant Testing* in Volume IV of the SWMMWW (Ecology 2024).

Discharges from potable water sources to drainage systems may be conditionally allowed (refer to SMC, Section 22.802.030) if they are de-chlorinated to a total residual chlorine concentration of 0.1 ppm or less, pH adjusted if necessary, and volumetrically and velocity controlled to prevent resuspension of sediments in the stormwater conveyance system. These discharges must be reported to Seattle Public Utilities at (206)386-1800 if they impact the City's MS4.

3.6.11. BMP 42: Urban Streets

This BMP applies to businesses and public entities that perform activities on urban streets.

Description of Pollutants

Urban streets can be a source of pollutants such as soil, fine dust, vegetation, nutrients, trash, oil and grease, vehicle combustion products, ice control salts, and pollutants that wash onto roadways from other areas.

Required BMP Elements

Required BMP elements are contained in *S430 — BMPs for Urban Streets* in Volume IV of the SWMMWW (Ecology 2024).

3.6.12. BMP 43: Nurseries and Greenhouses

This BMP applies to businesses and public entities that operate nurseries and greenhouses.

Description of Pollutants

Nurseries and greenhouses can be a source of nutrients (phosphorus, nitrogen, etc.), sediment, bacteria, and organic matter that can degrade water quality.

Required BMP Elements

Required BMP elements are contained in *S449 — BMPs for Nurseries and Greenhouses* in Volume IV of the SWMMWW (Ecology 2024).

3.6.13. BMP 44: Color Events

This BMP applies to the general public, businesses, and religious and commercial entities that participate in, host, or sponsor color events.

Description of Pollutants

The dye materials used in color events can degrade water quality and impact aquatic life. Even if the dye is labeled "biodegradable" or "nontoxic" it is not allowed to be discharged into storm drains or water bodies.

> The term "biodegradable" on a product label does not mean that the product is safe or environmentally friendly. The product may degrade faster than alternative products but can still be harmful to the environment.

Required BMP Elements

Required BMP elements are contained in *S436 — BMPs for Color Events* in Volume IV of the SWMMWW (Ecology 2024).

3.6.14. BMP 45: Pet Waste

This BMP applies to the general public, businesses, and public entities.

Description of Pollutants

Pet waste can carry viruses and bacteria that could cause disease and lead to beach closures or bans on shellfish harvesting.

Required BMP Elements

Required BMP elements are contained in *S440 — BMPs for Pet Waste* in Volume IV of the SWMMWW (Ecology 2024).

3.6.15. BMP 46: Labeling Storm Drain Inlets on Your Property

This BMP applies to businesses and public entities.

Description of Pollutants

Storm drain inlets themselves are not a source of pollutants; however, they can be used to discharge pollutants. Labels on storm drains can educate the public about bans on dumping materials into storm drains.

Required BMP Elements

Required BMP elements are contained in *S442 — BMPs for Labeling Storm Drain Inlets on Your Property* in Volume IV of the SWMMWW (Ecology 2024).

3.6.16. BMP 47: Well, Utility, Directional, and Geotechnical Drilling

This BMP applies to businesses and public entities that are involved with drilling activities.

Description of Pollutants

Drilling activities can allow exposed soil and contaminated soil to wash into the drainage system.

Required BMP Elements

Required BMP elements are contained in *S446 — BMPs for Well, Utility, Directional, and Geotechnical Drilling* in Volume IV of the SWMMWW (Ecology 2024).

3.6.17. BMP 48: Goose Waste

This BMP applies to the general public, businesses, and public entities.

Description of Pollutants

Goose waste can contribute to algae growth in water due to its high nutrient content. Goose feces may contain pathogens that can affect people who use receiving waters.

Required BMP Elements

Required BMP elements are contained in *S452 — BMPs for Goose Waste* in Volume IV of the SWMMWW (Ecology 2024).

3.6.18. BMP 49: Pesticides and an Integrated Pest Management Program

This BMP applies to businesses and public entities that use pesticides.

Description of Pollutants

Inadequate management of pesticides can allow them to enter stormwater and receiving waters, resulting in impacts on non-targeted organisms.

Required BMP Elements

Required BMP elements are contained in *Appendix I* of this manual and *S435 — BMPs for Pesticides and an Integrated Pest Management Program* in Volume IV of the SWMMWW (Ecology 2024).

3.6.19. BMP 50: Storage of Dry Pesticides and Fertilizers

This BMP applies to businesses and public entities that store dry pesticides and fertilizers.

Description of Pollutants

Inappropriate management of pesticides and fertilizers results in contamination of stormwater and receiving waters, which can degrade water quality and negatively affect fish and other aquatic life.

Required BMP Elements

Required BMP elements are contained in *S435 — BMPs for Pesticides and an Integrated Pest Management Program* in Volume IV of the SWMMWW (Ecology 2024).

3.6.20. BMP 51: Irrigation

This BMP applies to businesses and public entities that have irrigation systems.

Description of Pollutants

Improper irrigation can encourage pest problems, leach nutrients, and make a lawn completely dependent on artificial watering.

Required BMP Elements

Required BMP elements are contained in *S450 — BMPs for Irrigation* in Volume IV of the SWMMWW (Ecology 2024).

3.6.21. BMP 52: Dock Washing

This BMP applies to the general public, businesses, and public entities that are involved in dock washing.

Description of Pollutants

Washing docks can result in the discharge of dirt and other pollutants that may be toxic to aquatic life.

Required BMP Elements

Required BMP elements are contained in *S434 — BMPs for Dock Washing* in Volume IV of the SWMMWW (Ecology 2024).

3.6.22. BMP 53: Roof Vents

This BMP applies to businesses and public entities that have roof vents.

Description of Pollutants

This BMP applies to processes that vent emissions to the roof, result in the accumulation of pollutants on roofs, or both. Pollutants from these processes may build up on roofs and may pollute stormwater runoff. Also see BMP 37.

Required BMP Elements

Required BMP elements are contained in *S447 — BMPs for Roof Vents* in Volume IV of the SWMMWW (Ecology 2024).

3.6.23. BMP 54: Streets and Highways

This BMP applies to businesses and public entities that maintain and apply deicers and anti-icers to streets and highways.

Streets include sidewalks, roadways, woonerfs, and other parts of the right-of-way, but do not include parking lots (see SMC 23.84A.036 for these definitions).

Description of Pollutants

This BMP applies to maintenance and deicing and anti-icing of streets and highways. Chemicals used for deicing and anti-icing may be harmful to aquatic organisms.

Required BMP Elements

Required BMP elements are contained in *S406 — BMPs for Streets and Highways* in Volume IV of the SWMMWW (Ecology 2024).

3.6.24. BMP 55: Fertilizer Application

This BMP applies to businesses and public entities that use fertilizers.

Description of Pollutants

Improper application of fertilizer can be a source of nutrients (phosphorus, nitrogen, etc.) that can degrade water quality.

Required BMP Elements

Required BMP elements are contained in *S443 — BMPs for Fertilizer Application* in Volume IV of the SWMMWW (Ecology 2024).

3.6.25. BMP 56: Light Rail Washing

This BMP applies to washing of light rail elevated guideways and light rail vehicles.

Description of Pollutants

Potential pollutant sources are from the light rail electrical and mechanical components that may include metals, dust, and hydrocarbons. Improper washing of light rail guideways and vehicles will result in contributions of pollutants to the area surrounding the elevated guideways.

Required BMP Elements

Required BMP elements are contained in ***S453 — BMPs for Washing Light Rail Elevated Guideways and S454 — BMPs for Washing Light Rail Vehicles*** (Ecology 2024).

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VOLUME 5

ENFORCEMENT

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Note:

Some pages in this document have been purposely skipped or blank pages inserted so that this document will copy correctly when duplexed.

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CHAPTER 1 – Introduction

The City of Seattle Department of Construction and Inspection (SDCI) and Seattle Public Utilities (SPU) produced this document as a joint Directors' Rule (DR) to interpret the enforcement provisions that are described in the Seattle Municipal Code (SMC) 22.800 through 22.808 (Stormwater Code). This volume is designed to help clarify the application of enforcement in Seattle.

If the Director finds a violation of the Stormwater Code has occurred or is occurring, a Notice of Violation (NOV) or an Order is given to the responsible party of that violation. The civil penalty attached with the NOV or Order is determined using the enforcement penalty matrix described in Section 2.1.

CHAPTER 2 – Penalty Assessment Matrix

2.1. Enforcement Penalty Matrix

The enforcement penalty matrix (Table 1) is composed of a set of criteria formulated as questions for the Director to evaluate and answer. The Director uses 22.808.050 to determine the total points to be assessed according to the violation. Once the total number of penalty points is determined, a rating and a corresponding penalty amount is established (Table 2).

Table 1. Enforcement Penalty Matrix.

Enforcement Evaluation Criterion	No (0 points)	Possibly (1 point)	Probably (2 points)	Definitely (3 points)
Public Health Risk?				
Environmental Damage or Adverse Impacts to Infrastructure?				
Willful or Knowing Violation?				
Unresponsive in Correcting Action?				
Improper or Inadequate Operation or Maintenance?				
Failure to Obtain and Comply with Necessary Permits, Certifications, and Approvals?				
Economic Benefit to Non-compliance?				
Repeat Violation?				

Table 2. Penalty Points Rating and Corresponding Penalty Amount.

Rating	1–2	3–4	5–8	9–11	12–14	15
Penalty	$250	$500	$1,000	$1,500	$2,000	$2,500
Rating	**16**	**17**	**18**	**19**	**20+**	
Penalty	$3,000	$3,500	$4,000	$4,500	$5,000	

2.2. Application of Penalty Criteria

The framework below provides guidance on how to rate each criterion of the enforcement penalty matrix (Table 1). The civil penalty is determined by the total score of the matrix.

1. Did the violation pose a public health risk[1]?
    a. Answer “no” if there is no evidence to support a claim of public health risk or adverse health effects.
    b. Answer “possibly” if evidence supports a claim of public health risk and there is a plausible connection between this violation and health effect(s).
    c. Answer “probably” if evidence supports a claim of public health risk and there is a likely connection between this violation and health effect(s).
    d. Answer “definitely” if there is direct evidence linking public health risk or adverse effects with the violation.
2. Did the violation result in environmental damage or adverse impacts to infrastructure[2]?
    a. Answer “no” if there is no evidence to support a claim of environmental or infrastructure damage.
    b. Answer “possibly” if environmental or infrastructure damage can be inferred from evidence or knowledge of the effects of the violation.
    c. Answer “probably” if there is evidence to support a claim of environmental or infrastructure damage and there is a likely connection between the violation and the damage or impairment.
    d. Answer “definitely” if there is direct evidence linking environmental or infrastructure damage with the violation.
3. Was the action a willful and knowing violation?
    a. Answer “no” if the violator obviously did not know that the action or inaction constituted a violation.
    b. Answer “possibly” if the violator should have known.
    c. Answer “probably” if it is likely the violator knew.
    d. Answer “definitely” if the violator clearly knew or was previously informed by inspectors.

[1] Risk involving the physical or social well-being of a community or environment.

[2] Results in damage to publicly owned infrastructure that contributes to its impairment.

4. Was the responsible party[3] unresponsive in correcting the violation?
    a. Answer “no” if the violation was corrected as soon as the responsible party learned of it.
    b. Answer “possibly” if the violation was corrected in a less than timely and cooperative fashion.
    c. Answer “probably” if the responsible person made some attempt to correct the problem but did not correct it.
    d. Answer “definitely” if the responsible party made no attempt to correct the violation.
5. Was the violation the result of improper operation, inadequate maintenance, or inadequate implementation of a required plan that addresses stormwater management (e.g., O&M[4] manual, DCP[5], SWPPP[6], or TESC[7] plan)?
    a. Answer “no” if the violation was not the result of improper operation or inadequate maintenance.
    b. Answer “possibly” if the facility has an O&M manual, DCP, SWPPP, or TESC plan, but it is out of date or inadequate.
    c. Answer “probably” if there is no O&M manual, DCP, SWPPP, or TESC plan and the violation would have been less severe if the plan were developed and followed.
    d. Answer “definitely” if the facility has no O&M manual, DCP, SWPPP, or TESC plan or did not follow its plan AND the violation was clearly the result of improper operation or maintenance.
6. Did the responsible party fail to obtain and comply with relevant permits, certifications, and approvals that require or would have required the responsible party to manage stormwater in a manner that could have prevented or mitigated the Code violation?
    a. Answer “no” if the paperwork was complete and appropriate for the job or task that caused the violation.
    b. Answer “possibly” if the responsible party obtained and received approval for some but not all of the required permit(s).

[3] Owners, operators, and occupants of property, and any person causing or contributing to a violation of the City Code are considered a “responsible party” for purposes of a Code violation (SMC, Section 22.801.190).

[4] Operations and maintenance

[5] Drainage Control Plan

[6] Stormwater Pollution Prevention Plan

[7] Temporary Erosion and Sediment Control

c. Answer “probably” if the responsible party obtained some but not all of the required permit(s) and did not receive approvals for the job or task that caused the violation.

d. Answer “definitely” if the responsible party either did not obtain the necessary permits or did obtain permits but did not comply with their conditions.

7. Did anyone benefit economically[8] from non-compliance?

   a. Answer “no” if it is clear that no one gained an economic benefit.

   b. Answer “possibly” if someone might have benefited.

   c. Answer “probably” if anyone benefited, but the benefit is not quantifiable.

   d. Answer “definitely” if the economic benefit is quantifiable.

8. Is this violation a repeat violation[9]?

   a. Answer “no” to indicate that there have been no prior violations.

   b. Answer “possibly” to indicate that there has been one prior violation.

   c. Answer “probably” to indicate that there have been two prior violations.

   d. Answer “definitely” to indicate that there have been three or more prior violations.

[8] Gain or no loss in resources.

[9] From Stormwater Code (SMC, Section 22.801.190): “Repeat violation” means a prior violation of this subtitle within the preceding 5 years that became a final order or decision of the Director or a court. The violation does not need to be the same nor occur on one site to be considered repeat.

APPENDIX A
Definitions

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A

- “Agency” means any governmental entity or its subdivision (SMC, Subsection 22.801.020.A).
- "Agency, City" means "City agency" as defined in Section 25.09.520. (SMC, Subsection 22.801.020.A)
- “Approved” means approved by the Director (SMC, Subsection 22.801.020.A).
- “Aquatic life use, fresh water” means "aquatic life uses" as defined in WAC 173-201A-200 (Fresh Water Designated Uses and Criteria). For the purposes of this subtitle, at minimum the following water bodies are designated for fresh water aquatic life use: small lakes, streams, wetlands, and fresh water designated receiving waters (SMC, Subsection 22.801.020.A).
- “Aquatic life use, marine water” means "aquatic life uses" as defined in WAC 173-201A-210 (Marine Water Designated Uses and Criteria) and includes marine surface waters of the state of Washington (SMC, Subsection 22.801.020.A).
- “Arterial” means "arterial" as defined in Section 11.14.035 (SMC, Subsection 22.801.020.A).

B

- “Basic treatment facility” means a drainage control facility designed to reduce concentrations of total suspended solids in drainage water (SMC, Subsection 22.801.030.B).
- “Basic treatment receiving water” means:
  1. All marine waters, including Puget Sound;
  2. Lake Union;
  3. Lake Washington;
  4. Ship Canal and bays between Lake Washington and Puget Sound; and
  5. Duwamish River (SMC, Subsection 22.801.030.B).
- “Best management practice” (BMP) means a schedule of activities, prohibitions of practices, operational and maintenance procedures, structural facilities, or managerial practice or device that, when used singly or in combination, prevents, reduces, or treats contamination of drainage water, prevents or reduces soil erosion, or prevents or reduces other adverse effects of drainage water. When the Directors develop rules and/or manuals prescribing BMPs for particular purposes, whether or not those rules and/or manuals are adopted by ordinance, BMPs specified in the rules and/or manuals shall be the BMPs required for compliance with this subtitle (SMC, Subsection 22.801.030.B).
- “Building permit” means a document issued by the Seattle Department of Construction and Inspections authorizing construction or other specified activity in accordance with the Seattle Building Code or the Seattle Residential Code (SMC, Subsection 22.801.030.B).

C

- “Capacity-constrained system” means a drainage system or public combined sewer that the Director of SPU has determined to have inadequate capacity to carry existing and anticipated loads, or a drainage system that includes ditches or culverts (SMC, Subsection 22.801.040.C).
- “Certified Erosion and Sediment Control Lead” (CESCL) means an individual who has current certification through an approved erosion and sediment control training program that meets the minimum training standards established by Ecology (SMC, Subsection 22.801.040.C).
- “Civil engineer, licensed” means a person who is licensed by the State of Washington to practice civil engineering (SMC, Subsection 22.801.040.C).
- “City agency” means "City agency" as defined in Section 25.09.520 (SMC, Subsection 22.801.040.C).
- “Closely related projects” means two or more projects that are concurrently under review, under issued permits not yet approved for final construction, or both, and share any of the following physical or functional interdependencies:
    1. A feature physically spans the property lines between lots or the project sites, such as shared structures, shared driveways, shared pedestrian access (including easements to rights-of-way), shared drainage and utility designs, foundation footings, or retaining walls. For purposes of this subsection, abutting driveways or pedestrian accesses are not considered to span the property lines if the required driveway or pedestrian access width for each project independently meets development standards;
    2. A shared driveway is proposed to access a parking area for more than one project, regardless of whether the parking is required;
    3. Parking, including maneuvering, aisle requirements, or other parking related easements, regardless of whether the parking is required, is proposed to be provided (or partially provided) on the site of another project, even if the project sites do not abut each other;
    4. Proposed structures are joined or share a common wall;
    5. Proposed projects share required open space, amenity area, or both;
    6. The design of two or more project sites are dependent on grading, construction of retaining walls or foundations, or both across the lot lines or project sites;
    7. One site is required to permanently access, construct, and maintain the structures or development features on an abutting or adjacent site; or
    8. Other features that create physical or functional interdependence between the projects (SMC, Subsection 22.801.040.C).
- “Combined sewer.” See "public combined sewer" (SMC, Subsection 22.801.040.C).
- “Combined sewer basin” or “public combined sewer basin” means the area tributary to a public combined sewer feature, including, but not limited to, a combined sewer overflow outfall, trunk line connection, pump station, or regulator (SMC, Subsection 22.801.040.C).

- "Common Plan of Development or Sale" means a site where multiple separate and distinct construction activities may be taking place at different times on different schedules and/or by different contractors, but still under a single plan. Examples of "common plan of development or sale" include:
    1. Phased projects and projects with multiple filings/lots, even if the separate phases or filings/lots will be constructed under separate contract or by separate owners (e.g., a development where lots are sold to separate builders);
    2. A development plan that may be phased over multiple years, but is still under a consistent plan for long-term development;
    3. Projects in a contiguous area that may be unrelated but still under the same contract, such as construction of a building extension and a new parking lot at the same facility; and
    4. Linear projects such as roads, pipelines, or utilities (SMC, Subsection 22.801.040.C).
- "Compaction" means the densification, settlement, or packing of earth material or fill in such a way that permeability is reduced by mechanical mean (SMC, Subsection 22.801.040.C).
- "Construction stormwater control plan" means a document that explains and illustrates the measures to be taken on the construction site to prevent erosion and discharge of sediment and other pollutants on a construction project (SMC, Subsection 22.801.040.C).
- "Construction wastewater (also known as construction process water)" is wastewater generated as a result of construction activities and includes process wastewater that is not fit for discharge to receiving waters.
- "Containment area" means the area designated for conducting pollution-generating activities for the purposes of implementing source controls or designing and installing source controls or treatment facilities (SMC, Subsection 22.801.040.C).
- "Contaminate" means the addition of sediment, any other pollutant or waste, or any illicit or prohibited discharge (SMC, Subsection 22.801.040.C).
- "Creek" means "stream" as defined by Section 22.801.200 and is used synonymously (SMC, Subsection 22.801.040.C).

D

- "Damages" means monetary compensation for harm, loss, costs, or expenses incurred by the City, including, but not limited, to the following: costs of abating or correcting violations of this subtitle; fines or penalties the City incurs as a result of a violation of this subtitle; and costs to repair or clean the public drainage system or public combined sewer as a result of a violation. For the purposes of this subtitle, damages do not include compensation to any person other than the City (SMC, Subsection 22.801.050.D).
- "Designated receiving waters" means the Duwamish River, Puget Sound, Lake Washington, Lake Union, Elliott Bay, Portage Bay, Union Bay, the Lake Washington Ship Canal, and other receiving waters determined by the Director of SPU and approved by Ecology as having sufficient capacity to receive discharges of drainage

water such that a site discharging to the designated receiving water is not required to implement flow control (SMC, Subsection 22.801.050.D).

- "Detention" means temporary storage of drainage water for the purpose of controlling the drainage discharge rate (SMC, Subsection 22.801.050.D).
- "Development" means the following activities:
  1. Class IV-general forest practices that are conversions from timberland to other uses;
  2. Land disturbing activity;
  3. The addition or replacement of hard surfaces;
  4. Expansion of a building footprint or addition or replacement of a structure;
  5. Structural development, including construction, installation, or expansion of a building or other structure;
  6. Seeking approval of a building permit, other construction permit, grading permit, street improvement permit, or master use permit that involves any of the foregoing activities; and
  7. Seeking approval of subdivision, short plat, unit lot subdivision, or binding site plans, as defined and applied in chapter 58.17 RCW, or other master use permit.

  Development is a type of project (SMC, Subsection 22.801.050.D).
- "Dewatering" is the act of removing groundwater or construction stormwater away from a construction site. See definitions for Construction Stormwater Dewatering or Groundwater Dewatering.
- "Dewatering, Construction Stormwater" is the removal of stormwater from a construction site. Construction stormwater does not include construction (process) wastewater or groundwater.
- "Dewatering, Groundwater" is the removal of groundwater, both temporary and permanent, from a project site. Examples of temporary groundwater dewatering include dewatering of groundwater during construction (e.g. trench dewatering, well-point dewatering, dewatering from sumps in excavations)—and dewatering for temporary remediation systems. Examples of permanent groundwater dewatering include dewatering through foundation drainage systems that extend into any zone of groundwater, perched or otherwise, as well as any other subsurface drainage system that extends into a zone of groundwater. See Groundwater definition.
- "Director" means the Director of the Department authorized to take a particular action, and the Director's designees, who may be employees of that department or another City department (SMC, Subsection 22.801.050.D).
- "Director of SDCI" means the Director of the Seattle Department of Construction and Inspections or the designee of the Director of the Seattle Department of Construction and Inspections, who may be employees of that department or another City department (SMC, Subsection 22.801.050.D).
- "Director of SDOT" means the Director of Seattle Department of Transportation of The City of Seattle or the designee of the Director of Seattle Department of Transportation, who may be employees of that department or another City department (SMC, Subsection 22.801.050.D).

- "Director of SPU" means the General Manager and Chief Executive Officer of Seattle Public Utilities of The City of Seattle or the designee of the General Manager and Chief Executive Officer of Seattle Public Utilities, who may be employees of that department or another City department (SMC, Subsection 22.801.050.D).
- "Discharge point" means the location from which drainage water from a site is released (SMC, Subsection 22.801.050.D).
- "Discharge rate" means the rate at which drainage water is released from a site. The discharge rate is expressed as volume per unit of time, such as cubic feet per second (SMC, Subsection 22.801.050.D).
- "Drainage basin" means the geographic and hydrologic tributary area or subunit of a watershed through which drainage water is collected, regulated, transported, and discharged to receiving waters (SMC, Subsection 22.801.050.D).
- "Drainage basin plan" means a plan to manage the quality and quantity of drainage water in a watershed or a drainage basin, including watershed action plans (SMC, Subsection 22.801.050.D).
- "Drainage control" means the management of drainage water. Drainage control is accomplished through one or more of the following: collecting, conveying, and discharging drainage water; controlling the discharge rate from a site; controlling the flow duration from a site; controlling the quantity from a site; and separating, treating or preventing the introduction of pollutants (SMC, Subsection 22.801.050.D).
- "Drainage control facility" means any facility, including best management practices, installed or constructed for the purpose of controlling the discharge rate, flow duration, quantity, and/or quality of drainage water (SMC, Subsection 22.801.050.D).
- "Drainage control plan" means a plan for collecting, controlling, transporting and disposing of drainage water falling upon, entering, flowing within, and exiting the site, including designs for drainage control facilities (SMC, Subsection 22.801.050.D).
- "Drainage system" means a system intended to collect, convey and control release of only drainage water. The system may be either publicly or privately owned or operated, and the system may serve public or private property. It includes components such as pipes, ditches, culverts, curbs, gutters, and drainage control facilities. Drainage systems are not receiving waters (SMC, Subsection 22.801.050.D)
- "Drainage water" means stormwater and all other discharges that are permissible pursuant to subsections 22.802.030.A and 22.802.030.B (SMC, Subsection 22.801.050.D).

E

- "Earth material" means any rock, gravel, natural soil, fill, or re-sedimented soil, or any combination thereof, but does not include any solid waste as defined by chapter 70A.205 RCW (SMC, Subsection 22.801.060.E).
- "Ecology" means the Washington State Department of Ecology (SMC, Subsection 22.801.060.E).
- "Effective hard surface" means those hard surfaces that are connected via sheet flow or discrete conveyance to a drainage system (SMC, Subsection 22.801.060.E).

- “Environmentally critical area” (ECA) means an area designated in Section 25.09.012 (SMC, Subsection 22.801.060.E).
- “EPA” means the United States Environmental Protection Agency (SMC, Subsection 22.801.060.E).
- “Erodible or leachable materials” means wastes, chemicals, or other substances which, when exposed to rainfall, measurably alter the physical or chemical characteristics of the drainage water. Examples include: erodible soils that are stockpiled; leachable materials that are stockpiled; uncovered process wastes; manure; fertilizers; oily substances; ashes, kiln dust; and garbage dumpster leakage (SMC, Subsection 22.801.060.E).
- “Erosion” means the wearing away of the ground surface as a result of mass wasting or of the movement of wind, water, ice, or other geological agents, including such processes as gravitational creep. Erosion also means the detachment and movement of soil or rock fragments by water, wind, ice, or gravity (SMC, Subsection 22.801.060.E).
- “Excavation” means the mechanical removal of earth material (SMC, Subsection 22.801.060.E).
- “Exception” means relief from a requirement of this subtitle to a specific project (SMC, Subsection 22.801.060.E).
- “Existing grade” means "existing grade" as defined in Section 22.170.050 (SMC, Subsection 22.801.060.E).

F

- “Fill” means a deposit of earth material placed by artificial means (SMC, Subsection 22.801.070.F).
- “Flow control” means controlling the discharge rate, flow duration, or both of drainage water from the site through means such as infiltration or detention (SMC, Subsection 22.801.070.F).
- “Flow control facility” means a drainage control facility for controlling the discharge rate, flow duration, or both of drainage water from a site (SMC, Subsection 22.801.070.F).
- “Flow duration” means the aggregate time that peak flows are at or above a particular flow rate of interest (SMC, Subsection 22.801.070.F).

G

- “Garbage” means putrescible waste (SMC, Subsection 22.801.080.G).
- “Geotechnical engineer” or “Geotechnical/civil engineer” means a person licensed by The State of Washington as a professional civil engineer who has expertise in geotechnical engineering (SMC, Subsection 22.801.080.G).
- “Grading” means excavation, filling, in-place ground modification, removal of roots or stumps that includes ground disturbance, stockpiling of earth materials, or any combination thereof, including the establishment of a grade following demolition of a structure (SMC, Subsection 22.801.080.G).

- "Green stormwater infrastructure" means distributed BMPs, integrated into a project design, that use infiltration, filtration, storage, or evapotranspiration, or provide stormwater reuse (SMC, Subsection 22.801.080.G).
- "Groundwater" means "groundwater" as defined in chapter 173-200 WAC (Water Quality Standards for Groundwaters of the State of Washington) and includes water, perched or otherwise, in a saturated zone or stratum beneath the surface of land or below a surface water body (SMC, Subsection 22.801.080.G).

H

- "Hard surface" means an impervious surface, a permeable pavement, or a vegetated roof (SMC, Subsection 22.801.090.H).
- "High-use sites" means sites that typically generate high concentrations of oil due to high traffic turnover or the frequent transfer of oil or other petroleum products. High-use sites include:
    1. An area of a commercial or industrial site subject to an expected average daily traffic (ADT) count equal to or greater than 100 vehicles per 1,000 square feet of gross building area; 300 or more total trip ends per day; or both;
    2. An area of a commercial or industrial site subject to petroleum storage and transfer in excess of 1,500 gallons per year, not including routinely delivered heating oil;
    3. An area of a commercial or industrial site subject to parking, storage or maintenance of 25 or more vehicles that are over 10 tons gross weight (trucks, buses, trains, heavy equipment, etc.);
    4. A road intersection with a measured ADT count of 25,000 vehicles or more on the main roadway and 15,000 vehicles or more on any intersecting roadway, excluding projects proposing primarily pedestrian or bicycle use improvements (SMC, Subsection 22.801.090.H).

I

- "Illicit connection" means any direct or indirect infrastructure connection to the public drainage system or receiving water that is not intended, not permitted, or not used for collecting drainage water (SMC, Subsection 22.801.100.I).
- "Impervious surface" means any surface exposed to rainwater from which most water runs off. Impervious surfaces include, but are not limited to, roof tops, walkways, patios, driveways, formal planters, parking lots or storage areas, concrete or asphalt paving, areas with underdrains designed to remove stormwater from subgrade (e.g. playfields, athletic fields, rail yards), gravel surfaces subject to vehicular use, compact gravel, packed earthen materials, and oiled macadam or other surfaces which similarly impede the natural infiltration of stormwater. Open, uncovered retention/detention facilities shall not be considered as impervious surfaces for the purposes of determining whether the thresholds for application of minimum requirements are exceeded. Open, uncovered retention/detention facilities shall be considered impervious surfaces for purposes of stormwater modeling (SMC, Subsection 22.801.100.I).

- “Industrial activities” means material handling, transportation, or storage; manufacturing; maintenance; treatment; or disposal. Areas with industrial activities include plant yards, access roads and rail lines used by carriers of raw materials, manufactured products, waste material, or by-products; material handling sites; refuse sites; sites used for the application or disposal of process waste waters; sites used for the storage and maintenance of material handling equipment; sites used for residual treatment, storage, or disposal; shipping and receiving areas; manufacturing buildings; storage areas for raw materials, and intermediate and finished products; and areas where industrial activity has taken place in the past and significant materials remain and are exposed to stormwater (SMC, Subsection 22.801.100.I).
- “Infiltration” means the downward movement of water from the surface to the subsoil (SMC, Subsection 22.801.100.I).
- “Infiltration facility or Infiltration BMP” means a drainage control facility that temporarily stores, and then percolates, drainage water into the underlying soil (SMC, Subsection 22.801.100.I).
- “Integrated Drainage Plan” means a plan developed, reviewed, and approved pursuant to subsection 22.800.080.E (SMC, Subsection 22.801.100.I).
- “Interflow” means that portion of rainfall and other precipitation that infiltrates into the soil and moves laterally through the upper soil horizons until intercepted by a stream channel or until it returns to the surface (SMC, Subsection 22.801.100.I).
- “Inspector” means a City inspector, their designee, or licensed civil engineer performing the inspection work required by this subtitle (SMC, Subsection 22.801.100.I).

L

- “Land disturbing activity” means any activity that results in a change in the existing soil cover, both vegetative and nonvegetative, or the existing topography. Land disturbing activities include, but are not limited to, clearing, grading, filling, excavation, or addition of new or the replacement of hard surface. Compaction, excluding hot asphalt mix, that is associated with stabilization of structures and road construction is also considered a land disturbing activity. Vegetation maintenance practices, including landscape maintenance and gardening, are not considered land disturbing activities. Stormwater facility maintenance is not considered land disturbing activity if conducted according to established standards and procedures (SMC, Subsection 22.801.130.L).
- “Large project” means a project including:
  1. 5,000 square feet or more of new plus replaced hard surface; or
  2. 10,000 square feet or more of land disturbing activity (SMC, Subsection 22.801.130.L).
- “Listed creeks” means Blue Ridge Creek, Broadview Creek, Discovery Park Creek, Durham Creek, Frink Creek, Golden Gardens Creek, Kiwanis Ravine/Wolfe Creek, Licton Springs Creek, Madrona Park Creek, Mee-Kwa-Mooks Creek, Mount Baker Park Creek, Puget Creek, Riverview Creek, Schmitz Creek, Taylor Creek, and Washington Park Creek (SMC, Subsection 22.801.130.L).

M

- “Master use permit” means a "master use permit" as defined in Section 23.84A.025 (SMC, Subsection 22.801.140.M).
- “Maximum extent feasible” means the requirement is to be fully implemented, constrained only by the physical limitations of the site, practical considerations of engineering design, and reasonable considerations of financial costs (SMC, Subsection 22.801.140.M).
- “Metals treatment facility” means a drainage control facility designed to reduce concentrations of dissolved metals in drainage water (SMC, Subsection 22.801.140.M).
- “Municipal separate storm sewer system” (MS4) means “municipal separate storm sewer system” as defined in the municipal stormwater NPDES permit (SMC, Subsection 22.801.140.M).
- “Municipal stormwater NPDES permit” means the permit issued to the City under the federal Clean Water Act for public drainage systems (SMC, Subsection 22.801.140.M).

N

- “Native vegetation” means "native vegetation" as defined in Section 25.09.520 (SMC, Subsection 22.801.150.N).
- “New hard surface” means the creation of a hard surface or the conversion, modification, or upgrade of an existing hard surface to another hard surface. Examples of a new hard surface include, but are not limited to, converting modifying, or upgrading:
    1. Vegetation, lawn, dirt, or other earthen material to a hard surface (e.g., compact gravel, packed earthen material, permeable pavement, a bituminous surface treatment ("chip seal"), asphalt, concrete, or a structure);
    2. Gravel to permeable pavement, chip seal, asphalt, concrete, or a structure;
    3. A hard surface to a modified hard surface (e.g., grading an existing parking area and repaving);
    4. A hard surface to a structure; or
    5. A structure to another hard surface or another structure not otherwise meeting the definition of replaced hard surface.
    6. If asphalt or concrete has been overlaid by a chip seal, the existing condition is considered asphalt or concrete.
    7. If, for a structure, the existing foundation is removed or, for any other hard surface, the subgrade or base course grade elevation is modified beyond what is required to repair the existing hard surface or base course, then the structure or other hard surface is a new hard surface (SMC, Subsection 22.801.150.N).
- “Non-listed creeks” means any creek not identified in the definition of "Listed creeks" in Section 22.801.130 (SMC, Subsection 22.801.150.N).
- “NPDES” means National Pollutant Discharge Elimination System, the national program for controlling discharges under the federal Clean Water Act (SMC, Subsection 22.801.150.N).

- "NPDES permit" means an authorization, license or equivalent control document issued by the EPA or Ecology to implement the requirements of the NPDES program (SMC, Subsection 22.801.150.N).
- "Nutrient-critical receiving water" means a surface water or water segment that is determined to be impaired due to phosphorus contributed by stormwater, as specified in rules promulgated by the Director of SPU which shall be based on consideration of waterbodies reported by Ecology, and approved by EPA, under Category 5 (impaired) under Section 303(d) of the Clean Water Act for total phosphorus through Ecology's Water Quality Assessment (SMC, Subsection 22.801.150.N).

O

- "Oil control treatment facility" means a drainage control facility designed to reduce concentrations of oil in drainage water (SMC, Subsection 22.801.160.O).
- "On-site BMP" means a best management practice identified in subsection 22.805.070.D (SMC, Subsection 22.801.160.O).
- "Owner" means any person having title to and/or responsibility for, a building or property, including a lessee, guardian, receiver or trustee, and the owner's duly authorized agent (SMC, Subsection 22.801.160.O).

P

- "Parcel-based project" means any project that is not a roadway project, sidewalk project, or trail project. The boundary of the public right-of-way shall form the boundary between the parcel and roadway portions of a project (SMC, Subsection 22.801.170.P).
- "Pavement maintenance practices" means repair and maintenance of an existing surface including sidewalks, limited to:
  1. Targeted pothole and square cut patching;
  2. Overlaying existing asphalt, concrete, or brick pavement with asphalt or concrete, so long as the base course is not exposed;
  3. Shoulder grading;
  4. Reshaping or regrading drainage systems, including adding curb, gutter, or wedge curbs;
  5. Crack sealing; and
  6. Vegetation maintenance

  "Pavement maintenance practices" does not include work that: increases the vehicle capacity of a roadway or parking area; adds new hard surface or results in replaced hard surface (except for pothole or square cut patching); or materially alters a roadway's characteristics. (SMC, Subsection 22.801.170.P).
- "Person" means an individual, receiver, administrator, executor, assignee, trustee in bankruptcy, trust estate, firm, partnership, joint venture, club, company, joint stock company, business trust, municipal corporation, the State of Washington, political subdivision or agency of the State of Washington, public authority or other public body, corporation, limited liability company, association, society or any group of

individuals acting as a unit, whether mutual, cooperative, fraternal, nonprofit or otherwise, and the United States or any instrumentality thereof (SMC, Subsection 22.801.170.P).

- “Pervious surface” means a surface that is not impervious. See also "impervious surface" (SMC, Subsection 22.801.170.P).
- “Phosphorus treatment facility” means a drainage control facility designed to reduce concentrations of phosphorus in drainage water (SMC, Subsection 22.801.170.P).
- “Plan” means a graphic or schematic representation, with accompanying notes, schedules, specifications and other related documents, or a document consisting of checklists, steps, actions, schedules, or other contents that has been prepared pursuant to this subtitle, such as a site plan, drainage control plan, construction stormwater control plan, stormwater pollution prevention plan, or integrated drainage plan (SMC, Subsection 22.801.170.P).
- “Pollution-generating activity” means any activity that is regulated by the joint SPU/SDCI Directors' Rule titled " Seattle Stormwater Manual" at "Volume 4 - Source Control" or any activity with similar impacts on drainage water. These activities include, but are not limited to: cleaning and washing activities; transfer of liquid or solid material; production and application activities; dust, soil, and sediment control; commercial animal care and handling; log sorting and handling; boat building, mooring, maintenance, and repair; logging and tree removal; mining and quarrying of sand, gravel, rock, peat, clay, and other materials; cleaning and maintenance of swimming pool and spas; deicing and anti-icing operations for airports and streets; maintenance and management of roof and building drains at manufacturing and commercial buildings; maintenance and operation of railroad yards; maintenance of public and utility corridors and facilities; and maintenance of roadside ditches (SMC, Subsection 22.801.170.P).
- “Pollution-generating hard surface” means those hard surfaces considered to be a significant source of pollutants in drainage water. Such surfaces include those that are subject to any of the following: vehicular use; industrial activities; and storage of erodible or leachable materials, wastes, or chemicals that receive direct rainfall or the run-on or blow-in of rainfall. Such surfaces also include roofs subject to venting of significant sources of pollutants and metal roofs unless coated with an inert, non-leachable material (e.g., baked-on enamel coating) (SMC, Subsection 22.801.170.P).
- “Pollution-generating pervious surface” means any pervious surface subject to any of the following: vehicular use; industrial activities; storage of erodible or leachable materials, wastes, or chemicals, and that receive direct rainfall or run-on or blow-in of rainfall; use of pesticides and fertilizers; or loss of soil. Typical pollution-generating pervious surfaces include lawns and landscaped areas, such as golf courses, parks, cemeteries, and sports fields (natural and artificial turf) (SMC, Subsection 22.801.170.P).
- “Pre-developed condition” means the vegetation and soil conditions that are used to determine the allowable post-development discharge peak flow rates and flow durations, such as pasture or forest (SMC, Subsection 22.801.170.P).
- “Private drainage system” means a drainage system that is not a public drainage system (SMC, Subsection 22.801.170.P).

- “Project” means any proposed action to alter or develop a site, including development (SMC, Subsection 22.801.170.P).
- “Project site” means that portion of a property, properties, or rights-of-way subject to land disturbing activities, new hard surfaces, or replaced hard surfaces (SMC, Subsection 22.801.170.P).
- “Public combined sewer” means a publicly owned and maintained system which carries drainage water and wastewater and flows to a publicly owned treatment works (SMC, Subsection 22.801.170.P).
- “Public drainage system” means a drainage system owned or operated by The City of Seattle (SMC, Subsection 22.801.170.P).
- “Public place” means and includes streets, avenues, ways, boulevards, drives, places, alleys, sidewalks, and planting (parking) strips, squares, triangles and right-of-way for public use and the space above or beneath its surface, whether or not opened or improved (SMC, Subsection 22.801.170.P).
- “Public sanitary sewer” means the sanitary sewer that is owned or operated by The City of Seattle (SMC, Subsection 22.801.170.P).
- “Public storm drain” means the part of a public drainage system that is wholly or partially piped, owned or operated by a City agency and designed to carry only drainage water (SMC, Subsection 22.801.170.P).

R

- “Real property” means "real property" as defined in Chapter 3.110 (SMC, Subsection 22.801.190.R).
- “Receiving water” means the surface water, such as a creek, stream, river, lake, wetland or marine water, or groundwater, receiving drainage water. Drainage systems and public combined sewers are not receiving waters (SMC, Subsection 22.801.190.R).
- “Repeat violation” means a prior violation of this subtitle within the preceding five years that became a final order or decision of the Director or a court. The violation does not need to be the same nor occur on one site to be considered repeat (SMC, Subsection 22.801.190.R).
- “Replaced hard surface” or “replacement of hard surface” means
    1. For structures, the removal of the structure down to (i.e., exposing the top of) the foundation without removing the foundation and replacement of the structure; and
    2. For other hard surfaces, the removal of the surface down to the existing base course or exposing the top of the subgrade and replacement, including repair of the base course layer.

    If, for a structure, the existing foundation is removed or, for any other hard surface, the subgrade or base course grade elevation is modified beyond what is required to repair the existing hard surface or base course, then the structure or other hard surface is a new hard surface (SMC, Subsection 22.801.190.R).
- “Responsible party” means all of the following persons:
    1. Owners, operators, and occupants of property; and

2. Any person causing or contributing to a violation of the provisions of this subtitle (SMC, Subsection 22.801.190.R).

- "Right-of-way" means "right-of-way" as defined in Section 23.84A.032 (SMC, Subsection 22.801.190.R).
- "Roadway" means "roadway" as defined in Section 23.84A.032 (SMC, Subsection 22.801.190.R).
- "Roadway project" means a project located in the public right-of-way that involves the creation of a new or replacement of an existing roadway or alley. The boundary of the public right-of-way shall form the boundary between the parcel and roadway portions of a project (SMC, Subsection 22.801.190.R).
- "Runoff" means the portion of rainfall or other precipitation that becomes surface flow and interflow (SMC, Subsection 22.801.190.R).

S

- "Sanitary sewer" means a system that conveys wastewater and is not designed to convey drainage water (SMC, Subsection 22.801.200.S).
- "SDCI" means the Seattle Department of Construction and Inspections (SMC, Subsection 22.801.200.S).
- "SDOT" means the Seattle Department of Transportation (SMC, Subsection 22.801.200.S).
- "Service drain" means "service drain" as defined in Section 21.16.030 (SMC, Subsection 22.801.200.S).
- "Side sewer" means "side sewer" as defined in Section 21.16.030 (SMC, Subsection 22.801.200.S).
- "Sidewalk" means "sidewalk" as defined in Section 23.84A.036 (SMC, Subsection 22.801.200.S).
- "Sidewalk project" means a project for the creation of a new sidewalk or replacement of an existing sidewalk, including any associated planting strip, apron, curb ramp, curb, or gutter, and necessary roadway grading and repair. If the total new plus replaced hard surface in the roadway exceeds 10,000 square feet, the entire project is a roadway project (SMC, Subsection 22.801.200.S).
- "Site" means the area defined by the legal boundaries of a parcel or parcels of land subject to development. For roadway projects, the length of the project site and the right-of-way boundaries define the site. A site may include multiple parcels and/or sections of right-of-way if multiple parcels and/or sections of right-of-way are subject to development (SMC, Subsection 22.801.200.S).
- "Slope" means an inclined ground surface (SMC, Subsection 22.801.200.S).
- "Small lakes" means Bitter Lake, Green Lake, and Haller Lake (SMC, Subsection 22.801.200.S).
- "Small project" means a project with:

  1. Less than 5,000 square feet of new and replaced hard surface; and

2. Less than 10,000 square feet of land disturbing activities (SMC, Subsection 22.801.200.S).

- "SMC" means the Seattle Municipal Code (SMC, Subsection 22.801.200.S).
- "Soil" means naturally deposited non-rock earth materials (SMC, Subsection 22.801.200.S).
- "Solid waste" means "solid waste" as defined in Section 21.36.016 (SMC, Subsection 22.801.200.S).
- "Source controls" mean structures or operations that prevent contaminants from coming in contact with drainage water through physical separation or careful management of activities that are known sources of pollution (SMC, Subsection 22.801.200.S).
- "SPU" means Seattle Public Utilities (SMC, Subsection 22.801.200.S).
- "Standard design" is a design pre-approved by the Director for drainage and erosion control available for use at a site with pre-defined characteristics (SMC, Subsection 22.801.200.S).
- "Standard Plans and Specifications" means the City of Seattle Standard Plans and Specifications for Road, Bridge, and Municipal Construction in effect on the date of permit application (SMC, Subsection 22.801.200.S).
- "Storm drain" means both public storm drain and service drain (SMC, Subsection 22.801.200.S).
- "Stormwater" means runoff during and following precipitation and snowmelt events, including surface runoff, drainage and interflow (SMC, Subsection 22.801.200.S).
- "Stream" means a watercourse through which naturally occurring surface waters flow sufficiently, whether on a perennial or intermittent basis, to carve a defined channel or bed evidencing the passage of water, including but not limited to bedrock channels, gravel beds, alluvial mineral beds, defined-channel swales, and beds containing hydraulically sorted sediments. "Stream" does not include watercourses created entirely by artificial means, such as irrigation or roadside ditches, stormwater runoff devices, or canals, unless the watercourse conveys a stream that flowed naturally prior to the creation of the watercourse. "Stream" is used synonymously with "creek" (SMC, Subsection 22.801.200.S).
- "Surface waters" means "surface waters of the state" as defined in chapter 173-201A WAC (Water Quality Standards for Surface Waters of the State of Washington) and includes lakes, rivers, ponds, streams, inland waters, saltwaters, wetlands, and all other surface waters and watercourses within the jurisdiction of the state of Washington (SMC, Subsection 22.801.200.S).

T

- "Topsoil" means the weathered surface soil, including the organic layer, in which plants have most of their roots (SMC, Subsection 22.801.210.T).
- "Trail" means a path of travel for recreation and/or transportation within a park, natural environment, or corridor (SMC, Subsection 22.801.210.T).

- “Trail project” means a project for the creation of a new trail or replacement of an existing trail, and which does not contain pollution-generating hard surfaces (SMC, Subsection 22.801.210.T).
- “Treatment facility” means a drainage control facility designed to remove pollutants from drainage water (SMC, Subsection 22.801.210.T).

U

- “Uncontaminated” means not containing sediment or other pollutants or contaminants above natural background levels and not containing pollutants or contaminants in levels greater than City-supplied drinking water when referring to potable water (SMC, Subsection 22.801.220.U).

V

- “Vegetation” means "vegetation" as defined in Section 25.09.520 (SMC, Subsection 22.801.230.V).
- “Vehicular use” means regular use of a hard or pervious surface by motor vehicles. The following surfaces, whether paved or not, are considered subject to regular vehicular use: roads; unvegetated road shoulders; bike lanes within the traveled lane of a roadway; driveways; parking lots; unfenced fire lanes; vehicular equipment storage yards; rail lines and railways, including light rail elevated and non-elevated guideways and tracks; and airport runways and other surfaces intended for movement or storage of aircraft.

  The following are not considered regularly used by motor vehicles: sidewalks and trails not subject to drainage from roads for motor vehicles; paved bicycle pathways separated from and not subject to drainage from roads for motor vehicles; fenced fire lanes; and infrequently used maintenance access roads with recurring routine vehicle use of no more than once per day (SMC, Subsection 22.801.230.V).

W

- “Wastewater” means "wastewater" as defined in Section 21.16.030 (SMC, Subsection 22.801.240.W).
- “Water Quality Standards” means Surface Water Quality Standards, chapter 173-201A WAC, Groundwater Quality Standards, chapter 173-200 WAC, and Sediment Management Standards, chapter 173-204 WAC (SMC, Subsection 22.801.240.W).
- “Watercourse” means the route, constructed or formed by humans or by natural processes, generally consisting of a channel with bed, banks or sides, in which surface waters flow. Watercourse includes small lakes, bogs, streams, creeks, and other receiving waters but does not include designated receiving waters (SMC, Subsection 22.801.240.W).
- “Watershed” means a geographic region within which water drains into a particular river, stream, or other body of water (SMC, Subsection 22.801.240.W).
- “Wetland” means a wetland designated under Section 25.09.012 (SMC, Subsection 22.801.240.W).

- “Wetland function” means the physical, biological, chemical, and geologic interactions among different components of the environment that occur within a wetland. Wetland functions can be grouped into three categories: functions that improve water quality; functions that change the water regime in a watershed, such as flood storage; and functions that provide habitat for plants and animals (SMC, Subsection 22.801.240.W).
- “Wetland values” means wetland processes, characteristics, or attributes that are considered to benefit society (SMC, Subsection 22.801.240.W).

APPENDIX B

Drainage Control Report and Additional Submittal Requirements

City of Seattle | Stormwater Manual

July 2026

City of Seattle

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B-1. Preliminary Drainage Control Review Submittal Requirements for Master Use Permits

Preliminary Drainage Control Review is required for certain Master Use Permit (MUP) applications per SMC 22.807.020.A (refer to *Volume 1, Section 2.8.1*). The general submittal requirements are described in *Volume 1, Section 2.8.1*. However, different types of MUPs require different levels of drainage review and detail.

The following describes the specific submittal requirements and drainage review process for the most common types of MUP that will typically require drainage review.

B-1.1. Subdivisions and Short Plats

B-1.1.1. Subdivisions

"Full" Subdivisions per SMC 23.22 require a high level of detail for approval of Preliminary Drainage Control Review. Prior to Preliminary Plat Approval, a Preliminary Drainage Control Plan, Preliminary Drainage Report (Report), and all supporting documents as described in *Volume 1, Section 2.8.1* must be submitted and approved. The Preliminary Drainage Control Plan and Report shall identify all BMPs necessary to meet the minimum requirements (e.g., on-site stormwater management, flow control, water quality treatment, etc.) including size and location. The level of detail required is the same as required for Standard and Comprehensive Drainage Control Review.

The Preliminary Drainage Control Plan approval does not constitute approval for construction. A Standard or Comprehensive Drainage Control Plan and Report must be submitted with a construction permit. Depending on the scope and location, required construction permit will be a Grading Permit, Building Permit, or a Seattle Department of Transportation (SDOT) Street Improvement Plan (SIP) Permit.

Subsequent construction permits in the subdivision must demonstrate with Standard or Comprehensive Drainage Control Plans that they are compliant with the intent of the approved Preliminary Drainage Control Plan.

Note: Additional requirements apply to permitting and construction of drainage control facilities and drainage systems that will be shared by multiple parcels, lots, tracts, etc., within the Subdivision. Refer to *Section B-1.1.3*.

B-1.1.2. Short Plats

Short Plats (a.k.a. Short Subdivisions) per SMC 23.24 require a similar level of detail as Full Subdivisions for approval of Preliminary Drainage Control Review.

Deferred Drainage Plans for Some Projects: The requirement for a Preliminary Drainage Control Plan and Report may be deferred until the construction permit by the Director if all of the following conditions are met:

1. The full development potential in the Short Plat, including all lots, parcels, and tracts, does not exceed the thresholds established for flow control or water quality treatment,
2. The project has an approved offsite discharge point for drainage (e.g., public storm drain) and any required or planned extension of the public storm drainage system (i.e., mainline extension) is clearly feasible via gravity flow and SPU design requirements,
3. The downstream drainage system has adequate capacity,
4. Drainage Condition #1 in *Section B-1.1.4* is placed on the first sheet of the recorded plat.

Otherwise, a Preliminary Drainage Control Plan and Report, and all supporting documents as described in *Volume 1, Section 2.8.1* must be submitted and approved prior to approval of the Short Plat.

Subsequent construction permits in the short subdivision must demonstrate with Standard or Comprehensive Drainage Control Plans that they are compliant with the intent of the approved Preliminary Drainage Control Plan. Depending on the scope and location, this will require a Grading Permit, Building Permit, or an SDOT SIP Permit.

Note: Additional requirements apply to permitting and construction of drainage control facilities and drainage systems that will be shared by multiple parcels, lots, tracts, etc., in the Subdivision. Refer to *Section B-1.1.3*.

B-1.1.3. Shared Drainage Control Facilities and Systems for Subdivisions and Short Plats

Drainage control facilities and systems proposed on Preliminary Drainage Control Plans that will serve multiple parcels, lots, tracts, etc. in a Subdivision or Short Plat are subject to the following code requirement.

Stormwater Code Language	References
SMC 22.805.010.E. Construction of drainage control facilities and drainage systems for plats. 1. *In the case of a subdivision under Chapter 23.22, drainage control facilities or drainage systems that are identified on the associated preliminary drainage control plan or the approved preliminary plat and will serve multiple proposed lots, parcels, tracts, or rights-of-way shall be constructed prior to approval of the final plat unless a bond is provided according to subsection 23.22.070.C. If a bond is provided in lieu of construction prior to approval of the final plat, the construction permit for the facilities or systems must be issued prior to issuance of any building permit for any other construction within the subdivision and construction of the facilities or systems shall be completed and final inspection approved prior to final inspection approval of any building permit for any other construction within the subdivision and prior to occupancy of any buildings, but in no event later than two years after final plat approval.* 2. *In the case of a short plat under Chapter 23.24 with shared drainage control facilities or drainage systems that are identified on the preliminary drainage control plan and will serve multiple proposed lots, parcels, tracts, or rights-of-way:* a. *The construction permit that includes the shared facilities or systems shall be issued prior to issuance of any other building permit for any other construction within the lots, parcels, tracts, or rights-of-way served by the shared facilities or systems; and* b. *Construction of the shared facilities or systems shall be completed and final inspection approved prior to final inspection approval of any building permit for any other construction within the lots, parcels, tracts, or rights-of-way served by the shared facilities, and prior to occupancy of any buildings on these lots, parcels, or tracts.*	a. *Volume 1, Section 2.8.1* – Preliminary Drainage Control Review b. SMC 22.807.020.A – Thresholds for Drainage Control Review c. SMC, Chapter 23.22 – Subdivisions d. SMC, Chapter 23.24 – Short Plats

In addition, shared drainage control facilities and shared service drains require a joint use and maintenance agreement (JUMA) between the parcels, lots, tracts, etc. that are served by the shared feature per the requirements of the Side Sewer Code (SMC, Section 21.16.250.C).

B-1.1.4. Typical Drainage Conditions for Subdivisions and Short Plats

Subdivisions and Short Plats will require one or more drainage conditions. The applicable drainage conditions must be placed on the first sheet of the plat that will be recorded. The following are some of the typical drainage conditions that may apply. The conditions may require modifications per the reviewer and additional drainage conditions may apply as required by the Director.

Typical Drainage Condition #1 (Required on all Subdivisions and Short Plats): The subdivision of the property will not reduce the requirements of the Seattle Stormwater Code and the Seattle Side Sewer Code. The proposed parcels within this [Subdivision/Short Plat] will meet the standards required by the higher area threshold of the entire property being subdivided rather than the standards required for each of the proposed parcels individually.

Typical Drainage Condition #2 (Required for all Subdivisions or Short Plats that require submittal of Preliminary Drainage Control Plans): Approval of the Preliminary Drainage Control Plans and Report reviewed with this Subdivision/Short Subdivision is preliminary. A final Standard or Comprehensive Drainage and Wastewater Control Plan, a Construction Stormwater Control and Soil Management Plan, a final Drainage Report (if triggered) that addresses the full Subdivision or Short Plat, and all supporting documents will be required for all future construction permits within this Subdivision or Short Plat.

Typical Drainage Condition #3 (Required if the Preliminary Drainage Control Plan shows drainage control facilities that will serve multiple lots, parcels, or tracts within the Subdivision/Short Subdivision): The construction/building permit that includes the shared facilities or systems shown on the preliminary drainage plan shall be issued prior to issuance of the any other building permit for any other construction within the lots, parcels, tracts, or rights-of-way served by the shared facilities or systems; and construction of the shared facilities or systems shall be completed and final inspection approved prior to final construction inspection approval of any building permit for any other construction within the lots, parcels, tracts, or rights-of-way served by the shared facilities, and prior to occupancy of any buildings of these lots, parcels, or tracts. [*for full subdivisions*: but in no event later than two years after final plat approval.]

Typical Drainage Condition #4 (Required if a Public Storm Drain mainline extension is required): The public storm drain shall be extended across the full street frontage of the Subdivision/Short Plat per SMC 22.805.020.L-N unless an adjustment or exception is approved by the Director of Seattle Public Utilities per SMC 22.800.040.B or C. The permits for the public storm drain extension must be issued prior to issuance of the first building permit in the subdivision, and construction of the public storm drain must be completed before final construction inspection approval of any building permit within the subdivision.

B-1.1.5. Easements for Subdivisions and Short Plats

All lots, parcels, and tracts must be demonstrated to have access through easements for the proposed drainage features or conveyance systems that must cross the other lots, parcels, and tracts within the subdivision or short plat and for all shared drainage facilities. Easements must be either established in the plat; or the previously recorded easement shall be shown and called out on the plat, including the King County recording number.

Note: Per SPU Policy DWW-160 “The City does not allow the use of an easement in lieu of an extension of the public storm or sewer system (i.e., public sanitary sewer [PSS], public combined sewer [PS], public storm drain [PSD]). Any adjustments or exceptions to this restriction must be authorized by the SPU General Manager/CEO or a designee.” A mainline extension may be required if there are any proposed lots that abut a public street right-of-way where there is no existing public piped storm drain. Refer to the Public Drainage System Requirements Director’s Rule (SPU Director’s Rule DWW-210).

B-1.1.6. Determining Minimum Requirements for Subdivisions and Short Plats

The steps to determine the minimum requirements that apply to Subdivisions and Short Plats are described in *Volume 1*, *Chapter 2*. The project type for Subdivisions and Short Plats is

parcel-based, regardless of the land use zoning, and the boundaries of the project site include the full area of the Subdivision or Short Plat. The following code section includes requirements for calculating the new plus replaced hard surface for a Subdivision or Short Plat.

Stormwater Code Language	References
SMC 22.805.010.D.2 *In neighborhood residential (NR) zones, the hard surface coverage is the maximum lot coverage allowed per Subtitle III of Title 23, plus required and proposed pedestrian and vehicular access and amenities, including roadways, driveways, walkways, plazas, and patios identified on the preliminary drainage control plan and associated preliminary site plan, unless otherwise approved by the Director. In all other zones, the hard surface coverage shall be based on an approved site plan showing the maximum allowed build-out including all phases of the subdivision or short plat.*	e. *Volume 1, Section 2.5* – Step 5 – Calculate Land-Disturbing Activity and New Plus Replaced Hard Surface f. *Volume 1*, *Section 2.6* – Calculate New Plus Replaced Pollution Generating Surface g. SMC 22.800.040.B – Adjustments h. SMC, Chapter 23.22 – Subdivisions i. SMC, Chapter 23.24 – Short Plats

If there is an existing building or other improvements, such as a roadways, driveways, walkways, etc. that will remain throughout and after development, those areas may be omitted from the total new plus replaced hard surface area that is used to determine the stormwater requirements if the recorded short plat or subdivision clearly indicates that those buildings will remain. However, if the buildings and other improvements do not account for the maximum build-out on the proposed lot/s where they are located, then additional new hard surface area must be included in the total new plus replaced hard surface area to account for the difference in areas.

B-1.2. Unit Lot Subdivisions

Unit Lot Subdivisions per SMC 23.22.062 and 23.24.045 typically have a building permit that is already issued or is being reviewed simultaneously with the Unit Lot Subdivision. If Standard or Comprehensive Drainage Review is already completed or in process for a Building Permit that includes all proposed development in the Unit Lot Subdivision, then the Drainage Control Plan and Drainage Report are not required to be submitted with the Unit Lot Subdivision submittal.

In the case where an application for a Building Permit that covers all development in the Unit Lot Subdivision has not been made, a Preliminary Drainage Plan and Drainage Report (if required), and all supporting documents must be submitted with the Unit Lot Subdivision application (similar to Short Plats and Subdivisions).

Easements

All unit lots must be demonstrated to have access through easements for the proposed drainage features or conveyance systems that must cross the other unit lots within the subdivision and for all shared drainage facilities. Easements must be either established in the

Unit Lot Subdivision or the previously recorded easement shall be shown and called out on the Unit Lot Subdivision plat, including the King County recording number.

B-1.3. Lot Boundary Adjustments

Preliminary Drainage Review for Lot Boundary Adjustments (LBA) per SMC 23.28 is required. A separate Preliminary Drainage Control Plan is not required with the Master Use Permit (MUP) submittal if:

1. Drainage infrastructure is accessible or could feasibly be extended to each adjusted lot, and
2. All lots that abut the public place (i.e., street right-of-way) have a public drainage system in their street frontage, have access directly to a receiving water, or have a public drainage system that could feasibly be extended across full frontage of the lots abutting the public place.

   Or

3. The lots are already fully developed and the LBA plat identifies that the existing buildings and other improvements will remain.

If the adjusted lots that abut the public place (i.e., street right-of-way) do not have a public piped storm drain (PSD) in their street frontage or access directly to a receiving water, then the following LBA Drainage Adequacy Note #1 must be added to the first page of the recorded LBA plat.

> ***LBA Drainage Adequacy Note #1***
>
> *There is no available public piped storm drain (PSD) in the street frontage of one or more of the adjusted lots. An extension of the public storm drain may be required across the full street frontage of the adjusted lot/s if required per SMC 22.805.020.L unless an alternative is allowed by the SPU Public Drainage System Requirements Director's Rule DWW-210 (e.g., use of a ditch, culvert, public piped combined main; curb weep or on-site infiltration for small projects). Note: the thresholds for determining requirements include all "Closely Related Projects" and the full "Common Plan of Development or Sale" as described in the SMC 22.805.010.B/Seattle Stormwater Manual Volume 1, Sections 2.1.2 and 2.1.3.*

If lots are already fully developed and the LBA plat identifies that the existing buildings and other improvements will remain, but the adjusted lots that abut the public place (i.e., street right-of-way) do not have a public piped storm drain (PSD) in their street frontage or access directly to a receiving water, then the following Modified LBA Drainage Adequacy Note #1 must be added to the first page of the recorded LBA plat.

> ***Modified LBA Drainage Adequacy Note #1***
>
> *There is no available public piped storm drain (PSD) in the street frontage of one or more of the adjusted lots. If there is future development, an extension of the public storm drain may be required across the full street frontage of the adjusted lot/s if*

required per SMC 22.805.020.L unless an alternative is allowed by the SPU Public Drainage System Requirements Director's Rule DWW-210 (e.g., use of a ditch, culvert, public piped combined main; curb weep or on-site infiltration for small projects). Note: the thresholds for determining requirements include all "Closely Related Projects" and the full "Common Plan of Development or Sale" as described in the SMC 22.805.010.B/Seattle Stormwater Manual Volume 1, Sections 2.1.2 and 2.1.3.

If an extension of a public drainage system is infeasible as determined by the Director, a Preliminary Drainage Control Plan and associated documents must be submitted to demonstrate that the potential development on each lot can be constructed with infiltration or dispersion BMPs to meet the requirements of *Volume 3, Section 4.3.2* for small projects or 100 percent infiltration for large projects as described in Volume 3, Section 4.5.1. In this scenario, LBA Drainage Adequacy Note #2 must be added to the first page of the recorded LBA plat.

LBA Drainage Adequacy Note #2

A Preliminary Drainage Control Plan was submitted to demonstrate adequacy of drainage for potential development on the adjusted lots using [_____] (onsite infiltration or dispersion BMPs). Approval of this plan is preliminary. A Drainage and Wastewater Control Plan, a Construction Stormwater Control and Soil Management Plan, a Drainage Report, and all supporting documents will be required for all future construction permits within each of the lots.

The level of detail required on the Preliminary Drainage Control Plan must include a Site Plan showing the proposed or potential development and the sizes and possible locations of stormwater BMPs that will manage the runoff fully on site.

Easements

All adjusted lots must be demonstrated to have legal access for the proposed drainage features or conveyance systems that must cross the other lots to reach street frontage where drainage infrastructure is located or will be extended or have access to a receiving water. Easements must be either established in the LBA, or the previously recorded easement shall be shown and called out on the LBA plat, including the King County recording number.

Note: Per SPU Policy DWW-160, "*The City does not allow the use of an easement in lieu of an extension of the public storm or sewer system (i.e., public sanitary sewer [PSS], public combined sewer [PS], public storm drain [PSD]). Any adjustments or exceptions to this restriction must be authorized by the SPU General Manager/CEO or a designee.*" A mainline extension may be required if there are any adjusted lots that abut a public street right-of-way where there is no existing public piped storm drain (PSD). Refer to the Public Drainage System Requirements Director's Rule (SPU Director's Rule DWW-210).

B-2. Drainage Report Format/Content Requirements

Drainage Reports are a required part of many Drainage Control Plans as indicated in *Volume 1, Chapter 2.8*. The following table describes the typical, required elements and recommended format for Drainage Reports. Elements that are not applicable to a particular project may be indicated as "not applicable" in the Drainage Report. Additional information that is not included in this table may be as described in *Volume 1, Section 8.4*.

Required Elements and Recommended Format for Drainage Reports.

Drainage Report Section	Drainage Report Section	Stormwater Manual Reference	Submittal Notes (if applicable)
1. Introduction	1.1. Project overview 1.2. Existing and Proposed Conditions	*Volume 1, Chapter 2.8*	Narrative describing the project. Describe the existing and proposed conditions including a summary of existing hard surface area.
2. Determining minimum requirements	2.1. Define the boundaries of the project site	*Volume 1, Section 2.1*	Include a vicinity map highlighting the project area. Include a description of the drainage basin(s) where the project is located and a map highlighting the areas in the project that are in different drainage basins (if applicable). If there are multiple basins, include a table with area calculations and identification of drainage basins.
	2.2. Identify the type of project	*Volume 1, Section 2.2*	The project will be classified as a specific project type; this will determine the minimum requirements.
	2.3. Identify the receiving water and downstream conveyance	*Volume 1, Section 2.3*	Include at least one map that shows the existing drainage infrastructure per basin. Include a table or narrative describing the type of receiving waters and types downstream conveyance systems per basin.
	2.4. Perform site assessment and planning	*Volume 1, Section 2.4*	The Drainage Report shall contain, at a minimum, the evaluation and conclusion of each of these items (Section 2.4.1 through 2.4.11) when applicable.

Required Elements and Recommended Format for Drainage Reports.

Drainage Report Section	Drainage Report Section	Stormwater Manual Reference	Submittal Notes (if applicable)
2. Determining minimum requirements	2.4.1. Project boundaries 2.4.2. Setbacks 2.4.3. Location of buildings 2.4.4. Foundation and footing drains	*Volume 1, Section 2.4.2*	The Drainage Report shall contain, at a minimum, the evaluation and conclusion of each of these items (Section 2.4.1 through 2.4.11) when applicable.
	2.4.5. Soil condition assessment and infiltration feasibility analysis	*Volume 1, Section 2.4.3; Volume 3, Section 3.2*	The Drainage Report shall contain, at a minimum, the evaluation and conclusion of each of these items (Section 2.4.1 through 2.4.11) when applicable.
	2.4.6. Environmentally critical areas (ECAs)	*Volume 1, Section 2.4.4*	The Drainage Report shall contain, at a minimum, the evaluation and conclusion of each of these items (Section 2.4.1 through 2.4.11) when applicable.
	2.4.7. Dewatering (Temporary and Permanent)	*Volume 1, Section 2.4.5*	Identify any temporary or permanent groundwater that the project will discharge and include estimates of the discharge rates from a licensed professional.
	2.4.8. Topography 2.4.9. Site Assessment 2.4.10. Landscaping principles	*Volume 1, Section 2.4.6* *Volume 1, Section 2.4.7* *Volume 1, Section 2.4.8*	
	2.4.11. Site design considerations and dispersion feasibility	*Volume 1, Section 2.4.9 Volume 3, Section 3.2*	
	2.5. Calculate land disturbing activity and new plus replaced hard surface	*Volume 1, Section 2.5*	Provide a map highlighting the project's new plus replaced hard surface and limits of disturbance per basin. Provide a color map that identifies different types of surfaces (i.e., hard vs. pervious) and area calculations.

Required Elements and Recommended Format for Drainage Reports.

Drainage Report Section	Drainage Report Section	Stormwater Manual Reference	Submittal Notes (if applicable)
2. Determining minimum requirements	2.6. Calculate new plus replace pollution generating surface	*Volume 1, Section 2.6*	If water quality treatment is required, provide a map highlighting the pollution generating hard and pervious areas per basin and delineate the areas tributary to each Water Quality BMP.
	2.7. Determine which minimum requirements apply	*Volume 1, Section 2.7*	Include a summary of all minimum requirements that apply.
3. Minimum requirements for all projects	3.1. Maintaining natural drainage patterns 3.2. Discharge point 3.3. Flood-prone areas	*Volume 1, Section 3.1* *Volume 1, Section 3.2* *Volume 1, Section 3.3*	The Drainage Report shall contain, at a minimum, an evaluation and conclusion of each of these items (*Section 3.1* through *3.12*) when applicable.
	3.4. Construction site stormwater pollution prevention control	*Volume 1, Section 3.4; Volume 1, Chapter 8; Volume 2, Chapter 2*	Include small- or large-project CSC checklist and CSC plan. A narrative is also required and a short narrative describing the selected BMPs and the results of any required calculations.
	3.5. Protect wetlands 3.6. Protect streams and creeks 3.7. Protect shorelines 3.8. Ensure sufficient capacity	*Volume 1, Section 3.5* *Volume 1, Section 3.6* *Volume 1, Section 3.7* *Volume 1, Section 3.8*	
	3.9. Install source control BMPs	*Volume 1, Section 3.9; Volume 4, Section 1.6*	Include the Worksheet for Identifying Applicable Source Control BMPs (*Volume 4*, Table 1)
	3.10. Do not obstruct watercourses	*Volume 1, Section 3.10*	
	3.11. Comply with side sewer code	*Volume 1, Section 3.11*	Side sewers in ROW shall be shown on SIP plans but require a separate permit.
	3.12. Extension of public drainage system 3.13. Public drainage system requirements 3.14. Maintenance and inspection	*Volume 1, Section 3.12* *Volume 1, Section 3.13* *Volume 1, Section 3.14*	

Required Elements and Recommended Format for Drainage Reports.

Drainage Report Section	Drainage Report Section	Stormwater Manual Reference	Submittal Notes (if applicable)
4. Minimum requirements based on project type	4.1. Soil amendment	*Volume 1, Section 5.1*	Include site plans highlighting the area requiring soil amendment (disturbed area).
	4.2. On-site Stormwater management	*Volume 1, Section 5.2; Volume 3, Chapter 3*	Include a narrative with a summary of the BMPs selected and describe any modeling required for the sizing of the BMPs or special considerations such as presettling. Describe in the infeasibility criteria for On-site Stormwater Management BMPs that were not selected. Reference the appropriate Appendix of the Report for the On-site Stormwater Management Calculator and any other required infeasibility documentation.
	4.3. Flow control: 4.3.1. Wetland protection standards 4.3.2. Pre-developed forest standard 4.3.3. Pre-developed pasture standard 4.3.4. Existing condition standard 4.3.5. Peak control standard	*Volume 1, Section 5.3; Volume 3, Sections 3.4 and 4.1*	When using hydrologic modeling software, provide conclusions for each simulation to explain how the proposed flow control BMP complied with SMC, Section 22.805.080. Include a map identifying the tributary area connected to the flow control BMP that specifies the amount of area being collected.
	4.4. Water quality treatment: 4.4.1. Basic treatment 4.4.2. Oil treatment 4.4.3. Phosphorus treatment 4.4.4. Enhanced treatment	*Volume 1, Section 5.4; Volume 3, Section 3.5*	
5. Conclusion			Describe the project and how each of the requirements were met, giving a summary of the problems and solutions proposed for this project.

Required Elements and Recommended Format for Drainage Reports.

Drainage Report Section	Drainage Report Section	Stormwater Manual Reference	Submittal Notes (if applicable)
Appendix A	Figures and Maps		
Appendix B	Construction Stormwater Control and Temporary Dewatering Calculations		
Appendix C	On-site Stormwater Management Workbook and any related documentation or calculations		Include the full workbook and any required documentation to justify infeasibility criteria selected (e.g., financial infeasibility criteria, rainwater demand analysis for rainwater harvesting, Geotechnical Engineering analysis and recommendations, etc.).
Appendix D	Flow Control Calculations (if required)		
Appendix E	Water Quality Calculations (if required)		
Appendix F	Landscape Management Plan (if required)		
Appendix G	Source Control Calculations (if required)		
Appendix H	Infiltration Checklist and Documentation		
Appendix I	Soil and Infiltration Investigation Documentation		Infiltration checklists and documentation. Groundwater investigation and estimated flowrate documentation. Geotechnical Report.
Appendix J	Inspections and Operations and Maintenance (O&M) Requirements and schedule		

APPENDIX C
On-site List Infeasibility Criteria

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Tables

Table C.1. On-site List Infeasibility Criteria: All Dispersion and Infiltration BMPs. 1
Table C.2. On-site List Infeasibility Criteria: Category 1 BMPs. 3
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Table C.5. On-site List Infeasibility Criteria: Category 4 BMPs.[a] 11
Table C.6. On-site List Infeasibility Criteria: Category 5 BMPs.[a] 12

This appendix provides infeasibility criteria for use in evaluating BMPs to meet the On-site Stormwater Management Requirement using the On-Site List approach (SMC, Section 22.805.070.D.2) to manage new and replaced hard surfaces. Refer to *Volume 1, Section 5.2.2* to determine which On-site BMPs require evaluation for a project. Evaluation is based on project type, discharge location, and other criteria. Step-by-step instructions for using the On-site List Approach are provided in *Volume 3, Section 3.3.1.*

Prior to evaluating On-site BMPs, review the site design consideration in *Volume 1, Chapter 7 — Site Assessment and Planning* to conserve natural areas, retain native vegetation, reduce impervious surfaces, and integrate stormwater controls into the existing site layout to the maximum extent feasible. The infeasibility criteria provided in this appendix apply to BMPs if the area proposed for the BMP is the only available area for the BMP, after all reasonable efforts to regrade the site and allow for alternative placement of the BMP have been made.

When using the On-site List approach, an on-site BMP is considered infeasible if an infeasibility criterion in Tables C.1 through C.6 is met.

Table C.1. On-site List Infeasibility Criteria: All Dispersion and Infiltration BMPs.

BMP	On-site List Infeasibility Criteria	Additional Information from Applicant
All BMPs	● Installation requires removal of an existing tree. To use this infeasibility criterion, the tree must be in good health and meet minimum size requirements: deciduous trees must have trunks at least 2 inches in diameter measured 6 inches above the ground, and evergreen trees must be at least 5 feet tall. In addition, the existing tree must be in an area that will be protected throughout construction. Refer to SMC Chapter 25.11 Tree Protection requirements. ● Where BMP installation is prohibited per Regulations for Environmentally Critical Areas (SMC Chapter 25.09). ● Where BMP installation would require pumping to a designated point of discharge, but failure of the pump may destabilize a steep slope. ● Where unable to maintain a desired access of 36 inches in a required building setback from a property line, except when using the Soil Amendment BMP (*Volume 3, Section 5.1*). (Not applicable to permeable pavement facilities or surfaces.) ● Where unable to maintain clearance for required ingress, egress, or ADA pathways. (Not applicable to permeable pavement facilities or surfaces.) ● Where BMP installation would require a pump when a pump is not already required to provide site storm drainage. Requiring a pump as the result of using the Rainwater Harvesting BMP does not make this BMP infeasible.	

Table C.1 (continued). On-site List Infeasibility Criteria: All Dispersion and Infiltration BMPs.

BMP	On-site List Infeasibility Criteria	Additional Information from Applicant
All Dispersion BMPs	● A licensed professional (as defined in *Appendix D*, *Section D-1*) recommends dispersion not be used anywhere within project site due to reasonable concerns of erosion, slope failure, or flooding (requires a signed and stamped written determination based on site-specific conditions from a licensed professional). ● The dispersion flow path area does not provide positive drainage. ● The dispersion flow path area is within a landslide-prone area (SMC, Section 25.09.080). ● The dispersion flow path area is within 100 feet of a contaminated site or landfill (active or closed). ● The dispersion flow path area is in a steep slope area (SMC, Section 25.09.020) or within a setback to a steep slope area (calculated as 10 times the height of the steep slope to a 500-foot maximum setback). ● The dispersion flow path area is within 30 feet of proposed or existing septic system drainfields and reserve areas or within 10 feet of proposed or existing septic sewage tanks and distribution boxes.	
All Infiltration BMPs	The following criteria each establish that the BMP is infeasible but only if based on an evaluation of site-specific conditions and documented within a signed and stamped written determination from a licensed professional (as defined in *Appendix D*, *Section D-1*): ● Infiltration is not recommended due to reasonable concerns about erosion, slope failure, or flooding. ● The area available for siting would threaten the safety or reliability of pre-existing underground utilities, pre-existing underground storage tanks, pre-existing structures, or pre-existing road or parking lot surfaces or subgrades. ● The area available for siting would threaten shoreline structures such as bulkheads. ● The area available for siting would threaten existing or proposed buildings or structures. ● Infiltration is not recommended based on the results of a Groundwater Monitoring analysis or a Characterization of Infiltration Receptor analysis per Appendix D, Sections D-5 and D-6. ● The bottom of the infiltration facility would be in, or within the minimum vertical setback from a soil layer determined to be a hydraulically restricted layer per Appendix D, Section D-2.2.4 or solid rock. The following criteria each establish that the BMP is infeasible, without further justification, though some criteria evaluation require professional services: ● Evaluation of infiltration is not required per the “Infiltration Investigation Map.” ● The area available for siting does not allow for overflow conveyance to an approved point of discharge per *Volume 3*, *Section 4.3.2*. ● The area available for siting is within a steep slope area or land-slide prone area (or setback) (refer to *Volume 3*, *Section 3.2)*.	

Table C.1 (continued). On-site List Infeasibility Criteria: All Dispersion and Infiltration BMPs.

BMP	On-site List Infeasibility Criteria	Additional Information from Applicant
All Infiltration BMPs (continued)	● The area available for siting does not meet the minimum horizontal setback requirements (refer to *Volume 3*, *Section 3.2).* ● The area available for siting does not meet the minimum vertical setback requirements from groundwater or hydraulically restrictive layers (refer to *Volume 3*, *Section 3.2*, and *Appendix D).* ● Infiltration is restricted due to contaminated soil or groundwater (refer to *Volume 3*, *Section 3.2).*	

Table C.2. On-site List Infeasibility Criteria: Category 1 BMPs.

BMP	On-site List Infeasibility Criteria	Additional Information from Applicant
Full Dispersion	● One or more of the infeasibility criteria for "All BMPs" or "All Dispersion BMPs" (Table C.1) apply. ● The site has less than a 65 to 10 ratio of the native vegetation area to the impervious area. ● The minimum native vegetation flow path length is less than 100 feet.	
Infiltration Trenches	● One or more of the infeasibility criteria for "All BMPs" or "All Infiltration BMPs" (Table C.1) apply. ● Field testing indicates potential infiltration trench site(s) have a measured underlying soil infiltration rate less than 2 inches per hour (*Volume 3*, *Section 5.4.2*). ● Where the site cannot be reasonably designed to locate a catch basin between the infiltration trench and point of connection to the public system.	
Drywells	● One or more of the infeasibility criteria for "All BMPs" or "All Infiltration BMPs" (Table C.1) apply. ● Field testing indicates potential drywell site(s) have a measured underlying soil infiltration rate less than 5 inches per hour (*Volume 3*, *Section 5.4.3*). ● Where the site cannot be reasonably designed to locate a catch basin between the drywell and point of connection to the public system.	
Rainwater Harvesting	● One or more of the infeasibility criteria for "All BMPs" (Table C.1) apply. ● Project lacks non-pollution-generating roof from which to harvest rainwater. ● Non-potable water demand is insufficient to meet the On-site Performance Standard per modeling conducted in accordance with *Volume 3, Section 5.5.1.6*. ● Installation is not economically feasible based on reasonable consideration of financial cost (e.g., roof area is less than 20,000 sf or the ratio of roof area to average daily rainwater demand is less than 10,000 square feet/gpm) (refer to *Appendix H*). Documentation is required.	

Table C.3. On-site List Infeasibility Criteria: Category 2 BMPs.[a]

BMP	On-site List Infeasibility Criteria	Additional Information from Applicant
Rain Gardens	● One or more of the infeasibility criteria for "All BMPs" or "All Infiltration BMPs" (Table C.1) apply. ● In the right-of-way, the longitudinal road slope exceeds 8 percent. ● For right-of-way applications, the rain garden would have a linear geometry and the roadway has a longitudinal slope greater than 8 percent. (Note: this infeasibility criterion is to limit the need to install bioretention systems with numerous weirs to make the bottom slope of bioretention 3 percent or less. Installation, when the overall slope is greater than 8 percent, is allowed but not required for On-site Stormwater Management.) ● The minimum bottom width (12-inch average) or side slopes of the rain garden cannot be met due to but not limited to: encroachment within the critical root zone of an existing tree(s) or minimum setbacks to structures, utilities, or property lines. Refer to City of Seattle Standard Plan No. 133 and Standard Specification 1-07.16(2), 8-01 for applicable root zone requirements. ● The infiltration area is within the minimum vertical or horizontal clearance from utilities, according to clearances required by the utility owner. ● Field testing indicates soils have a measured underlying soil infiltration rate less than 0.3 inch per hour. ● The facility is located within a 1/4 mile of nutrient critical water body, unless the optional HPBSM and polishing layer are used.	
Infiltrating Bioretention Facilities	● One or more of the infeasibility criteria for "All BMPs" or "All Infiltration BMPs" (Table C.1) apply. ● For right-of-way applications, the infiltrating bioretention facility would have a linear geometry with a longitudinal slope greater than 8 percent. (Note: this infeasibility criterion is to limit the need to install bioretention systems with numerous weirs to make the bottom slope of bioretention 3 percent or less. Installation, when the overall slope is greater than 8 percent, is allowed but not required for On-site Stormwater Management.) ● The minimum bottom width of the infiltrating bioretention facility (2 feet for facilities with vertical sides and 18-inch average for facilities with sloped sides) cannot be met due to but not limited to: encroachment within the critical root zone of an existing tree(s) or minimum setbacks to structures, utilities, or property lines (refer to City of Seattle Standard Plan No. 133 for applicable root zone requirements). ● The infiltration area is within the minimum vertical and horizontal clearance from utilities, according to clearances required by the utility owner. ● Field testing indicates soils have a measured underlying soil infiltration rate less than 0.3 inch per hour. ● Field testing indicates soils have a measured underlying soil infiltration rate less than 0.6 inch per hour and an underdrain cannot be installed per the design criteria.	

Table C.3 (continued). On-site List Infeasibility Criteria: Category 2 BMPs.[a]

BMP	On-site List Infeasibility Criteria	Additional Information from Applicant
Infiltrating Bioretention Facilities (continued)	● The facility is located within a 1/4 mile of nutrient critical water body, unless the optional HPBSM and polishing layer are used. ● The facility with an underdrain would route underdrained water to a nutrient-critical receiving water unless the optional HPBSM and polishing layer are used. ● In the right-of-way, installation requires a vertical walled facility. ● A vertical wall facility is required to provide sufficient bottom area and the depth to the bottom of the ponding area from the surrounding grade would need to be 22 inches or more to accommodate gravity flow. Note: deeper facilities, with handrails if required, are allowed but can be considered infeasible for the on-site list approach.	
Infiltrating Soil Cell Bioretention with Tree	● One or more of the infeasibility criteria for “All BMPs” or “All Infiltration BMPs” (Table C.1) apply. ● The infiltrating soil cell bioretention would have a linear geometry with a longitudinal slope greater than 5 percent or a bottom slope greater than 3 percent. ● The minimum bottom width (2 feet) of the infiltrating soil cell bioretention cannot be met due to, but not limited to: encroachment within the critical root zone of an existing tree(s) or minimum setbacks to structures, utilities, or property lines (refer to City of Seattle Standard Plan No. 133 for applicable root zone requirements). ● The infiltration area is within the minimum vertical and horizontal clearance from utilities, according to clearances required by the utility owner. ● Field testing indicates soils have a measured underlying soil infiltration rate less than 0.3 inch per hour. ● Field testing indicates soils have a measured underlying soil infiltration rate less than 0.6 inch per hour and an underdrain cannot be installed per the design criteria. ● The facility is located within a 1/4 mile of nutrient critical water body, unless the optional HPBSM and polishing layer are used. ● The facility with an underdrain would route underdrained water to a nutrient-critical receiving water unless the optional HPBSM and polishing layer are used. ● The minimum infiltrating soil cell bioretention design criteria cannot be met. ● The mature height, size, and/or rooting depth is not compatible with trees listed as approved species in the Green Factor Tree List posted on SDCI’s website for parcels and SDOT’s Approved Street Tree List for the ROW.	

Table C.3 (continued). On-site List Infeasibility Criteria: Category 2 BMPs.[a]

BMP	On-site List Infeasibility Criteria	Additional Information from Applicant
Permeable Pavement Facilities	● One or more of the infeasibility criteria for "All BMPs" or "All Infiltration BMPs" (Table C.1) apply. The following criteria each establish that the BMP is infeasible but only if based on an evaluation of site-specific conditions and a written recommendation from a licensed professional (as defined in *Appendix D*, *Section D-1*): ● Infiltrating or ponding water below pavement area would compromise adjacent pavements. ● Fill soils are used that can become unstable when saturated. ● The permeable pavement design does not provide sufficient strength to support heavy loads in areas with "industrial activity" as identified in 40 CFR 122.26(b)(14). The following criteria each establish that the BMP is infeasible, without further justification, though some criteria require professional services: ● The subgrade slope exceeds 6 percent after reasonable efforts to grade. ● The permeable pavement wearing course slope exceeds 6 percent after reasonable efforts to grade. ● For projects in the right-of-way, the permeable pavement surface area would be less than 2,000 square feet of contiguous pavement and the project discharges to: o A designated receiving water body, or o A combined system, or o A capacity constrained system which does not drain to a creek wetland or small lake. ● The anticipated mature tree spread (based on tree species) would overhang more than 50 percent of permeable pavement area. ● The pavement is over a structure, such as, but not limited to: parking garages, box culverts, and bridges. ● The pavement is subject to long-term excessive sediment deposition (e.g., construction and landscaping material yards). ● Underlying soils are unsuitable for supporting traffic loads when saturated (e.g., a residential access road has a California Bearing Ratio of 5 percent or less). ● Field testing indicates soils have a measured underlying soil infiltration rate less than 0.3 inch per hour. ● Pavement is replacing an existing pollution-generating hard surface in the right-of-way. ● The street type is classified as arterial or collector rather than local access. Refer to RCW 35.78.010, RCW 36.86.070, and RCW 47.05.021. Note: This infeasibility criterion does not extend to sidewalks and other non-traffic bearing surfaces associated with the collector or arterial.	

Table C.3 (continued). On-site List Infeasibility Criteria: Category 2 BMPs.[a]

BMP	On-site List Infeasibility Criteria	Additional Information from Applicant
Permeable Pavement Facilities (continued)	● Streets that receive more than very low traffic volumes and areas having more than very low truck traffic. Streets with a projected average daily traffic volume of 400 vehicles or less are very low volume roads (AASHTO 2001) (U.S. Dept. of Transportation 2013). Areas with very low truck traffic volumes are streets and other areas not subject to through truck traffic but may receive up to weekly use by utility trucks (e.g., garbage, recycling), daily school bus use, and multiple daily use by pick-up trucks, mail/parcel delivery trucks, and maintenance vehicles. Note: This infeasibility criterion does not extend to sidewalks and other non-traffic bearing surfaces. ● The pavement area is defined as a "high use site" in SMC, Section 22.801.090. ● In areas with "industrial activity" as identified in 40 CFR 122.26(b)(14). ● Where the risk of concentrated pollutant spills is more likely, including, but not limited to, gas stations, truck stops, and industrial chemical storage sites. ● In areas where routine, heavy roadway applications of sand occur in frequent snow zones to maintain traction during weeks of snow and ice accumulation, including sidewalks within 7 feet of driving lanes with sand application. ● Where run-on from unstabilized erodible areas would occur without presettling. ● The areas contributing runoff to the permeable pavement facilities exceed the maximum run-on limits: o Pollution-generating impervious surfaces (e.g., roadways, parking lots) exceed the maximum run-on area ratio of 2:1 o Non-pollution generating impervious surfaces (e.g., roofs, sidewalks) and stabilized pervious surfaces exceed the maximum run-on area ratio of 5:1 ● Where the Director has determined that permeable pavement in active zones of a skate park, bike park, or sport court violates safety standards.	
Permeable Pavement Surfaces	● One or more of the infeasibility criteria provided for permeable pavement facilities apply. (Note, however, that for permeable pavement surfaces, the infeasibility criteria for "All Infiltration BMPs" are not applicable). ● Field testing indicates soils have a measured underlying soil infiltration rate less than 0.3 inch per hour. (Note: field infiltration tests are not required for permeable pavement surfaces but must be used to demonstrate infeasibility). ● The site is a contaminated site or abandoned landfill. ● Installation is within 10 feet of a petroleum, chemical, or liquid hazardous waste storage tank or connecting underground pipes. ● Run-on from an adjacent impervious area is greater than 10 percent of the permeable pavement surface area.	

Table C.3 (continued). On-site List Infeasibility Criteria: Category 2 BMPs.[a]

BMP	On-site List Infeasibility Criteria	Additional Information from Applicant
Permeable Pavement Surfaces (continued)	● A licensed professional (as defined in *Appendix D*, *Section D-1*) recommends permeable pavement not be used anywhere within the project site due to reasonable concerns of erosion, slope failure, or flooding (requires a signed and stamped written determination based on site-specific conditions from a licensed professional). ● Where the Director has determined that permeable pavement in active zones of a skate park, bike park, or sport court violates safety standards. ● Based on subsurface investigation,[a] groundwater or hydraulically restrictive layer is too shallow per the following Minimum Vertical Separation table (See Table C.3a). ● The hard surface in question is a set of stairs or a 6-foot-long or less landing between sets of stairs.	
Sidewalk/ Trail Compost-Amended Strip	● One or more of the infeasibility criteria for "All BMPs," or "All Dispersion BMPs" (Table C.1) apply. ● The flow path downstream of the Sidewalk/Trail Compost-Amended Strip is within 10 feet of a proposed or existing septic system or drainfield, as measured from the toe of the Sidewalk/Trail Compost-Amended Strip slope. ● The sidewalk or trail to be dispersed exceeds a cross slope of 5 percent or a longitudinal slope of 8 percent. ● The sidewalk or trail to be dispersed has a cross slope of less than 1 percent. ● Field testing indicates underlying soils have a design soil infiltration rate less than 0.15 inch per hour. Note that field infiltration tests are not required for the Sidewalk/Trail Compost-Amended Strip but must be used to demonstrate infeasibility. ● The minimum Sidewalk/Trail Compost-Amended Strip design criteria cannot be met.	

[a] Category references Parcel-based Project list. Refer to SMC, Section 22.805.070.D and *Volume 1 Section 5.2.2* for categories relevant to other types of projects.

Table C.3a. Permeable Pavement Surface Minimal Vertical Separation

Season	Minimum Investigation Depth (ft)[b]	Minimum Vertical Separation, ft[a] Groundwater	Minimum Vertical Separation, ft[a] Hydraulically Restrictive Layer
Wet Season (November – March)	2	1	1
Dry Season (April – October)	3	2	1

[a] Subsurface investigation is not required for permeable pavement surfaces, but subsurface investigation must be performed to demonstrate infeasibility due to lack of vertical separation.

[b] The minimum investigation depth and vertical separation shall be measured from the bottom of the BMP. The bottom of the BMP is defined as the deepest portion of proposed BMP where water is expected to move into the underlying soil (i.e., at the aggregate subbase or Water Quality Treatment Course [if required]).

Table C.4. On-site List Infeasibility Criteria: Category 3 BMPs.[a]

BMP	On-site List Infeasibility Criteria	Additional Information from Applicant
Infiltrating Soil Cell Bioretention without Tree	● One or more of the infeasibility criteria for "All BMPs" or "All Infiltration BMPs" (Table C.1) apply. ● The infiltrating soil cell bioretention would have a linear geometry with a longitudinal slope greater than 5 percent or a bottom slope greater than 3 percent. ● The minimum bottom width (2 feet) of the infiltrating soil cell bioretention cannot be met due to, but not limited to: encroachment within the critical root zone of an existing tree(s) or minimum setbacks to structures, utilities, or property lines (refer to City of Seattle Standard Plan No. 133 for applicable root zone requirements). ● The infiltration area is within the minimum vertical and horizontal clearance from utilities, according to clearances required by the utility owner. ● Field testing indicates a measured underlying soil infiltration rate less than 0.3 inch per hour. ● Field testing indicates a measured underlying soil infiltration rate less than 0.6 inch per hour and an underdrain cannot be installed per the design criteria. ● The facility is located within a 1/4 mile of nutrient critical water body, unless the optional HPBSM and polishing layer are used. ● The facility with an underdrain would route underdrained water to a nutrient-critical receiving water unless the optional HPBSM and polishing layer are used. ● The minimum infiltrating soil cell bioretention design criteria cannot be met.	
Sheet Flow Dispersion	● One or more of the infeasibility criteria for "All BMPs" or "All Dispersion BMPs" (Table C.1) apply. ● The area to be dispersed (e.g., driveway, patio) exceeds a slope of 15 percent. ● The minimum vegetated flow path for sheet flow dispersion cannot be met. Note: A 10-foot flow path is required to disperse runoff from a contributing flow length of up to 20 feet. An additional 10 feet of flow path is required for each additional 20 feet of contributing flow path or fraction thereof. Refer to *Volume 3*, *Figure 5.5*. ● The flow path does not meet the minimum horizontal setback requirements to property lines, structures and other flow paths (refer to *Volume 3*, *Section 5.3.5*).	
Concentrated Flow Dispersion	● One or more of the infeasibility criteria for "All BMPs" or "All Dispersion BMPs" (Table C.1) apply. ● There are no concentrated flows to disperse. ● The minimum dispersion trench length of 10 feet cannot be met. ● The vegetated flow path for the dispersion trench is less than 25 feet. ● The vegetated flow path for a rock pad is less than 50 feet. ● Greater than 700 square feet of surface area drains to the BMP. ● The flow path does not meet the minimum horizontal setback requirements to property lines, structures, and other flow paths (refer to *Volume 3*, *Section 5.3.6*).	

Table C.4 (continued). On-site List Infeasibility Criteria: Category 3 BMPs.[a]

BMP	On-site List Infeasibility Criteria	Additional Information from Applicant
Splashblock Downspout Dispersion	● One or more of the infeasibility criteria for "All BMPs" or "All Dispersion BMPs" (Table C.1) apply. ● There are no downspouts. ● The vegetated flow path is less than 50 feet. ● Greater than 700 square feet of surface area drains to the BMP. ● The flow path does not meet the minimum horizontal setback requirements to property lines, structures, and other flow paths (refer to *Volume 3*, *Section 5.3.3*).	
Trench Downspout Dispersion	● One or more of the infeasibility criteria for "All BMPs" or "All Dispersion BMPs" (Table C.1) apply. ● There are no downspouts. ● The minimum dispersion trench length of 10 feet for every 700 square feet of drainage area cannot be met. ● The vegetated flow path is less than 25 feet. ● The flow path is within the setbacks to property lines, structures, and other flow paths (refer to *Volume 3, Section 5.3.4*).	
Non-Infiltrating Bioretention	● One or more of the infeasibility criteria for "All BMPs" (Table C.1) apply. ● In the right-of-way, the infiltrating bioretention facility would have a linear geometry and roadway with an overall longitudinal slope greater than 8 percent. (Note: this infeasibility criterion is to limit the need to install bioretention systems with numerous weirs to make the bottom slope of bioretention 3 percent or less. Installation, when the overall slope is greater than 8 percent, is allowed but not required for On-site Stormwater Management.) ● The minimum bottom width of the non-infiltrating bioretention facility (2 feet) cannot be met due to, but not limited to: encroachment within the critical root zone of an existing tree(s), minimum setbacks to structures/utilities, or project limits/planting strip too small (refer to City of Seattle Standard Plan No. 133 for applicable root zone requirements). ● Minimum vertical and horizontal clearances from utilities are unachievable as required by utility owner. ● The facility would route underdrained water to a nutrient-critical receiving water unless the optional HPBSM and polishing layer are used. ● The area available for siting is within a setback equal to the height of the slope to a maximum of 50 feet from the top of steep slope and known landslide area. ● The BMP would be located on a structure or roof that cannot provide sufficient structural support for the BMP without reasonable effort to increase the strength of the roof design. ● Less than 1 foot between the liner and seasonal high groundwater elevation. ● A vertical wall facility is required to provide sufficient bottom area and the depth to the bottom of the ponding area from the surrounding grade would need to be 22 inches or more to accommodate gravity flow. Note: deeper facilities, with hand rails if required, are allowed but can be considered infeasible for the on-site list approach.	

[a] Category references Parcel-based Project list. Refer to SMC, Section 22.805.070.D and *Volume 1 Section 5.2.2* for categories relevant to other types of projects.

Table C.5. On-site List Infeasibility Criteria: Category 4 BMPs.[a]

BMP	On-site List Infeasibility Criteria	Additional Information from Applicant
Non-infiltrating Soil Cell Bioretention with Tree	● One or more of the infeasibility criteria for "All BMPs" (Table C.1) apply. ● The non-infiltrating soil cell bioretention would have a linear geometry with a longitudinal slope greater than 5 percent or a bottom slope greater than 3 percent. ● The minimum bottom width of the non-infiltrating soil cell bioretention (2 feet) cannot be met due to, but not limited to: encroachment within the critical root zone of an existing tree(s), minimum setbacks to structures/utilities, or project limits/planting strip too small (refer to City of Seattle Standard Plan No. 133 for applicable root zone requirements). ● Minimum vertical and horizontal clearances from utilities are unachievable as required by utility owner. ● The facility would route underdrained water to a nutrient-critical receiving water unless the optional HPBSM and polishing layer are used. ● The area available for siting is within a setback equal to the height of the slope to a maximum of 50 feet from the top of steep slope and known landslide area. ● Less than 1 foot between the liner and seasonal high groundwater elevation. ● The minimum non-infiltrating soil cell bioretention design criteria cannot be met.	
Rainwater Harvesting	See On-site List Infeasibility Criteria in Table C.2.	
Vegetated Roof Systems	● One or more of the infeasibility criteria for "All BMPs" (Table C.1) apply. ● Project does not include a roof. ● Roof design has a slope less than 1 degree (0.2:12) or greater than 10 degrees (2:12). ● Installation is not economically feasible based on reasonable consideration of financial cost (refer to *Appendix H*). Documentation is required. ● The portion of the roof is an amenity area subject to pedestrian use (e.g., balcony, patio, walkway, pet runs, etc.). ● The portion of the roof is required for HVAC equipment and/or maintenance access ways (e.g., window washing, HVAC maintenance, etc.). ● The portion of the roof is completely covered with solar panels.	
Residential Cistern	● One or more of the infeasibility criteria for "All BMPs" (Table C.1) apply. ● Project does not include non-pollution generating surfaces. ● The SFR cistern would be within restricted setbacks.	

[a] Category references Parcel-based Project list. Refer to SMC, Section 22.805.070.D and *Volume 1 Section 5.2.2* for categories relevant to other types of projects.

Table C.6. On-site List Infeasibility Criteria: Category 5 BMPs.[a]

BMP	On-site List Infeasibility Criteria	Additional Information from Applicant
Perforated Stub-out Connections	● One or more of the infeasibility criteria for "All BMPs" or "All Infiltration BMPs" (Table C.1) apply. ● The location for the perforated pipe portion of the system is under impervious or heavily compacted (e.g., driveways and parking areas) surfaces. ● The minimum perforated stub-out length of 10 feet per 5,000 square feet of contributing roof area cannot be met. ● Where the site cannot be reasonably designed to locate a catch basin between the perforated stub-out and point of connection to the public system.	
Trees	● The mature height, size, and/or rooting depth is not compatible with Medium and Large trees listed as approved species in the Green Factor Tree List posted on SDCI's website for parcels and SDOT's Approved Street Tree List for the ROW.	

[a] Category references Parcell-based Project list. Refer to SMC, Section 22.805.070.D and *Volume 1 Section 5.2.2* for categories relevant to other types of projects.

APPENDIX D

Subsurface Investigation and Infiltration Testing for Infiltration BMPs

City of Seattle | Stormwater Manual

July 2026

City of Seattle

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D-1. Roles and Responsibilities of Licensed Professionals

This appendix provides the minimum investigation requirements for infiltration best management practices (BMPs). This information does not preclude the use of professional judgment to evaluate and manage risk associated with design, construction, and operation of infiltration BMPs.

When a licensed professional is required to perform a subsurface investigation and/or infiltration testing, that professional shall be an engineer, engineering geologist, geologist, hydrogeologist, or soil scientist licensed by the State of Washington who has experience in infiltration and or groundwater testing and infiltration BMP design, except in the following cases:

- The licensed professional shall be either a geotechnical engineer or hydrogeologist licensed by the State of Washington when:
  - A Comprehensive Subsurface Investigation is required.
  - A correction factor for a Comprehensive Subsurface Investigation is required to be determined.
  - Infiltration is proposed in an Environmentally Critical Area (ECA) steep slope or landslide-prone areas or within a setback of 10 times the height of the steep slope area to a maximum of 500 feet above a steep slope area.
- The licensed professional shall be a hydrogeologist licensed in the State of Washington when:
  - Runoff from 5,000 square feet or more of impervious surface area will be infiltrated within 500 feet up-gradient or 100 feet down-gradient of a contaminated site or landfill (active or closed).
  - Groundwater mounding and/or seepage analysis is required.
  - A deep subsurface infiltration test is required.

Acceptance testing shall be performed by a licensed professional from the same category as was required for the design investigations.

Recommendations that deviate from the minimum investigation requirements specified in this appendix shall be contained in a stamped and signed letter from a licensed professional and must provide rationale and specific data supporting their professional judgment. For more information on the role of the geotechnical engineer or hydrogeologist, refer to City of Seattle Director's Rule 5-2016, *General Duties and Responsibilities of Geotechnical Engineers*.

D-2. Subsurface Investigation

D-2.1. Description

Subsurface investigations consist of any type of excavation that allows for the collection of soil samples and the observation of subsurface materials and groundwater conditions, including hand-auger holes, test pits, and drilled boreholes.

This section includes general subsurface investigation requirements followed by specific information regarding four types of subsurface investigations:

- Simple subsurface investigation
- Standard subsurface investigation
- Comprehensive subsurface investigation
- Deep infiltration subsurface investigation

D-2.2. General Subsurface Investigation Requirements

This section includes requirements for subsurface investigation locations, timing, alternatives, investigation depth and vertical separation requirements, and subsurface reports.

D-2.2.1. Subsurface Investigation Locations

For Single-Family Residential (SFR) and Parcel-based projects, the site is defined as the project area. For Trail, Sidewalk, or Roadway projects, the site is defined by one intersection to the other and blocks may vary in length. In many cases, subsurface investigations should be performed at the site of the infiltration BMP or as close as possible, but no more than 50 feet away, to obtain relevant subsurface information. Subsurface investigations can be conducted at the same location as the infiltration tests (refer to *Section D-3*).

D-2.2.2. Subsurface Investigation Timing

Subsurface investigations should be performed in the wet season (November through March) if possible, when soils may contain a higher water content and groundwater levels are typically higher. Refer to *Sections D-2.3* through *D-2.5* for wet season and dry season requirements for the different types of subsurface investigations.

D-2.2.3. Alternatives to Subsurface Investigation

In some cases, available data and the licensed professional's interpretation of subsurface material characteristics can be used to demonstrate that infiltration is infeasible on a site and precludes the need for all of the subsurface investigation or infiltration testing. Examples of these instances include, but are not limited to:

- Groundwater monitoring data that meets the requirements of the groundwater monitoring section (refer to *Section D-5*), at the site of the proposed BMP showing groundwater elevations not meeting the vertical separation requirements (refer to *Section D-2.2.4)*.
- Identification by the licensed professional of hydraulically restrictive materials beneath the proposed BMP and within the vertical separation requirements (refer to *Section D-2.2.4*).
- To support these instances, the licensed professional must submit a stamped and signed letter that provides rationale and specific data supporting their professional judgment for each area deemed infeasible for infiltration.

D-2.2.4. Investigation Depth and Vertical Separation Requirements

Investigation depth is measured below the bottom of the proposed infiltration BMP. The bottom of the infiltration BMP is defined as the deepest portion of the proposed BMP where infiltrating water is expected to move into the underlying soil.

The vertical separation requirements depend upon the type of subsurface investigation required and the seasonal timing of the geotechnical exploration conducted to evaluate clearance and are typically 1 foot less than the minimum investigation depths summarized in *Sections D-2.3* through *D-2.5*. If groundwater or a hydraulically restrictive material is encountered within the vertical separation depth, then no further investigation is required.

Examples of materials that may be interpreted as hydraulically restrictive include:

- Glacially consolidated soils that have greater than 50 percent fines
- Glacially unconsolidated soils that have greater than 70 percent fines
- Bedrock

D-2.2.5. Subsurface Report

Projects that are required to perform subsurface investigations per *Volume 3*, *Section 3.2*, shall prepare a report documenting results of the subsurface investigations described in *Sections D-2.3* through *D-2.6* and infiltration tests described in *Section D-3*.

D-2.3. Simple Subsurface Investigation

This section summarizes the minimum requirements of a Simple Subsurface Investigation. Refer to Table 3.1 in *Volume 3*, *Section 3.2* to determine the minimum subsurface investigation requirements for a project.

A simple subsurface investigation report can be used to document the investigation and testing results. This report shall include the following, as applicable:

- Map of investigation and testing location
- Soil characteristics
- Depth to groundwater (if encountered)
- Results of subsurface investigations as required in Table 3.1 of *Volume 3, Section 3.2* and evaluation of vertical separation results.

Simple Subsurface Investigation Elements for All BMPs

Minimum Investigation Depth and Vertical Separation Requirements

Season	Minimum Investigation Depth (ft)[a]	Minimum Vertical Separation, ft [a] Groundwater	Minimum Vertical Separation, ft [a] Hydraulically Restrictive Layer
Wet Season (November – March)	2	1	1
Dry Season (April – October)	3	2	1

Soil Characteristics

Type and texture of soil

[a] The bottom of the BMP is defined as the deepest portion of the proposed BMP where infiltrating water is expected to move into the underlying soil.

D-2.4. Standard Subsurface Investigation

This section summarizes the minimum requirements of a Standard Subsurface Investigation. Refer to Table 3.1 in *Volume 3*, *Section 3.2* to determine the minimum subsurface investigation requirements for a project.

A standard subsurface investigation report shall be used to document the investigation and testing results. This report shall include the following, as applicable:

- Map of investigation and testing location
- Soil characteristics for each soil and/or rock unit encountered
- Depth to groundwater (if encountered)
- Detailed logs for each investigation
- Results of subsurface investigations as required in Table 3.1 of *Volume 3, Section 3.2* and evaluation of vertical separation results.

If a small pilot infiltration test (PIT) is required, the report shall be signed and stamped by a licensed professional.

Standard Subsurface Investigation Elements

Minimum Investigation Depth and Vertical Separation Requirements

Season	Minimum Investigation Depth (ft)[a]	Minimum Vertical Separation (ft)[a] Groundwater	Minimum Vertical Separation (ft)[a] Hydraulically Restrictive Layer
Infiltration Basins			
Wet Season (November – March)	6	5	5
Dry Season (April – October)	7	6	5

Standard Subsurface Investigation Elements (continued)

Minimum Investigation Depth and Vertical Separation Requirements

Season	Minimum Investigation Depth (ft)[a]	Minimum Vertical Separation (ft)[a] Groundwater	Minimum Vertical Separation (ft)[a] Hydraulically Restrictive Layer
All Other Infiltration BMPs			
Wet Season (November – March)	2	1	1
Dry Season (April – October)	4	3	1

Characterization for each soil and/or rock unit (strata with the same texture, color/mottling, density, and type)

- USCS classification or textural class
- Material texture, color/mottling, density and type
- Relative moisture content
- Grain size distribution, including fines content determination
- Presence of stratification or layering
- Presence of groundwater
- Iron oxide staining or mottling that may provide an indication of high water level
- Cation exchange capacity (refer to *Volume 3*, *Section 4.5.2*)

Detailed logs for each investigation

- Map showing the location of the test pits or borings
- Depth of investigations
- Investigation methods (hand augers, test pits, or drilled borings), material descriptions
- Depth to water (if present)
- Presence of stratification
- Existing boring or groundwater information

The report shall document how the information collected relates to the infiltration feasibility of the site based on the setbacks provided in *Volume 3*, *Section 3.2* and this appendix. If more than 2,000 sf of the site infiltration will occur within a single BMP, the Standard Subsurface Investigation report shall be prepared by a licensed professional.

[a] The bottom of the BMP is defined as the deepest portion of the proposed BMP where infiltrating water is expected to move into the underlying soil. For Small PITs, sampling of distinct materials below the bottom of the BMP and within the vertical separation depth is required. Beyond this depth, samples should be collected every 2.5 feet.

D-2.5. Comprehensive Subsurface Investigation

This section summarizes the minimum requirements of a Comprehensive Subsurface Investigation. Refer to Table 3.1 in *Volume 3, Section 3.2* to determine the minimum subsurface investigation requirements for a project. The comprehensive subsurface investigation report shall be prepared, signed and stamped by a geotechnical engineer or hydrogeologist.

A comprehensive subsurface investigation report shall be used to document the investigation and testing results. This report shall include the following, as applicable:

- Map of investigation and testing location
- Soil characteristics for each soil and/or rock unit encountered
- Depth to groundwater (if encountered)

- Detailed logs for each investigation
- Results of subsurface investigations as required in Table 3.1 of *Volume 3, Section 3.2* and evaluation of vertical separation results.

Comprehensive Subsurface Investigation Elements

Minimum Investigation Depth

BMP Type	Season	Minimum Investigation Depth (ft)[a,b]	Minimum Vertical Separation (ft) Groundwater	Minimum Vertical Separation (ft) Hydraulically Restrictive Layer
Infiltration Basins	Wet Season (November – March)	6	5	5
	Dry Season (April – October)	10	8	5
Permeable Pavement Facilities	Wet Season (November – March)	2	1	1
	Dry Season (April – October)	4	3	1
Infiltrating Bioretention with Underdrain	Wet Season (November – March)	2	1	1
	Dry Season (April – October)	10	8	1
Infiltrating Bioretention without Underdrain and all Other Infiltration BMPs	Wet Season (November – March)	4	3	3
	Dry Season (April – October)	10	8	3

Characterization for each soil and/or rock unit (strata with the same texture, color/mottling, density, and type)

Same as Standard Subsurface Investigation (*Section D-2.4*)

Detailed logs for each investigation

Same as Standard Subsurface Investigation (*Section D-2.4*)

[a] The bottom of the BMP is defined as the deepest portion of the proposed BMP where infiltrating water is expected to move into the underlying soil. For Small PITs, sampling of distinct materials below the bottom of the BMP and within the vertical separation depth is required. Beyond this depth, samples should be collected every 2.5 feet.

[b] If the bottom of the BMP is not known, the minimum investigation depth shall be 16 feet below grade. Investigations that will also serve as groundwater monitoring wells shall not be less than 20 feet below the bottom of the proposed BMP and the criteria for vertical separation to groundwater or hydraulically restrictive materials listed above shall apply.

D-2.6. Deep Infiltration Subsurface Investigation

This section summarizes the minimum requirements of a Deep Infiltration Subsurface Investigation. Refer to Table 3.2 in *Volume 3, Section 3.2* to determine the minimum subsurface investigation requirements for a project. The deep infiltration subsurface investigation report shall be prepared by a licensed geotechnical engineer or hydrogeologist.

Deep Infiltration Subsurface Investigation Elements are as follows:

- Minimum Investigation Depth: At least 10 feet below regional groundwater table or into aquitard underlying target soil.
- Characterization for each soil and/or rock unit (strata with the same texture, color/mottling, density, and type): Same as Standard Subsurface Investigation *(Section D-2.4)*.
- Detailed logs for each investigation: Same as Standard Subsurface Investigation *(Section D-2.4)*

D-3. Infiltration Tests

D-3.1. Description

Step 4 in *Volume 3, Section 3.2* is Conduct Infiltration Testing. This section provides procedures for the following infiltration testing methods:

- Simple Infiltration Test (Small-scale infiltration test)
- Small Pilot Infiltration Test (PIT)
- Large PIT
- Deep Infiltration Test

To determine which infiltration test method is required for a project, refer to Table 3.1 and Table 3.2 in *Volume 3, Section 3.2*.

If possible, perform infiltration testing at the location of the proposed infiltration BMP. Infiltration testing results from a nearby location within 50 feet of the proposed infiltration BMP may be approved at the discretion of the licensed professional. If greater than 5,000 sf is infiltrated on the site, then acceptance testing is required (refer to *Volume 3, Section 3.2*).

If variable soil conditions are observed at the site, multiple infiltration tests are recommended in the different soil types.

After the measured infiltration rates are determined using the procedures provided in this section, correction factors must be applied to calculate the design infiltration rate used for BMP sizing (refer to *Section D-4*).

The test method may be modified due to site conditions if recommended by the licensed professional and the reasoning is documented in the report. Any modifications to the proposed test method should be approved by the City.

D-3.2. Simple Infiltration Test

The Simple Infiltration Test is a small-scale infiltration test procedure adapted from the Washington State Department of Ecology (Ecology) Rain Garden Handbook for Western Washington (https://fortress.wa.gov/ecy/publications/SummaryPages/1310027.html).

The Simple Infiltration Test does not require a licensed professional.

The Simple Infiltration Test is not allowed for projects with no off-site point of discharge (*Volume 3, Section 4.3.2*). These projects shall use a Small PIT.

Procedure

If testing is performed during the wet season (November through March), only one test is required. If the test is performed during the dry season (April through October), two tests must be performed in same hole within 2 days, with the beginning of each test spaced 24 hours apart.

1. Dig a hole a minimum of 2 feet deep. Preferably, the depth of the hole should be measured from the bottom of the facility but at a minimum shall be measured from the proposed site finished grade. The hole shall be at least 2 feet in diameter.
2. Record the type and texture of the soil. If the soil is primarily fine-grained such as silt or clay, or is glacial till, infiltration may not be feasible.
3. At the same time that you dig your test hole, check for high groundwater by using a post hole digger to excavate a hole to the minimum subsurface investigation depth, as provided in *Section D-2.3*, approximately 5 feet from the test hole. If standing water or seeping water is observed in the hole, measure the depth to the standing water or seepage.
4. Pre-soak period: Add 12 inches of water to the hole. This can be measured using a ruler, scale, or tape measure. Be careful to avoid splashing, which could erode the sides of the hole or disturb the soil at the base of the hole.
5. Record the depth of water in the hole in inches.
6. Record the time water was added to the hole.
7. Check and record the time and depth of water in the hole on an hourly basis for up to 2 hours. Estimate the infiltration rate in inches per hour by calculating the drop in water level in inches for each hour. Based on the lowest of these measurements, determine which time interval to use for the infiltration test by following these guidelines:
    - >3 inches per hour fall, check at 15--minute intervals
    - 3 inches to 1 inch per hour fall, check at 30--minute intervals
    - <1 inch per hour fall, check at hourly intervals
8. Infiltration Test: Fill the hole back up to a depth of 12 inches. Check and record the time and depth of water in the hole at regular intervals based on the time interval determined during the presoak period for a total of six measurements. If the hole empties prior to the six measurements, refill and continue recording until you have recorded six measurements.

9. Calculate measured infiltration rate. Refer to Table 3.3 in *Volume 3, Section 3.2* for minimum infiltration rates for each type of infiltration BMP. Using the collected data, estimate the infiltration rate in inches per hour by calculating the drop in water level in inches for each hour data was collected during the infiltration test. There should be a total of six values. The lowest calculated value is the measured infiltration rate in inches per hour
10. Mark test locations on site map.

D-3.3. Small Pilot Infiltration Test (Small PIT)

The testing procedure and data analysis requirements for the Small PIT are provided below. The report for this test shall include documentation of the testing procedure, analysis, and results to assess infiltration feasibility and an explanation of the correction factor used to determine the design infiltration rate.

The Small PIT report shall be prepared by a licensed professional. The test method may be modified due to site conditions if recommended by the licensed professional and the reasoning is documented in the report.

Procedure

1. Excavate the test pit to the depth of the bottom of the proposed infiltration BMP. In the case of bioretention, excavate to the lowest estimated elevation at which the imported soil mix will contact the underlying soil. For permeable pavement, excavate to the elevation at which the imported subgrade materials, or the pavement itself, will contact the underlying soil. If the underlying soils (road subgrade) will be compacted, compact the underlying soils prior to testing. Note that the permeable pavement design guidance recommends compaction not exceed 90 to 92 percent.
2. Lay back the slopes sufficiently to avoid caving and erosion during the test. Alternatively, consider shoring the sides of the test pit.
3. The size of the bottom of the test pit shall be a minimum of 12 square feet (sf). Document the size and geometry of the test pit.
4. Install a device capable of measuring the water level in the pit during the test. This may be a pressure transducer (automatic measurements) or a vertical measuring rod (minimum 5 feet long) marked in half-inch increments in the center of the pit bottom (manual measurements).
5. Use a rigid pipe with a splash plate or some other device on the bottom to convey water to the bottom of the pit and reduce side-wall erosion and excessive disturbance of the pit bottom. Excessive erosion and bottom disturbance may result in clogging of the infiltration receptor and yield lower than actual infiltration rates.
6. Pre-soak period: Add water to the pit so that there is standing water for at least 6 hours. Maintain the pre-soak water level at least 12 inches above the bottom of the pit.
7. Steady state period:
    a. At the end of the pre-soak period, add water to the pit at a rate that will maintain a depth of 12 inches above the bottom of the pit over a full hour.

b. Every 15 minutes during the steady state period, record the cumulative volume and instantaneous flow rate (in gallons per minute) necessary to maintain the water level at the same point (the design ponding depth) on the measuring rod or pressure transducer readout.

8. Falling head period: After 1 hour, turn off the water and record the rate of infiltration (the drop rate of the standing water) in inches per hour every 15 minutes using the pressure transducer or measuring rod data, for a minimum of 1 hour or until the pit is empty.
9. Within 24 hours after the falling head period, over-excavate the pit to determine if the test water is mounded on shallow restrictive layers or if it has continued to flow deep into the subsurface. The investigation depth varies depending on the type of subsurface investigation required (refer to Table 3.1 in *Volume 3*, *Section 3.2*) and the seasonal timing of the geotechnical exploration conducted to evaluate clearance. Minimum investigation depths are provided in *Section D-2*.

Data Analysis

Using the established steady state flow rate, calculate and record the measured infiltration rate in inches per hour. Use the falling head data to confirm the measured infiltration rate calculated from the steady state data.

Adjust the measured infiltration rate using the correction factor (CF) described in *Section D-4* to estimate the design infiltration rate.

D-3.4. Large Pilot Infiltration Test (Large PIT)

A Large PIT will more closely simulate actual conditions for the infiltration BMP than a Small PIT and may be preferred at the discretion of the licensed professional if not already required per Table 3.1 in *Volume 3*, *Section 3.2*. The testing procedure and data analysis requirements for the Large PIT are provided below. The report for this test shall include documentation of the testing procedure, analysis, and results to assess infiltration feasibility and an explanation of the correction factor used to determine the design infiltration rate.

The Large PIT report shall be prepared by a licensed professional. The test method may be modified due to site conditions if recommended by the licensed professional and the reasoning is documented in the report.

Procedure

1. Excavate the test pit to the depth of the bottom of the proposed infiltration BMP. In the case of bioretention, excavate to the lowest estimated elevation at which the imported soil mix will contact the underlying soil. For permeable pavement, excavate to the elevation at which the imported subgrade materials will contact the underlying soil. If the underlying soils (road subgrade) will be compacted, compact the underlying soils prior to testing. Note that the permeable pavement design guidance recommends compaction not exceed 90 to 92 percent.
2. Lay back the slopes sufficiently to avoid caving and erosion during the test. Alternatively, consider shoring the sides of the test pit.

3. The size of the bottom of the test pit should be as close to the size of the planned infiltration BMP as possible, but not less than 32 square feet in area (100 square feet is recommended). Where water availability is an issue, smaller areas may be considered, as determined by the licensed professional. Document the size and geometry of the test pit.

Refer to Steps 4 through 9 as described in the Small PIT Procedure above.

Data Analysis

Refer to the data analysis guidance for small PITs in *Section D-3.3*.

D-3.5. Deep Infiltration Test

The design infiltration capacity for deep infiltration shall be determined by performing a constant-rate infiltration test followed by a falling-head infiltration test. The Deep Infiltration Test report shall include documentation of the testing procedure, analysis, and results to assess infiltration feasibility and an explanation of the correction factor used to determine the design infiltration capacity of the proposed BMP.

The Deep Infiltration Test report shall be prepared by a licensed professional. The test method may be modified due to site conditions if recommended by the licensed geotechnical engineer or hydrogeologist and the reasoning is documented in the report.

Procedure

1. Perform the test by adding water (obtained from a potable water source) to the test well to maintain a constant hydraulic head in the well. The specific target hydraulic head will depend on the subsurface conditions, the design and construction of the test well, and the project goals. As a starting point, it is recommended to saturate the entire screened portion of the test well that is within the target soil zone.
2. Monitor the flow rate with a flow meter or other method that is capable of measuring flow to within 5 percent of the total flow rate.
3. Monitor water levels in the test well with a pressure transducer and datalogger on a maximum of 5-minute intervals.
4. Add water until the rate of water added is constant, or for a minimum of 4 hours.
5. Once a constant rate is achieved, the test is complete. Begin the falling head portion of the test. Monitor water levels during the falling head test until the water level has fallen to a minimum of 5 percent of the total head targeted during the constant rate portion of the test.
6. In addition to the required wells, monitor groundwater elevations in nearby monitoring wells as available.

Data Analysis

The test data shall be evaluated by a licensed hydrogeologist experienced in the analysis of well hydraulics and well testing data. As a result of the likely variability in soil conditions,

specific methods for analysis of the data are not provided. It is the responsibility of the professional analyzing the data to select the appropriate methodology.

D-4. Infiltration Rate Correction Factor

Measured infiltration rates described in *Section D-3* shall be reduced using correction factors to determine the design infiltration rates. The determination of a design infiltration rate from in-situ infiltration test data involves a considerable amount of engineering judgment. Therefore, when determining the final design infiltration rate, the licensed professional shall consider the results of both soil subsurface material conditions and in-situ infiltration tests results. In no case shall the design infiltration rate exceed 10 inches per hour.

Design Infiltration Rate = Measured Infiltration Rate x CF

A correction factor (CF) is applied to the measured infiltration rate to calculate the design infiltration rate. The design infiltration rate shall be used when sizing infiltration BMPs using the design criteria outlined in *Volume 3, Section 5.4*.

D-4.1. Simple Infiltration Test

A CF of 0.5 shall be applied to the measured infiltration rate to calculate the design infiltration rate.

D-4.2. Small and Large PITs

A CF of 0.5 must be used for all projects unless a lower value is warranted by site conditions, as recommended and documented by a licensed professional, and shall not be less than 0.2. In determining an appropriate CF, the following criteria shall be considered and are described below:

- Site variability and number of locations tested
- Uncertainty of test method
- Degree of influent control to prevent siltation and bio-buildup

Site variability and number of locations tested — This criterion depends on the level of uncertainty that adverse subsurface conditions may exist. The number of locations tested must be sufficient to represent the conditions throughout the BMP site. The following are examples of how site variability and number and locations of the tests may affect uncertainty:

- The subsurface conditions are known to be uniform based on previous exploration and site geological factors, one PIT may be adequate to justify that the uncertainty for that site is low.
- High variability may exist due to subsurface conditions (such as buried stream channels) identified on previous explorations and site geological factors. In these cases, even with many explorations and several PITs, the level of uncertainty may still be high.

- High uncertainty could also be assigned where conditions have a more typical variability, but few explorations and only one PIT is conducted. That is, the number of explorations and tests conducted do not match the degree of site variability anticipated.

Uncertainty of test method — This criterion represents the accuracy of the infiltration test method used. Larger scale tests are assumed to produce more reliable results (i.e., the Large PIT is more certain than the Small PIT).

Degree of influent control to prevent siltation and bio-buildup — High uncertainty for this criterion may be justified under the following circumstances:

- If the infiltration BMP is located in a shady area where moss buildup or litter fall buildup from the surrounding vegetation is likely and cannot be easily controlled through long-term maintenance.
- If there is minimal pre-treatment, and the influent is likely to contain moderately high total suspended solids (TSS) levels.

If influent into the BMP can be well controlled such that the planned long-term maintenance can easily control siltation and biomass buildup, then low uncertainty may be justified for this criterion.

D-5. Groundwater Monitoring

Groundwater monitoring wells (including the minimum subsurface investigation depth) shall be installed as determined in Sections D-2.3 through D-2.6 under the direct supervision of a licensed professional. The minimum number of groundwater monitoring wells, duration of monitoring, and frequency of monitoring are summarized in Table 3.1 and Table 3.2 in Volume 3, Section 3.2. A report shall be developed that is prepared by a licensed professional and includes a map detailing the locations of the monitoring wells relative to the project site and a description of the groundwater levels relative to the investigation depth and vertical separation requirements provided in Section D-2.

Groundwater monitoring is not required in the following situations when using shallow infiltration BMPs:

- Elevation data measured at project monitoring wells shows groundwater levels within the investigation depth and vertical separation requirements summarized in Section D-2.
- Available groundwater elevation data within 50 feet of the proposed infiltration BMP shows the highest measured groundwater level to be at least 10 feet below the bottom of the proposed infiltration BMP or if the initial groundwater measurement is more than 15 feet below the bottom of the proposed infiltration facility.

In these situations, no further investigation is required to meet on-site, flow control, or water quality treatment requirements. These exceptions do not apply to deep infiltration BMPs.

D-6. Characterization of Infiltration Receptor

The infiltration receptor is the unsaturated and saturated soil receiving stormwater from an infiltration BMP. Thresholds for triggering characterization of the infiltration receptor are summarized in Table 3.1 and Table 3.2 in Volume 3, Section 3.2.

Assessment and documentation by a licensed hydrogeologist characterizing the infiltration receptor shall include the following elements:

- Depth to groundwater and to hydraulically restrictive material.
- Seasonal variation of groundwater table based on well water levels and observed mottling of soils.
- Existing groundwater flow direction and gradient.
- Approximation of the lateral extent of infiltration receptor.
- Volumetric water holding capacity of the infiltration receptor soils. The volumetric water holding capacity is the storage volume in the soil layer directly below the infiltration BMP and above the seasonal high groundwater mark, or hydraulically restrictive material.
- Horizontal hydraulic conductivity of the saturated zone to assess the aquifer's ability to laterally transport the infiltrated water.

Note: As part of the infiltration receptor characterization for deep infiltration wells, the pretreatment requirements shall be evaluated as in the UIC Guidance Manual (Ecology 2006).

D-7. Groundwater Mounding and Seepage Analysis

Infiltration of large volumes of water may result in a rise in the water table or development of a shallow water table on hydraulically restrictive materials that slow the downward percolation of water. If this mounding of water is excessive, the infiltration BMP may become less effective and/or adjacent structures or facilities may be impacted by the rising water table. In addition, if the infiltration BMP is adjacent to a slope, slope stability may be decreased.

Thresholds for triggering groundwater mounding and seepage analysis are summarized in Table 3.1 and Table 3.2 in *Volume 3, Section 3.2*.

The mounding analysis shall evaluate the impact of the infiltration BMP on local groundwater flow direction and water table elevations and determine whether there would be any adverse effects caused by seepage zones on nearby building foundations, basements, roads, parking lots, or sloping sites. If the results of the mounding analysis indicate that adverse conditions could occur, as determined by a licensed professional, the infiltration BMP shall not be built.

If infiltration on the site may result in shallow lateral flow (interflow), the conveyance and possible locations where that interflow may re-emerge shall be assessed by a licensed hydrogeologist.

For deep infiltration BMPs, the following shall also be evaluated:

- Extent of groundwater mounding under the design flow rate.
- Potential impacts from the groundwater mounding to:
  - Deep infiltration BMP performance
  - Surrounding infrastructure, including, but not limited to, infiltration BMPs, drainage facilities, foundations, basements, utility corridors, or retaining walls
  - Off-site slope stability
  - Down-gradient existing contamination plumes

Several analytical tools are available to evaluate potential groundwater mounding beneath infiltration BMPs. These include both analytical and numerical groundwater flow software. In general, public domain software programs shall be used (such those initially authored by the United States Geological Survey (USGS) or the Environmental Protection Agency).

The software program MODRET is considered a standard tool for evaluating infiltration BMPs and is recommended in Ecology's Stormwater Management Manual for Western Washington. Although MODRET is a proprietary computer program, it is readily available for purchase and is based on USGS software. However, MODRET is limited to evaluation of a single BMP at a time and generally will not be suitable for evaluating clustered BMPs.

The preferred program for simulating groundwater mounding beneath infiltration BMPs is the USGS-based program MODFLOW. MODFLOW can be used to simulate a wide range of aquifer conditions and geometries. The primary limitation with MODFLOW is that most versions of the program do not simulate the movement of water through the unsaturated zone, which would normally be expected to slow the downward movement of water and allow for lateral spreading of water before reaching the water table. Instead, infiltrating water is input directly to the water table. For a shallow water table or perching layer this limitation should not greatly influence the overall results of the mounding simulation and represents a more conservative approach to simulating mounding.

Licensed hydrogeologists with formal training and experience in developing groundwater flow models shall conduct these analyses. It should also be noted that groundwater models do not provide specific answers but are tools to help understand the behavior of groundwater systems under a variety of conditions. The results of any model should be used in the context of the overall goal of the project and be applied as warranted by the risk tolerance of the owner.

D-7.1. Data Requirements

Data requirements for development of a groundwater mounding model include:

- Soil and groundwater conditions
- Aquifer parameters (e.g., hydraulic conductivity and specific yield)
- Aquifer geometry

- Pre-infiltration hydraulic gradient
- Flow rate from infiltration BMPs

Many of the data inputs for the groundwater mounding model should be available in the vicinity of the infiltration BMPs from the subsurface investigation and infiltration testing performed for design of the BMPs. Outside the area of the infiltration BMPs, data may be sparse and may need to be interpolated from regional data. The extent of the modeled area should be such that the edges of the model do not influence the data unless an actual boundary exists, such as Elliott Bay or Lake Washington.

In the absence of local information regarding the groundwater gradient and/or the distribution of hydraulic restrictive layers, mounding analyses should consider the general slope of the site and surrounding sites, as the general slope is likely indicative of the direction of interflow originating from infiltration BMPs and the regional hydraulic gradient.

Aquifer parameters shall be estimated based on knowledge of local soil types and from grain size distribution of the soil samples collected as part of the subsurface investigation and testing program. In general, groundwater flow models tend to be most sensitive to variations in hydraulic conductivity values. Obtain hydraulic conductivity values from field testing of the infiltration receptor soils using standard industry methods.

D-7.2. Analysis Procedures

The initial step for any groundwater modeling analysis is the development of a conceptual model of the groundwater system. The conceptual model should describe the anticipated groundwater flow system including the data requirements described above, direction and rate of groundwater flow, potential model boundaries, and approach for simulating infiltration. The conceptual model provides the basis for constructing the computer model.

Because of the limited available data necessary for model inputs, a parametric analysis shall be performed whereby model inputs, especially aquifer parameters, are varied over a range of values to evaluate the potential impact on the mounding results. The range values shall be based on known variability in the parameter and experience with similar soils in the area by the licensed professional developing the model.

The following ranges of aquifer parameters shall be used in the parametric analysis:

- Hydraulic conductivity: one order of magnitude (e.g., + and – a power of 10) for each receptor soil
- Aquifer thickness: plus or minus 50 percent of the known values
- Specific yield: minimum range of 0.05 to 0.2

If known field conditions warrant, increase the above ranges as necessary.

In general, multiple infiltration scenarios will need to be simulated to evaluate potential mounding below the infiltration BMPs. For example, both short-term peak storm events and long-term seasonal precipitation should be evaluated. Additional scenarios may include a

series of short-term high precipitation events. Although the actual events that need to be simulated will depend on subsurface conditions, number and types of infiltration BMPs, and potential risk factors, as a minimum the following scenario is required:

- A typical wet season (November through April) based on average monthly precipitation followed by a single-event rainfall modeling of the back-loaded long-duration storm for the 100-year recurrence interval, using data from the closest rain gage.

The licensed hydrogeologist performing the mounding analysis should use professional judgment and experience to potentially modify the above scenario or add additional scenarios on a project-specific basis, as needed.

As additional soil and groundwater information is collected during construction, testing, and operation of the infiltration BMP, the mounding analysis should be revised and refined to incorporate any new information. If groundwater monitoring indicates results inconsistent with the findings of the mounding analysis, in the opinion of a licensed hydrogeologist, the model should be re-evaluated. The re-evaluation should include simulation of the precipitation events prior to the observed groundwater monitoring data.

D-8. Acceptance Testing

Acceptance testing is required for shallow infiltration BMPs receiving runoff from greater than 5,000 square feet of impervious surface area, including:

- Infiltration Trenches
- Drywells
- Infiltration Bioretention (with and without underdrains)
- Infiltration Basins
- Infiltration Chambers

It may also be required for infiltration BMPs receiving runoff from a smaller contributing area, if required by the Director. Refer to *Volume 3, Section 3.2*.

All permeable pavement facilities and surfaces are required to perform acceptance testing per Wearing Course Subsection in *Volume 3, Section 5.4.6.5*. Acceptance testing of deep infiltration BMPs shall consist of the infiltration testing for deep infiltration wells described in *Section D-3.5* performed on the completed permanent wells.

D-8.1. Acceptance Criteria Definitions

The purpose of acceptance testing is to confirm the constructed infiltration BMP will perform in accordance with design. Infiltration acceptance criteria include:

1. **Subsurface Condition Observations:** The observed soil and groundwater conditions in the excavated BMP shall exhibit no adverse conditions that will result in:
    a. The maximum pool drawdown time to be exceeded. Refer to Criterion 4 (Pool Drawdown Time).

b. For BMPs intended to provide flow control or on-site stormwater management, a long-term infiltration rate lower than the design rate.

c. For BMPs intended to provide water quality treatment, a long-term infiltration rate that is higher than the design rate.

Observation and confirmation of the subsurface conditions shall be conducted by a licensed professional who is familiar/experienced with the field infiltration testing performed during design.

2. **Underlying Soil Infiltration Rate:** For BMPs without underdrains that rely on soil infiltration, the underlying soil infiltration rate achieved after construction of the infiltration BMP and adjusted to determine a long-term rate using correction factors shall be:

   a. High enough to ensure that the maximum pool drawdown time is not exceeded. Refer to Criterion 4 (Pool Drawdown Time).

   b. Equal to or greater than the design infiltration rate, where flow control or onsite stormwater management is intended.

   c. Less than or equal to the design infiltration rate where water quality treatment is intended.

3. **Bioretention Soil Infiltration Rate:** When water is applied to the infiltration BMP, it shall readily infiltrate into the bioretention soil and drain downward. If water ponds and does not drain downward, compaction or otherwise compromised bioretention soil is indicated.

4. **Pool Drawdown Time:** The surface pool drawdown time for maximum ponding depth shall be less than 24 hours after water has ceased being added to the BMP.

D-8.2. Acceptance Testing Requirements

Acceptance testing is intended to evaluate the post-construction infiltration performance of the BMP; therefore, timing of the testing during construction is important and shall be performed after all construction activities that could impact the targeted infiltration soil are completed. Activities such as compaction and contamination by finer soil particles can reduce the infiltration rate of bioretention and underlying soil. Water that runs off into the BMP that is not clear and contains sediment can reduce the infiltration rate of the BMP.

Infiltration acceptance testing shall be performed up to three steps. Steps 1 and 2 are recommended but optional. Step 3 is required.

Step 1. Observation of the Subsurface Conditions (optional)

During construction of the BMP, it is recommended that a licensed professional who is familiar/experienced with the field infiltration testing performed during design be on site to observe subsurface soil conditions and confirm the underlying soil conditions are consistent with those observed during the design infiltration testing. Refer to Criterion 1 (Subsurface Condition Observations) in *Section D-8.1*. If the soil conditions are observed to be consistent with design observations and testing, proceed to Step 3. If soil conditions

are not consistent with design observations and testing, it is recommended to proceed to Step 2.

Step 2. Infiltration Testing of Differing Soil Conditions (optional)

If the subsurface soil conditions are observed to be different than design observations and testing, and the BMP is designed to rely on infiltration into the underlying soil, infiltration testing is recommended immediately (prior to backfilling the BMP) to determine if the underlying soil meets the design infiltration rate. For BMPs with multiple cells, one test in a representative cell per soil type shall be required. Although it is preferred that acceptance testing be performed in a similar manner as the design infiltration testing, specific procedures can be based on the professional judgement of the licensed professional who performed the testing during design. If the infiltration rate adjusted to a long-term rate using correction factors meets Criterion 2 (Underlying Soil Infiltration Rate) in *Section D-8.1*, proceed to Step 3. If the rate adjusted to a long-term rate does not meet Criterion 2 (Underlying Soil Infiltration Rate) in *Section D-8.1*, retesting or redesign and reconstruction of the BMP shall be required.

Step 3. Acceptance Testing of Backfilled BMP (required)

Testing in this step shall be performed once the BMP has been backfilled, but prior to planting, if applicable:

- For BMPs without underdrains that rely on underlying soil infiltration, the acceptance test shall consist of testing the drawdown time to confirm it is less than or equal to the design ponding criteria. Refer to Criterion 4 (Pool Drawdown Time) in *Section D-8.1*. For BMPs with multiple cells, one test in a representative cell per soil type shall be required. If the acceptance test fails and the BMP performance is not equal to or better than the performance required by the design (refer to Criteria 3 and 4 [Bioretention Soil Infiltration Rate and Pool Drawdown Time] in *Section D-8.1*), then retesting or redesign and reconstruction of the BMP shall be required.
- For BMPs with an underdrain, acceptance testing shall verify the surface pool drawdown time for the maximum ponding depth meets the ponding criteria of the design or better. Refer to Criteria 3 and 4 (Bioretention Soil Infiltration Rate and Pool Drawdown Time) in *Section D-8.1*. If the acceptance test fails and the BMP performance is not equal to or better than the performance required by the design, then retesting or redesign and reconstruction of the BMP shall be required.

A monitoring well or piezometer is needed for Step 3 to observe water levels within the BMP if the BMP does not have an underdrain. For drywells, infiltration trenches and bioretention with an underdrain, the cleanout or observation port may be used to observe water levels if it allows accurate measurement of underlying soil infiltration. Drilling rigs or other mechanical methods are prohibited within the BMP footprint during construction; therefore, wells or piezometers must be placed using hand methods. The base of the well or piezometer shall be placed at the bottom of the BMP directly on top of the infiltrating soil.

D-8.3. Acceptance Testing Plan

An acceptance testing plan shall be prepared and submitted to the City signed and stamped by a licensed professional. The acceptance testing plan shall include, but is not limited to:

- A site plan showing and listing the proposed infiltration BMPs requiring acceptance testing.
- Measured infiltration rates, correction factors, and infiltration testing backup data relied on for design.
- Infiltration testing procedures and specifications including an estimate of the amount of water, duration, rate to apply water to the BMP required for conducting the test, and potential source of water.
- Specifications for monitoring wells, piezometer, and/or observation ports to be installed for testing and observation.
- Procedure for submittal and acceptance of results.

The acceptance testing plan shall be updated and resubmitted as required based on review by the City.

D-8.4. Acceptance Testing Submittal

The results of the acceptance testing shall be summarized in a memorandum signed and stamped by a licensed professional and submitted for final approval. The memorandum shall include:

- The infiltration rates, correction factors, and infiltration testing backup data relied on for the design.
- The measured infiltration rates, correction factors, and infiltration testing backup data resulting from the acceptance testing.
- A discussion of subsurface soil condition observations performed in Step 1. State why additional testing of subsurface conditions were or were not required.
- A discussion comparing the results of the Step 2 acceptance infiltration test (if performed) to the results of the design infiltration test. State whether the results of this test indicate the BMP will perform as intended during design.
- A discussion comparing the results of the Step 3 acceptance infiltration test to the results of the design infiltration test. State whether the results of this test indicate the BMP will perform as intended during design.
- If the acceptance testing is performed during the dry season, the licensed professional shall make a statement regarding the expected impact to the measured infiltration rate and how the BMP is expected to perform in the wet season.

APPENDIX E
Additional BMP Design Requirements

City of Seattle | Stormwater Manual

July 2026

City of Seattle

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Appendix E includes additional design requirements for the following:

- Flow Control Structures (*Section E-1*)
- Flow Splitters (*Section E-2*)
- Flow Spreaders (*Section E-3*)
- Level Spreaders (*Section E-4*)
- Pipe Slope Drains (*Section E-5*)
- Outlet Protection (*Section E-6*)
- Liners (*Section E-7*)
- Geotextiles (*Section E-8*)
- Drywell Sizing Tables (*Section E-9*)

E-1. Flow Control Structures

Flow control structures are catch basins or maintenance holes with a restrictor device for controlling outflow from a BMP to meet the desired performance.

The flow control device usually consists of two or more orifices and/or a weir section sized to meet performance requirements. Standard flow control device details are shown in Figures E.1, E.2, and E.3 and in City of Seattle Standard Plan 272a.

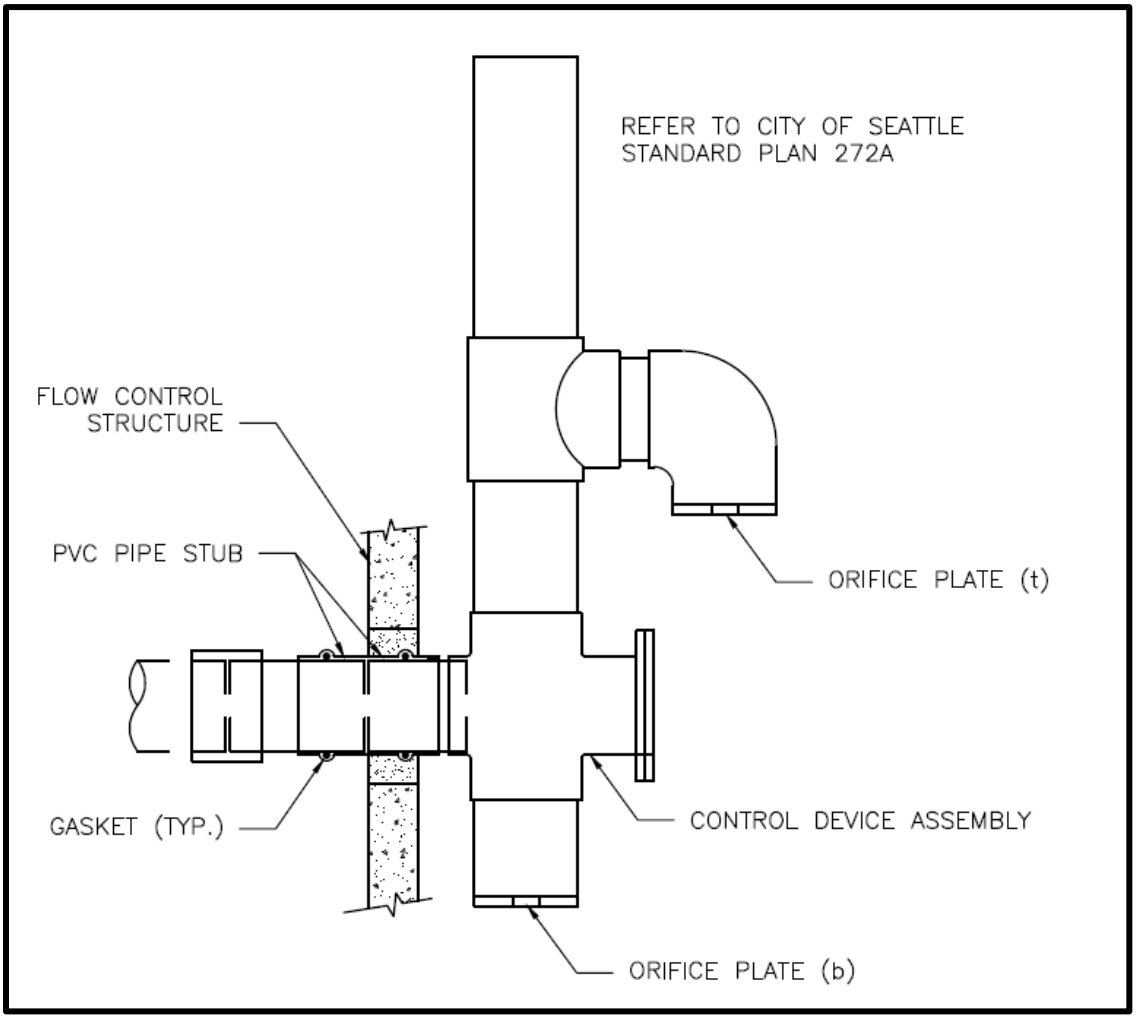

Figure E.1. Simple Orifice.

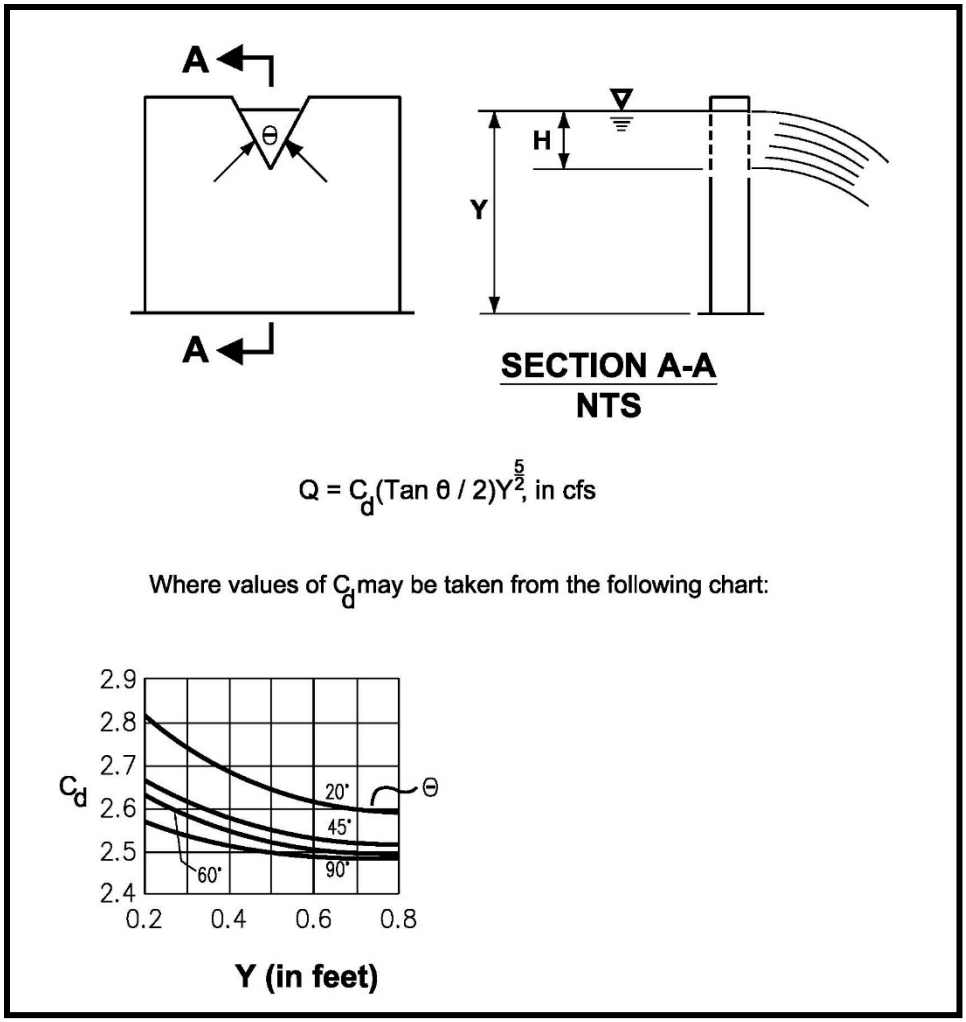

Figure E.2. V-Notch, Sharp-Crested Weir.

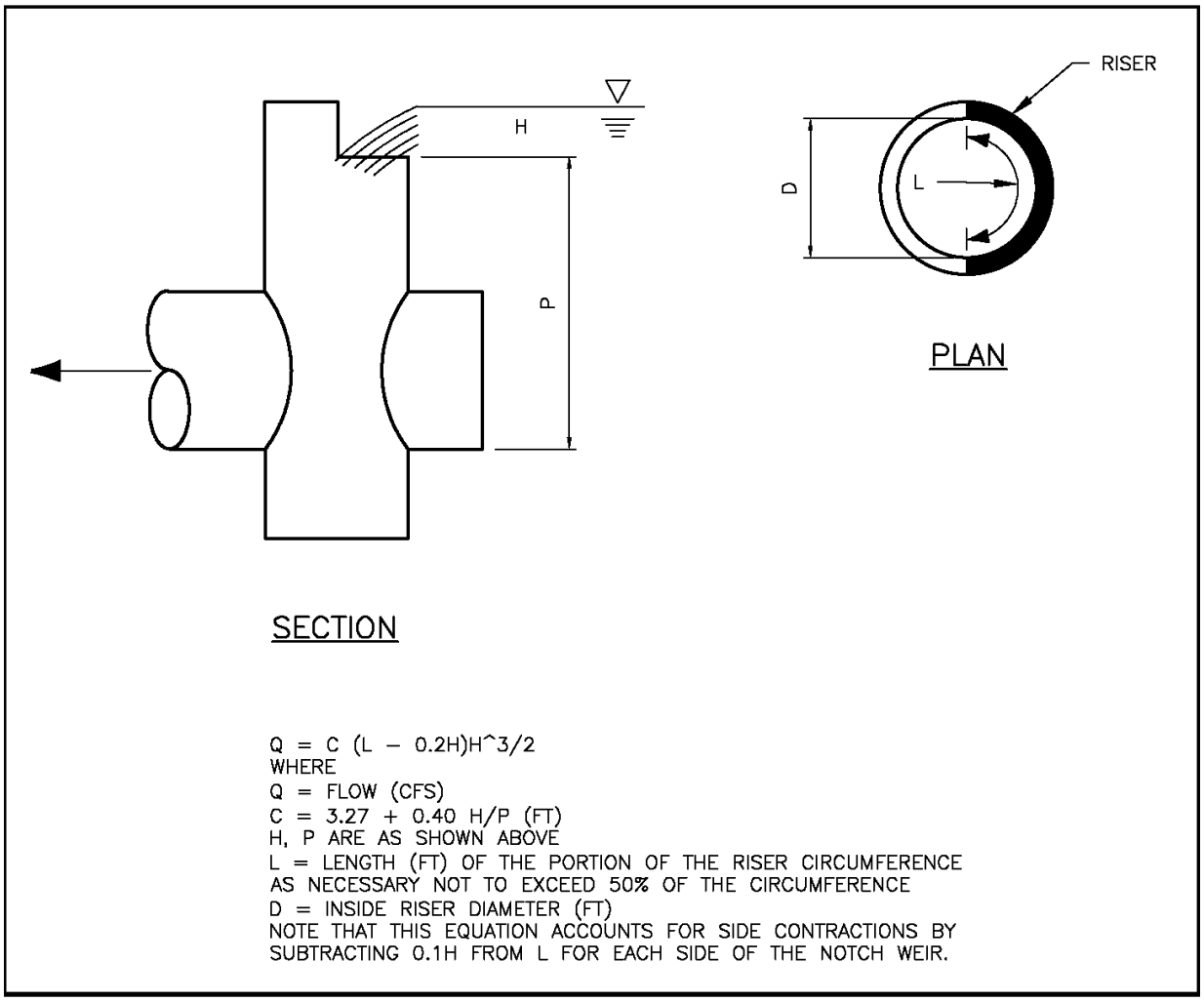

Figure E.3. Rectangular Notch, Sharp-Crested Weir.

E-1.1. General Requirements

Flow control structures shall comply with the specifications outlined in the City of Seattle's Standard Plans No. 270 and 272A. Additional general requirements are presented below.

Plans submitted for a permit shall include:

- Flow control structure rim elevation
- Storage pipe invert elevation
- Outlet pipe invert elevation
- Elevation at the top of the storage pipe
- Elevation at the top of the overflow pipe
- Orifice diameter(s)
- Orifice elevation(s)

For ponding BMPs, backwater effects shall be included in designing the height of the downstream conveyance system. High tailwater elevations may affect performance of the restrictor system and reduce live storage volumes.

For regionally sized detention BMPs, non-standard orifice orientation and orifice/weir and gate combinations for flow throttling may be used to meet both stormwater and operational requirements. These general requirements are not meant to be restrictive when a flow control need beyond what is discussed here can be demonstrated.

E-1.2. Access

The following access requirements apply to control structures:

- Access shall be provided to the flow control structure from the ground surface with a three-bolt locking maintenance hole ring and cover (refer to SDCI Director's Rule 4-2011, Requirements for Design & Construction of Side Sewers). Rim elevations shall match proposed finish grade. A rectangular cover, or a cover that allows water to enter through the top of the flow control structure, shall not be used. The ring and cover shall be set so the flow control device or the ladder is visible at the edge of the access opening.
- The inside diameter of the flow control structure shall be at least 4 feet to allow maintenance and repair access, and to accommodate stormwater overflow.
- Maintenance holes and catch basins shall meet the OSHA and WISHA confined space requirements, which include, but are not limited to, clearly marking entrances to confined space areas. This may be accomplished by hanging a removable sign in the access riser under the access lid.
- The flow control device shall not be Corrugated Metal Pipe (CMP). The mounting straps and the outlet adapter shall be installed in a manner that will make the flow control device easily removable for maintenance, repair, or replacement. The flow control device shall be designed and located under the maintenance hole ring and cover for inspection from the surface. The outlet pipe adapter may be a plastic, bell-end pipe, or a plastic coupling with rubber gaskets. The outside of the pipe or coupling shall be sanded, epoxy coated, and sand impacted to bond with the flow control structure.

E-1.3. Design Criteria

E-1.3.1. Multiple Orifice Restrictor

In most cases, control structures only need two orifices: one at the bottom and one near the top of the riser, oriented horizontally. Additional orifices may best utilize detention storage volume in a few cases.

Design requirements for multiple orifice flow restrictors are presented below.

- The minimum allowable orifice diameter is 0.5 inch for underground tanks or vaults and 0.25 inch for aboveground cisterns. In some instances, a 0.5-inch bottom orifice will be too large to meet target release rates, even with minimal head. In these cases, the live storage depth need not be reduced to less than 3 feet in an attempt to meet the performance standards. Also, underground weirs or orifices shall not be reduced to

less than 0.5-inch length or diameter in an attempt to meet the performance standards. See Volume 3, Section 4.1.3.2 for additional guidance when a 0.5-inch orifice is too large.

- In some cases, performance requirements may require the top orifice/elbow to be located too high on the riser to be physically constructed (e.g., a 13-inch diameter orifice positioned 0.5 feet from the top of the riser). In these cases, a notch weir in the riser pipe may be used to meet performance requirements.

E-1.3.2. Weir Restrictor

Design requirements for weir flow restrictors are presented below.

- A sharp crested overflow weir shall be used to provide for overflow of the detention BMP and should be analyzed for the developed 100-year peak flow discharge (Figure E.4).
- A notch weir may be used to restrict flows and replace a top orifice.
- The minimum allowable weir length is 0.25 inch.

E-1.4. Flow Control Device Sizing

E-1.4.1. Orifices

Flow-through orifice plates in the standard tee section or down-turned elbow may be approximated by the general equation:

$$Q = C\,A\,\sqrt{2gh}$$

where Q = flow (cfs)
C = coefficient of discharge (0.62 for plate orifice)
A = area of orifice (ft^2)
h = hydraulic head (ft)
g = gravity (32.2 ft/sec^2)

Figure E.4 illustrates this simplified application of the orifice equation.

The diameter of the orifice is calculated from the flow. The orifice equation is often useful when expressed as the orifice diameter in inches.

where *d* = orifice diameter (inches)
Q = flow (cfs)
h = hydraulic head (ft)

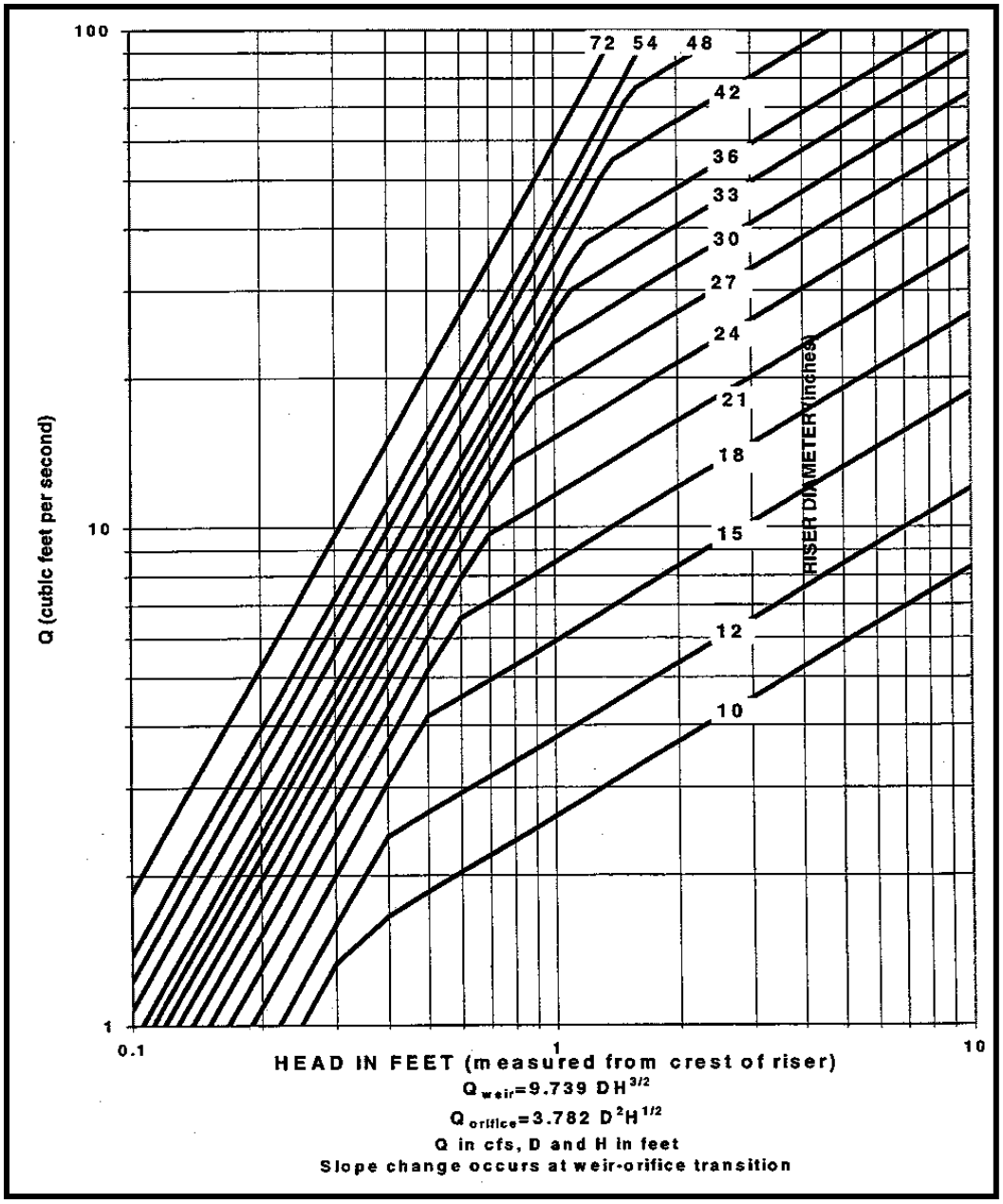

Figure E.4. Riser Inflow Curves.

E-1.4.2. Riser Overflow

The combined orifice and riser (or weir) overflow may be used to meet performance requirements; however, the design shall still provide for overflow of the developed 100-year peak flow assuming all orifices are plugged. The nomograph in Figure E.4 can be used to determine the head (in feet) above a riser of given diameter and for a given flow. For design requirements on overflows, refer to *Volume 3, Section 4.3.3*.

E-2. Flow Splitters

Flow splitters are typically structures with baffles, weirs, or orifice controls. Two examples of maintenance hole flow splitters are shown in Figure E.5 and Figure E.6. Other equivalent designs for splitting flows may also be acceptable.

E-2.1. General Design Criteria

The top of the weir shall be located at the water surface for the design flow. Flows modeled using a continuous simulation model shall be at a 15-minute time step or less.

The maximum head shall be minimized for flow in excess of the water quality design flow. Specifically, flow to the treatment BMP at the 100-year water surface shall not increase the design water quality flow by more than 10 percent.

As an alternative to using a solid top plate in Figure E.6, a full tee section may be used with the top of the tee at the 100-year water surface. This alternative would route emergency overflows (if the overflow pipe were plugged) through the treatment BMP rather than generate back up from the maintenance hole.

Backwater effects shall be included in the design of standpipe height in the maintenance hole.

E-2.2. Materials

- The splitter baffle may be installed in a maintenance hole or vault.
- The baffle wall shall be made of reinforced concrete or another suitable material resistant to corrosion and have a minimum 4-inch thickness.
- All metal parts shall be corrosion resistant. Examples of required materials include aluminum, stainless steel, and plastic. Zinc and galvanized materials are prohibited because of aquatic toxicity. Painted metal parts shall not be used because of poor longevity.

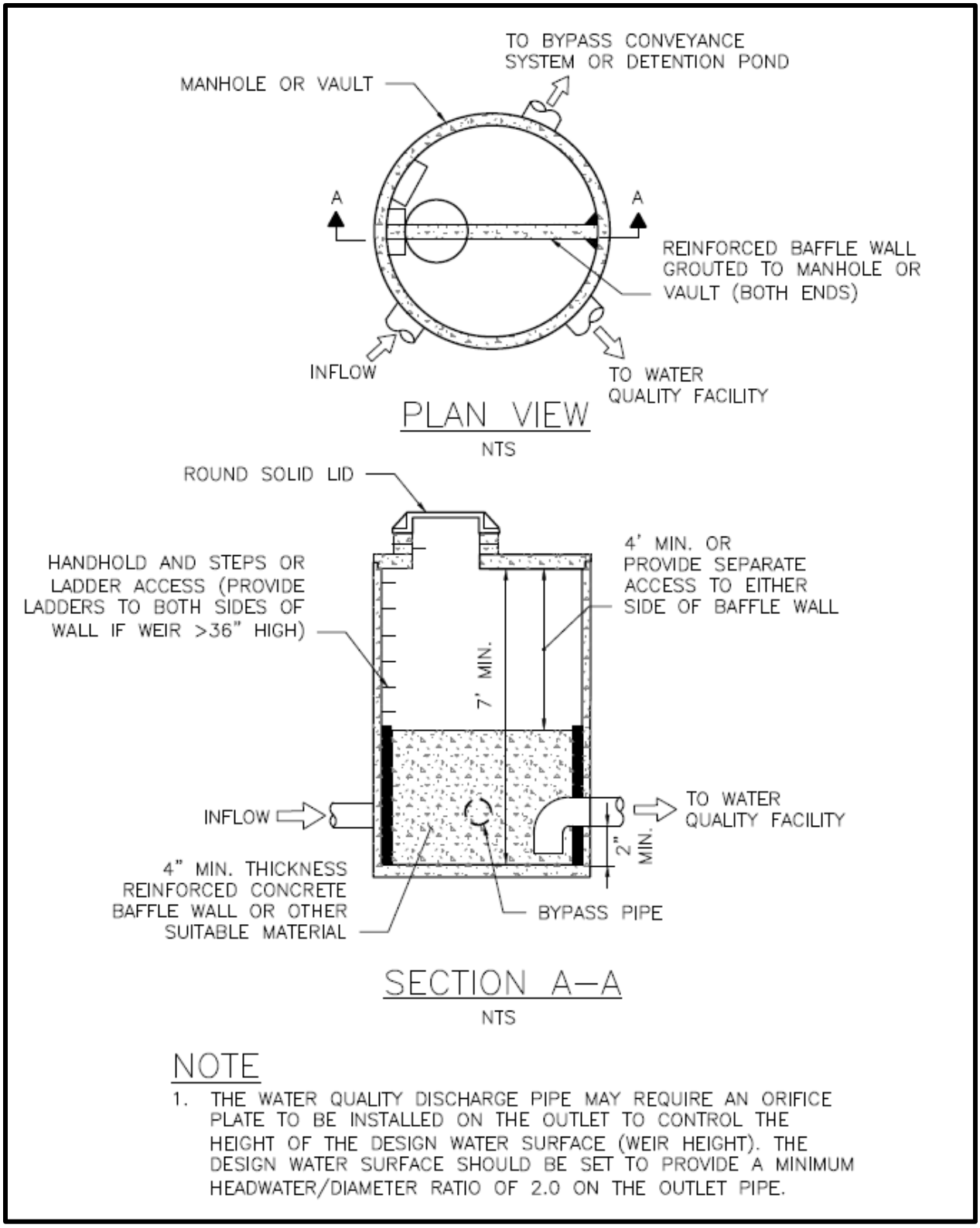

Figure E.5. Flow Splitter Example A.

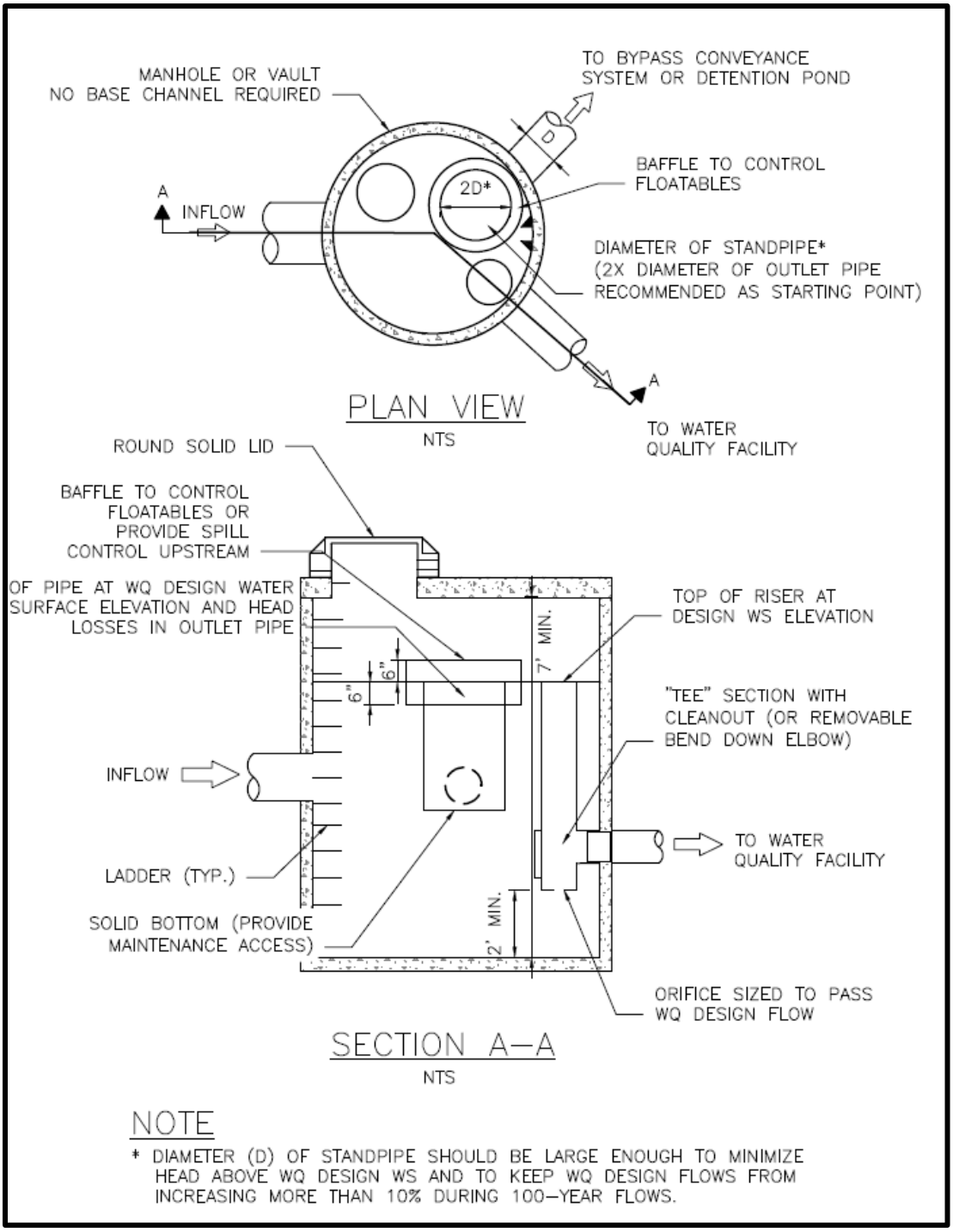

Figure E.6. Flow Splitter Example B.

E-3. Flow Spreaders

Flow spreaders uniformly spread flows across the inflow portion of non-infiltrating BMPs (e.g., sand filter, biofiltration swale, or filter strip). There are five flow spreader options presented in this section:

- Option A — Anchored plate
- Option B — Concrete sump box
- Option C — Notched curb spreader
- Option D — Through-curb ports
- Option E — Interrupted curb

Options A through C can be used for spreading flows that are concentrated. Any one of these options can be used when spreading is required by the BMP design criteria. Options A through C can also be used for unconcentrated flows, and in some cases shall be used, such as to correct for moderate grade changes along a filter strip.

Options D and E can only be used for flows that are already unconcentrated and enter a filter strip or continuous inflow biofiltration swale. Other flow spreader options are possible with prior approval by the Director.

E-3.1. General Design Criteria

- Where flow enters the flow spreader through a pipe, it is recommended that the pipe be submerged to the extent practical to dissipate energy as much as possible.
- For higher inflows (greater than 5 cfs for the 100-year storm), a Type 1 catch basin should be positioned in the spreader and the inflow pipe should enter the catch basin with flows exiting through the top grate of the catch basin. The top of the grate should be lower than the flow spreader plate, or if a notched spreader is used, lower than the bottom of the v-notches-.

E-3.2. Option A – Anchored Plate

- An anchored plate flow spreader shall be preceded by a sump having a minimum depth of 8 inches and minimum width of 24 inches. If not otherwise stabilized, the sump area shall be lined to reduce erosion and to provide energy dissipation.
- The top surface of the flow spreader plate shall be level, projecting a minimum of 2 inches above the ground surface of the treatment BMP, or v-notched with notches 6 to 10 inches on center and 1 to 6 inches deep (use shallower notches with closer spacing). Alternative designs may also be considered.
- A flow spreader plate shall extend horizontally beyond the bottom width of the BMP to prevent water from eroding the side slope. The horizontal extent shall be such that the bank is protected for all flows up to the 100-year flow, or the maximum flow that will enter the treatment BMP.
- Flow spreader plates shall be securely fixed in place.

- Flow spreader plates may be made of either wood, metal, fiberglass reinforced plastic, or other durable material. If wood, pressure treated 4- by 10-inch lumber or landscape timbers are acceptable.
- Anchor posts shall be 4-inch square concrete, tubular stainless steel, or other material resistant to decay. Refer to Volume V of the Stormwater Management Manual for Western Washington (SWMMWW) for an example of an anchored plate flow spreader.

E-3.3. Option B – Concrete Sump Box

- The wall of the downstream side of a rectangular concrete sump box shall be level and shall extend a minimum of 2 inches above the inlet to the treatment BMP. This serves as a weir to spread the flows uniformly across the BMP inlet.
- The downstream wall of a sump box shall have "wing walls" at both ends. Side walls and returns shall be slightly higher than the weir so that erosion of the side slope is minimized.
- Concrete for a sump box can be either cast-in-place or precast, but the bottom of the sump shall be reinforced with wire mesh for cast-in-place sump boxes.
- Sump boxes shall be placed over bases that consist of 4 inches of crushed rock, 5/8-inch minus to help assure the sump box remains level. Refer to Volume V of the SWMMWW for an example of a concrete sump box flow spreader.

E-3.4. Option C – Notched Curb Spreader

Notched curb spreader sections shall be made of extruded concrete laid side-by-side and level. Typically, five "teeth" per 4foot section provides good spacing. The space between adjacent teeth forms a v-notch.

E-3.5. Option D – Through-Curb Ports

Unconcentrated flows from paved areas entering filter strips or continuous inflow biofiltration swales can use through-curb ports (Option D) or interrupted curbs (Option E) to allow flows to enter the BMP. Through-curb ports use fabricated openings that allow concrete curbing to be poured or extruded while still providing an opening through the curb to admit water to the BMP.

Openings in the curb shall be at regular intervals and at least every 6 feet. The width of each opening shall be a minimum of 8 inches for non-right-of-way applications and a minimum of 10 inches in the right-of-way. Approximately 15 percent or more of the curb section length should be in open ports, and no port should discharge more than about 10 percent of the flow. Refer to Volume V of the SWMMWW for an example of a through-curb port flow spreader.

E-3.6. Option E – Interrupted Curb

Interrupted curbs are sections of curb placed to have gaps spaced at regular intervals along the total width (or length, depending on the BMP) of the treatment area. At a minimum, gaps shall be every 6 feet to allow distribution of flows into the treatment BMP before they become too concentrated. The opening shall be a minimum of 8 inches for non-right-of-way applications and a minimum of 10 inches in the right-of-way. As a general rule, no opening should discharge more than 10 percent of the overall flow entering the BMP.

E-4. Level Spreaders

E-4.1. Definition

A level spreader is constructed at zero percent grade and can be used to distribute concentrated runoff to sheet flow. Level spreaders can be used as either a temporary or a permanent BMP.

E-4.2. Purpose

To convert concentrated runoff to a thin layer of sheet flow to promote release onto a stable receiving area. For example, an existing vegetated area or a vegetated strip.

E-4.3. Condition Where Practice Applies

None identified for this BMP.

E-4.4. Planning Considerations

When properly constructed, the level spreader will significantly reduce the velocity of concentrated stormwater and spread it uniformly over a stabilized or undisturbed area.

Particular care shall be taken to ensure that the lower downslope side (or the lip) of the structure is level and on grade. If there are any depressions in the lip, flow will tend to concentrate at these points and erosion will occur, resulting in failure of the outlet. This problem may be avoided by using a grade board or a gravel lip over which the runoff shall flow when exiting the spreader. Regular maintenance is essential for this practice.

Level spreaders shall be constructed on undisturbed areas that are stabilized by existing vegetation, or areas that have been properly stabilized in accordance with the requirements of the Construction Stormwater Control section of this manual (*Volume* 2), and where concentrated flows will be dissipated at zero percent grade (Figure E.7).

E-4.5. Design Criteria

- The grade of the pipe and/or ditch for the last 20 feet before entering the level spreader shall be less than or equal to 1 percent, if feasible. If the grade is steeper, provide a flow dissipation device. The grade of the level spreader shall be zero percent to ensure uniform spreading of stormwater runoff.
- An 8-inch high gravel berm placed across the level lip shall consist of washed crushed rock, 2- to 4-inch or 0.75-inch to 1.5-inch size.
- The temporary level spreader length shall be calculated by one of the following methods:
    - Single Event Hydrograph Method: The peak volumetric flow rate from a 10-year, 24-hour design storm with a 10-minute time step or the 10-year recurrence flow, and selecting the appropriate length from Table E.1.

- Continuous Simulation Method:
  - The 10-year peak flow rate as determined by an approved continuous runoff model with a 15-minute time step or less.
  - If the level spreader will be permanent, level spreader length will be determined by estimating the flow expected from the 25-year, 24-hour design storm (Q25). Alternatively, an approved continuous runoff model should be used to model the 25-year recurrence interval.

- Use multiple spreaders for higher flows.
- The depth of the spreader as measured from the lip should be at least 8 inches and should be uniform across the entire length.
- The area below the level spreader outlet shall be stabilized and have a slope of less than 11 percent.

Figure E.7. Level Spreader Prior to Backfill and Downstream Stabilization.

Table E.1. Spreader Length Based on 10-Year, 24-Hour Storm.

Q_{10} or Q_{25} in cfs*	Minimum Length (in feet)
0 to 0.1	15
0.1 to 0.2	25
0.2 to 0.3	35
0.3 to 0.4	45
0.4 to 0.5	55

*Use Q10 for temporary level spreaders. Use Q25 for permanent level spreaders.

cfs= cubic feet per second

Q10 = 10-year, 24-hour design storm or peak flowrate for the 10-year recurrence flow

Q25 = 25-year, 24-hour design storm or peak flowrate for the 25-year recurrence flow

E-4.6. Maintenance

The spreader should be inspected regularly to ensure that it is functioning correctly. Do not place any material on the level spreader and prevent traffic from crossing over the level spreader. If the level spreader is damaged, it shall be immediately repaired.

E-5. Pipe Slope Drains

E-5.1. Definition

A slope drain consists of a pipe extending from the top to the bottom of a cut or fill slope and discharging into a stabilized watercourse or a sediment trapping device or onto a stabilization area. It can also be used for water discharging from a flow control or treatment BMP, or to safely convey water past the toe of the slope. Pipe slope drains can be used as a temporary BMP.

E-5.2. Purpose

To convey concentrated runoff down steep slopes without causing gullies, channel erosion, or saturation of landslide-prone soils (Figure E.8).

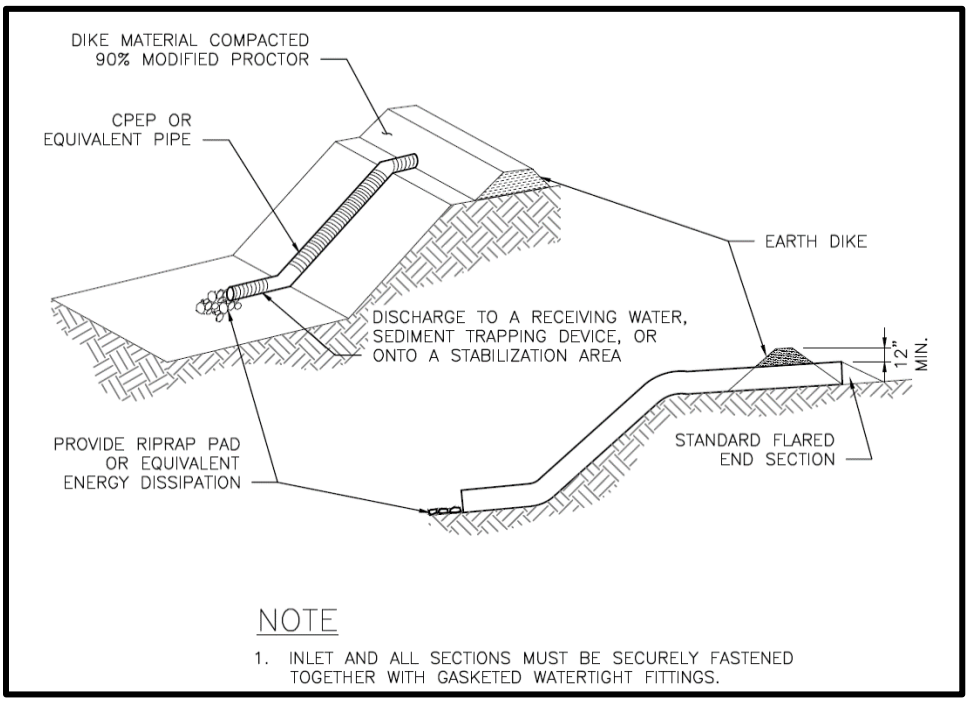

Figure E.8. Pipe Slope Drain Details.

E-5.3. Conditions Where Practice Applies

Pipe slope drains shall be used when conveying concentrated runoff down a steep slope has the potential to cause erosion.

E-5.4. Planning Considerations

There is often a lag between the time a cut or fill slope is completed and the time a permanent drainage system can be installed. During this period, the slope is usually not stabilized and is particularly vulnerable to erosion. Temporary slope drains can provide valuable protection of exposed slopes until permanent drainage structures can be installed.

The entrance section shall be securely entrenched, all connections shall be watertight, and the conduit shall be staked securely.

Additional protection requirements for steep slopes are included in the Environmentally Critical Area Ordinance (SMC, Section 25.09.090).

E-5.5. Design Criteria

- Permanent slope drains shall be designed by a licensed engineer and may have additional criteria for flow and water quality treatment requirements. Variations or alterations to the minimum BMP requirements outlined below require a licensed engineer's approval.
- Size the pipe to convey the projected flow. The capacity for temporary drains shall be sufficient to handle the flows calculated by one of the following methods:
    - Single Event Hydrograph Method: The peak volumetric flow rate calculated using a 10-year, 24-hour design storm with a 10-minute time step.
    - Continuous Simulation Method: The 10 percent annual probability flow (10-year peak flow rate) using a 15-minute time step or less, indicated by an approved continuous runoff model.

  The hydrologic analysis shall use the existing land cover condition for predicting flow rates from tributary areas outside the project limits. For tributary areas on the project site, the analysis shall use the temporary or permanent project land cover condition, whichever will produce the highest flow rates. If using WWHM, bare soil areas should be modeled as "landscaped area." Refer to *Appendix F* for additional information on stormwater modeling.
- Re-establish cover immediately on areas disturbed by installation.
- Ensure that the entrance area is stable and large enough to direct flow into the pipe.
- The entrance shall consist of a standard flared end section for culverts 12 inches and larger with a minimum 6-inch metal toe plate to prevent runoff from undercutting the pipe inlet. The slope of the entrance shall be at least 3 percent.
- Pipe slope drain size should be no greater than 6 inches. Intercept flow frequently by using multiple pipe slope drains. Multiple pipes should be no closer than 10 feet.
- The soil around and under the pipe and entrance section shall be thoroughly compacted to prevent undercutting.
- The flared inlet section shall be securely connected to the slope drain and have watertight connecting bands.
- Slope drain sections shall be securely fastened together and have gasketed watertight fittings, and be securely anchored into the soil.
- Thrust blocks should be installed any time 90 degree bends are utilized. Depending on size of pipe and flow, these can be constructed with sand bags, straw bales staked in place, "t" posts and wire, or ecology blocks.
- Pipe needs to be secured along its full length to prevent movement. This can be done with steel "t" posts and wire. Install a post on each side of the pipe and wire the pipe

to them. This should be done every 10 to 20 feet of pipe length, depending on the size of the pipe and quantity of water diverted.

- Earth dikes shall be used to direct runoff into a pipe slope drain. The height of the dike shall be at least 12 inches higher at all points than the top of the inlet pipe.
- The area below the outlet shall be stabilized with a riprap apron (refer to *Section E-6* for outlet protection).
- If the pipe slope drain is conveying sediment-laden water, direct all flows into a sediment trapping BMP.
- Refer to the City of Seattle Standard Specifications for all material specifications (https://www.seattle.gov/utilities/construction-resources/standards-and-guidelines/standard-specs-and-plans).

E-5.6. Maintenance

- Check inlet and outlet points regularly, especially after heavy storms. The inlet should be free of undercutting, and no water should be going around the point of entry. If there are problems, reinforce the headwall with compacted earth or sand bags. The outlet point should be free of erosion and installed with appropriate outlet protection.
- For permanent installations, inspect the pipe periodically for vandalism and physical distress such as slides and wind-throw. Clean the pipe and outlet structure at the completion of construction.
- Normally the pipe slope is so steep that clogging is not a problem with smooth wall pipe; however, debris may become lodged in the pipe or at the inlet.

E-6. Outlet Protection

E-6.1. Definition

Energy dissipating materials or devices placed at concentrated flow outlets, such as the outlets of pipes or paved channel sections. Outlet protection can be used as either a temporary or a permanent BMP.

E-6.2. Purpose

To prevent scour at stormwater outlets, and to minimize the potential for downstream erosion by reducing the velocity of concentrated stormwater flows.

E-6.3. Condition Where Practice Applies

Outlet protection is required wherever concentrated runoff could cause scour or erosion.

E-6.4. Planning Considerations

None identified for this BMP.

E-6.5. Design Criteria

- Permanent BMPs shall be designed by a licensed engineer and may have additional criteria for flow and water quality treatment requirements. Variations and/or alterations to the minimum BMP requirements require a licensed engineer's approval.
- Protect culvert outlets from erosion by rock lining the downstream and extending up the channel sides above the maximum tailwater elevation.
- Standard wing walls, tapered outlets, and paved channels should also be considered when appropriate for permanent outlet protection.
- With low flows, grass-lined channels (refer to Ecology BMP C201) can be an effective alternative for lining material.
- Blankets (refer to BMP E1.15: Mulching, Matting, and Compost Blankets in *Volume 2*) or riprap channel lining (refer to Ecology BMP C202) provide suitable options for lining materials.
- The following guidelines shall be used for outlet protection with riprap:
    - For outlets at the base of steep slope pipes (pipe slope greater than 10 percent), use an engineered energy dissipater
    - Filter fabric or erosion control blankets should be used under riprap to prevent scour and channel erosion. Refer to BMP E1.15: Mulching, Matting, and Compost Blankets in *Volume 2*.

E-6.6. Maintenance

Check for evidence of erosion, scour, or channeling. Rock may need to be added if sediment builds up in the pore spaces of the outlet pad. Vegetation, erosion control blankets, or rock pads may need replacement. Partial blocking of an outlet with a protective measure is not allowed unless designed by a licensed engineer.

E-7. Liners

Liners discussed in this section are intended to reduce the likelihood that pollutants in stormwater will reach groundwater when treatment BMPs are constructed or protect surrounding areas from seepage when necessary. In addition to groundwater protection considerations, some facility types require permanent standing water for proper functioning. An example is the first cell of a wet pond.

There are three types of liners:

1. **Treatment liners** amend the soil with materials that treat stormwater before it reaches more freely draining soils. They have slow rates of infiltration, generally less than 2.4 inches per hour, but not as slow as low permeability liners. Treatment liners may use in-place native soils or imported soils, provided that the design criteria outlined below are met.
2. **Low permeability liners** reduce infiltration to a very slow rate, generally less than 0.02 inch per hour. These types of liners are often used for industrial or commercial sites with a potential for high pollutant loading in the stormwater runoff. Low permeability liners may be constructed from compacted till, clay, or concrete. Till liners are preferred because of their general resilience and ease of maintenance.
3. **Impermeable liners** prevent the transmission of water between the BMP and native soils. Impermeable liners shall be used when BMPs are constructed in areas where infiltration is not permitted or is discouraged (e.g., landslide-prone areas or in contaminated soils). Impermeable liners shall be constructed from geomembrane.

Table E.2 shows the type of liner required for use with various treatment BMPs (detention, non-infiltrating, and pretreatment BMPs). Other liner configurations may be used with prior approval from the Director.

Liners shall be placed over the bottom and/or sides of the BMP as indicated in Table E.2.

When placing a liner for water quality treatment, areas above the treatment volume that are required to pass flows greater than the water quality treatment flow (or volume) need not be lined. However, the lining shall be extended to the top of the interior side slope and be anchored if it cannot be permanently secured by other means.

Table E.2. Lining Types Required by BMP Type.

BMP	Area to be Lined	Type of Liner Required
Presettling basin	Bottom and sides	Low permeability liner, treatment liner, or impermeable liner
Wet pond	First cell: bottom and sides to WQ design water surface	Low permeability liner, treatment liner, or impermeable liner
	Second cell: bottom and sides to WQ design water surface	Treatment liner
Combined detention/non-infiltrating BMP	First cell: bottom and sides to WQ design water surface	Low permeability liner, treatment liner, or impermeable liner
	Second cell: bottom and sides to WQ design water surface	Treatment liner
Stormwater wetland	Bottom and sides, both cells	Low permeability liner or impermeable liner
Sand filter basin	Required if over a critical aquifer recharge area, otherwise not required. Refer to *Volume 3, Section 5.8.5*.	Low permeability line, treatment liner, or impermeable liner
Sand filter vault	Not applicable	No liner needed
Linear sand filter	Not applicable if in vault	No liner needed
	Bottom and sides of presettling cell if not in vault	Low permeability liner, treatment liner, or impermeable liner
Media filter (in vault)	Not applicable	No liner needed
Wet vault	Not applicable	No liner needed
Non-infiltrating bioretention	Bottom and sides	Low permeability liner or impermeable liner
Open bottom or open sided detention products (e.g., arch pipe, modular plastic tanks, etc.)	Bottom and sides	Low permeability liner or impermeable liner

Notes

[a] The Director may approve native soils as a low permeability liner based on measured infiltration rates and the recommendation of a licensed professional.

[b] The Director may also require impermeable liner based on infiltration setbacks or site constraints.

E-7.1. Design Criteria for Treatment Liners

This section presents the design criteria for treatment liners.

- A 2-foot-thick layer of soil with a minimum organic content of 1 percent AND a minimum cation exchange capacity (CEC) of 5 milliequivalents/100 grams can be used as a treatment layer beneath a water quality or detention BMP.
- To demonstrate that in-place soils meet the above criteria, one sample per 1,000 square feet of BMP area shall be tested. Each sample shall be a composite of subsamples collected throughout the depth of the treatment layer (usually 2 to 6 feet below the expected BMP invert).

- Typically, side wall seepage is not a concern if the seepage flows through the same stratum as the bottom of the treatment BMP. However, if the treatment soil is an engineered soil or has very low permeability, the potential to bypass the treatment soil through the side walls may be significant. In those cases, the treatment BMP side walls should be lined with at least 18 inches of treatment soil, as described above, to prevent untreated seepage. This lesser soil thickness is based on unsaturated flow as a result of alternating wet-dry periods. Approved continuous simulation models must be run using the "No infiltration" option through the sidewalls if one sidewall is impervious unless the model can limit infiltration only to the unlined portion of the perimeter.
- Organic content shall be measured on a dry weight basis using ASTM D2974.
- Cation exchange capacity (CEC) shall be tested using EPA laboratory method 9081.
- Certification by a soils testing laboratory that imported soil meets the organic content and CEC criteria above shall be provided to the City.
- The liner shall extend vertically to the water quality design water surface elevation plus 6 inches at the minimum.

E-7.2. Design Criteria for Low Permeability Liners

This section presents the design criteria for each of the following four low permeability liner options: compacted till liners, clay liners, and concrete liners. For low permeability liners, the following criteria apply:

- Where the seasonal high groundwater elevation is likely to contact a low permeability liner, liner buoyancy may be a concern. In these instances, use of a low permeability liner shall be designed by a geotechnical engineer.
- Where grass is planted over a low permeability liner per the BMP design, a minimum of 6 inches of topsoil of sufficient organic content and depth or compost-amended native soil shall be placed over the liner in the area to be planted. Native underlying soils may be suitable for planting if amended per Soil Amendment BMP requirements in *Volume 3, Section 5.1*. Twelve inches of cover is preferred.
- Low permeability liners shall extend vertically to the design water surface elevation plus 6 inches at a minimum. For bioretention, the design water surface elevation shall be the 25-year water surface elevation.

E-7.2.1. Compacted Till Liners

- Liner thickness shall be 18 inches after compaction.
- Soil shall be compacted to 95 percent minimum dry density, modified proctor method (ASTM D-1557).
- A different depth and density sufficient to slow the infiltration rate to 2.4×10^{-5} inches per minute may also be used instead of the above criteria if designed by a geotechnical engineer.
- Soil shall be placed in maximum 6-inch lifts.
- Soils shall meet the gradation outlined in Table E.3 unless otherwise designed by a geotechnical engineer.

Table E.3. Compacted Till Liners.

Sieve Size	Percent Passing
6-inch	100
4-inch	90
#4	70 – 100
#200	20

E-7.2.2. Clay Liners

- Liner thickness shall be 12 inches after compaction.
- Clay shall be compacted to 95 percent minimum dry density, modified proctor method (ASTM D-1557).
- A different depth and density sufficient to slow the infiltration rate to 2.4×10^{-5} inches per minute may also be used instead of the above criteria, if designed by a geotechnical engineer and approved by the Director.
- Plasticity index shall not be less than 15 percent (ASTM D-423, D-424).
- Liquid limit of clay shall not be less than 30 percent (ASTM D-2216).
- Clay particles passing shall not be less than 30 percent (ASTM D-422).
- The slope of clay liners shall be restricted to 3H:1V for all areas requiring soil cover; otherwise, the soil layer shall be stabilized by another method so that soil slippage into the BMP does not occur. Any alternative soil stabilization method shall take maintenance access into consideration.

E-7.2.3. Concrete Liners

- Concrete liners may also be used for sedimentation chambers, for sedimentation and filtration basins less than 1,000 square feet in area, and non-infiltrating bioretention. Concrete shall be 5-inch thick Class 3000 or better and shall be reinforced by steel wire mesh. The steel wire mesh shall be 6 gage wire or larger and 6-inch by 6-inch mesh or smaller. An "Ordinary Surface Finish" is required per City of Seattle Standard Specification 6-02.3(14). When the underlying soil is clay or has an unconfined compressive strength of 0.25 ton per square foot or less, the concrete shall have a minimum 6-inch compacted aggregate base consisting of coarse sand and river stone, crushed stone or equivalent with diameter of 0.75 to 1 inch. Where visible, the concrete shall be inspected annually and all cracks shall be sealed.
- Portland cement liners are allowed irrespective of BMP size, and shotcrete may be used on slopes. However, specifications shall be designed by a licensed engineer who certifies the liner against cracking or losing water retention ability under expected conditions of operation, including BMP maintenance operations. Weight of maintenance equipment can be up to 80,000 pounds when fully loaded.
- Asphalt concrete may not be used for liners due to its permeability to many organic pollutants.
- If grass is to be grown over a concrete liner, slopes shall be no steeper than 5H:1V to prevent the top-dressing material from slipping. Textured liners may be used on slopes up to 3H:1V upon recommended design by a geotechnical engineer that the top dressing will be stable for all site conditions, including maintenance.

E-7.3. Design Criteria for Impermeable Liners

E-7.3.1. Geomembrane Liners

- Geomembrane liners shall be ultraviolet (UV) light resistant and have a minimum thickness of 30 mils. A thickness of 40 mils shall be used in areas of maintenance access or where heavy machinery will be operated over the membrane.
- The geomembrane fabric shall be protected from puncture, tearing, and abrasion by installing geotextile fabric on the top of and beneath the geomembrane. The geotextile fabric shall have a high survivability per the WSDOT Standard Specifications Section 9-33 Construction Geotextile. Equivalent methods for protecting the geomembrane liner may be permitted, subject to approval by Director. Equivalency will be based on the ability of the fabric to protect the geomembrane from puncture, tearing, and abrasion.
- Geomembranes shall be bedded according to the manufacturer's recommendations.
- Liners shall be covered with minimum of 12 inches of top dressing. Top dressing shall include 6 inches of crushed rock immediately over the liner to mark the location of the liner for future maintenance operations. As an alternative to crushed rock, orange plastic “safety fencing” or another highly visible, continuous marker may be embedded 6 inches above the membrane to alert maintenance workers of the liner below.
- If possible, liners should be of a contrasting color so that maintenance workers are aware of any areas where a liner may have become exposed when maintaining the BMP.
- Non-textured geomembrane liners shall not be used on slopes steeper than 5H:1V to prevent the top-dressing material from slipping. Textured liners may be used on slopes up to 3H:1V upon design by a geotechnical engineer that the top dressing will be stable for all site conditions, including maintenance.
- Geomembrane liners used to control seepage shall be joined using heat-fusion or equivalent and include boots around all pipe and structure penetrations.
- Geomembrane liners shall extend vertically to the design water surface elevation plus 6 inches at a minimum. For bioretention, the design water surface elevation shall be the 25-year water surface elevation.

E-8. Geotextiles

The following recommended applications are provided courtesy of Tony Allen (Geotechnical Engineer-WSDOT) with references provided to the relevant tables in the City of Seattle Standard Specifications:

- For sand filter drain strip between the sand and the drain rock or gravel layers, use Geotextile Properties for Underground Drainage, moderate survivability, Class A, from Tables 1 and 2 in the City of Seattle Standard Specifications 9-37.
- For sand filter matting located immediately above the impermeable liner and below the drains, the function of the geotextile is to protect the impermeable liner by acting as a cushion. The specification provided in Table 4 in the City of Seattle Standard Specifications 9-37 shall be used to specify survivability properties for the liner protection application. Table 2 in the City of Seattle Standard Specifications 9-37, Class C shall be used for filtration properties. Only nonwoven geotextiles are appropriate for- the liner protection application.
- For infiltration BMPs, use Geotextile for Underground Drainage, low survivability, Class C, from Tables 1 and 2 in the City of Seattle Standard Specifications 9-37.
- For a sand bed cover, a geotextile fabric is placed exposed on top of the sand layer to trap debris brought in by the stormwater and to protect the sand, facilitating easy cleaning of the surface of the sand layer. A polyethylene or polypropylene geonet shall be used in lieu of geotextile fabric. The geonet material shall have high UV resistance (90 percent or more strength retained after 500 hours in the weatherometer, ASTM D-4355), and high permittivity (ASTM D-4491, 0.8 sec^{-1} or more) and percent open area (CWO22125, 10 percent or more). Tensile strength shall be on the order of- 200 pounds grab (ASTM D-4632) or more.
- For above and below a geomembrane liner, the geotextile fabric shall be Geotextile for Separation per the COS Standard Specifications Section 9-37 Construction Geotextile.

E-9. Drywell Sizing Tables

For small projects with no approved off-site point of discharge (refer to *Volume 3, Section 4.3.2*), Table E.4, Table E.5, and Table E.6 specify the required area for drywells of 4-foot and 6-foot depths to be used as overflow/point of discharge downstream of a bioretention cell or a permeable pavement facility sized for the water quality treatment standard, pre-developed pasture standard, and the on-site stormwater management standard, respectively.

The minimum measured infiltration rate from a Small or Large Pilot Infiltration Test (PIT) that is required to use these tables is 0.25 inch per hour (in/hr).

Table E.4. Drywell Sizing Downstream of Bioretention Sized for Water Quality Treatment Standard or Permeable Pavement Facility.[c]

Contributing Area (sf)	Drywell Area (sf)[a, b, c] Drywell Depth = 4 ft	Drywell Area (sf)[a, b, c] Drywell Depth = 6 ft
500	27	19
1,000	98	67
1,500	164	115
2,000	240	169
2,500	314	222
3,000	390	278
3,500	468	336
4,000	548	396
4,500	630	459
5,000	713	524

[a] Sizing was performed using a 5-minute computational time-step and the "Seattle 38″ 158-year synthetic precipitation series.

[b] Drywell was sized to minimize the 25-year peak flow target to no more than 0.0001 cfs. Drywell design/modeling representation included a 4-foot or 6-foot depth, 25 percent porosity, 0.25 in/hr measured soil infiltration rate, and a variable length and width.

[c] Bioretention and permeable pavement facilities must be sized per the pre-sized requirements in *Volume 3, Chapter 5* based on the amount of contributing area.

Table E.5. Drywell Sizing Downstream of Bioretention Sized for the Pre-Developed Pasture Standard.[c]

Contributing Area (sf)	Drywell Area (sf)[a, b, c] Drywell Depth = 4 ft	Drywell Area (sf)[a, b, c] Drywell Depth = 6 ft
500	14	9
1,000	71	49
1,500	130	90
2,000	200	137
2,500	260	184
3,000	326	234
3,500	393	286
4,000	462	341
4,500	532	399
5,000	605	458

[a] Sizing was performed using a 5-minute computational time-step and the "Seattle 38" 158-year synthetic precipitation series.

[b] Drywell was sized to minimize the 25-year peak flow target to no more than 0.0001 cfs. Drywell design/modeling representation included a 4-foot or 6-foot depth, 25 percent porosity, 0.25 in/hr measured soil infiltration rate, and a variable length and width.

[c] Bioretention and permeable pavement facilities must be sized per the pre-sized requirements in *Volume 3* based on the amount of contributing area.

Table E.6. Drywell Sizing Downstream of Bioretention Sized for the On-Site Stormwater Management Standard.

Contributing Area (sf)	Bioretention Bottom Area (sf)[a,b]	Drywell Area (sf)[b,c] Drywell Depth = 4 ft	Drywell Area (sf)[b,c] Drywell Depth = 6 ft
500	9	56	39
1,000	17	99	68
1,500	30	170	119
2,000	44	249	178
2,500	60	332	238
3,000	76	417	299
3,500	94	501	361
4,000	112	587	424
4,500	131	665	488
5,000	151	753	544

[a] Bioretention design/modeling representation included 6 inches of ponding, 0.25 in/hr measured soil infiltration rate, 3H:1V BMP side slopes, a square bottom area, 12-inch bioretention soil thickness, 40 percent porosity, 3 in/hr bioretention soil infiltration rate, and a 12-inch overflow structure diameter.

[b] Sizing was performed using a 5-minute computational time-step and the "Seattle 38" 158-year synthetic precipitation series.

[c] Drywell was sized to reduce the 25-year peak discharge rate to no more than 0.0001 cfs. Drywell design/modeling representation included a 4-foot or 6-foot depth, 25 percent porosity, 0.25 in/hr measured soil infiltration rate, and a square bottom area.

Table E.7 specifies the required area for drywells of 4-foot and 6-foot depths that are not located downstream of a bioretention cell or permeable pavement facility.

Table E.7. Drywell Sizing Without Bioretention or Permeable Pavement Facility Upstream.

Contributing Area (sf)	Drywell Area (sf)[a, b] Drywell Depth = 4 ft	Drywell Area (sf)[a, b] Drywell Depth = 6 ft
500	125	88
1,000	249	175
1,500	347	263
2,000	498	350
2,500	623	438
3,000	747	526
3,500	872	613
4,000	996	701
4,500	1,121	788
5,000	1,245	876

[a] Sizing was performed using a 5-minute computational time-step and the "Seattle 38" 158-year synthetic precipitation series.

[b] Drywell was sized to minimize the 25-year peak flow target to no more than 0.0001 cfs. Drywell design/modeling representation included a 4-foot or 6-foot depth, 25 percent porosity, 0.25 in/hr measured soil infiltration rate, and a variable length and width.

Drywells that do not meet the above design criteria and assumptions shall be sized to meet the requirements for projects with no offsite point of discharge per *Volume 3, Section 4.3.2*.

E-10. Additional Presettling BMPs For Bioretention Owned or Maintained by Phase 1 Municipal Stormwater Permittees

The following presettling BMPs are described below: Manufactured Treatment Devices (MTDs) and "fat pipes".

E-10.1. Manufactured Treatment Devices

The MTDs included on the TAPE Pretreatment GULD list include systems that remove sediment using screening and/or settling of particles. A typical Pretreatment MTD provides residence time to allow particles to settle along with enhanced features to optimize settling and/or prevent resuspension during higher flows. **For use as presettling prior to bioretention, the MTD must be selected based on the normalized performance noted in Table E.8. A discussion of how and why the performance of the BMPs were normalized is provided below.**

The design flow rates for MTDs are provided in the manufacturers' literature and are often based on testing of one selected size and design flow rate of each system as part of a regulatory certification process (i.e., New Jersey Corporation for Advanced Technology (NJCAT) and Washington State Technology Assessment Protocol – Ecology (TAPE)). The design flow rates for the other sizes of each system appear to be determined using an extrapolation/estimation process performed by the manufacturers and then endorsed by regulatory agency, typically based on a hydraulic loading rate (gallons per minute per square foot [gpm/sf] of presettling area).

To normalize the performance of these selected MTDs so they can be compared to each other, Herrera reviewed the dimensions and design flow rates for the selected presettling MTDs. To better compare them to other types of BMPs, we evaluated them solely on the settling volume provided (as measured from overflow to top of dedicated sediment storage zone). From the design flow rate and the volume provided, a hydraulic residence time was derived. From the hydraulic residence time and the available settling depth, a particle size that would fully settle was derived. This particle size is reported below as "Particle Size Captured by MTD (micron)" in Table E.8.

Next, the hydraulic residence time that would equate to a capture of the 80micron particle size given the settling depth available was derived. The flow rate that corresponds to this residence time was then derived based on the volume provided in the device. This particle size is reported below as "Design Flow Rate Normalized to 80 microns (cfs)" in Table E.8. This design concept is supported using the Peclet Number to assess the performance of standard sumps as BMPs for stormwater treatment (McIntire et al. 2012). In this study, the researchers established that settling of particles in stormwater sumps can be estimated by scaling using the Peclet Number: Pe = (d*h*Vs)/Q where d = horizontal flow dimension in feet, h = vertical flow dimension in feet, Vs = particle settling velocity in ft/s, and Q = flow rate in cfs. For similar performance, the flow rate Q can be scaled based on the relationship between settling velocities for different particle sizes.

As seen in the results in Table E.8, the relationship between the design flow rate and the target particle size is highly variable between MTDs and between different models of the same MTD. Additionally, none of the MTDs capture a particle size of 80 microns at their design flow rates; the captured particle size ranges from 122 percent to over 700 percent of the target 80micron particle size. MTDs used for presettling prior to bioretention must be sized based on the design flow rate normalized on 80 microns.

Table E.8. Adjusted Target Particles and Design Flow Rates for Selected Approved Pretreatment Manufactured Treatment Devices.

Device Name (manufacturer)	Model	Published Design Flow Rate (cfs)	Particle Size Captured by MTD (micron)	Design Flow Rate Normalized to 80 Microns (cfs)
Vortechs System (Contech)	1000	0.55	111	0.31
	2000	1.00	126	0.45
	3000	1.50	136	0.60
	4000	2.20	147	0.79
	5000	3.00	157	0.97
	7000	3.90	162	1.20
	9000	5.00	168	1.46
	11000	6.10	170	1.75
	16000	8.80	173	2.45
Downstream Defender (Hydro International)	4 foot	1.30	192	0.31
	6 foot	4.10	259	0.66
	8 foot	9.40	311	1.21
	10 foot	17.70	357	1.93
Stormceptor (Imbrium Systems)	STC 450i	0.32	114	0.17
	STC 900	0.63	108	0.38
	STC 1200	0.63	104	0.40
	STC 1800	0.63	101	0.43
	STC 2400	1.06	98	0.75
	STC 3600	1.06	95	0.78
	STC 4800	1.77	100	1.21
	STC 6000	1.77	99	1.23
	STC 7200	2.47	98	1.75
	STC 11000	3.53	151	1.21
	STC 13000	3.53	150	1.23
	STC 16000	4.95	148	1.75
CDS Stormwater Treatment Systems (Contech)	CDS 2015-4	0.70	127	0.31
	CDS 2015-5	0.70	101	0.47
	CDS 2020-5	1.10	133	0.46

Table E.8 (continued). Adjusted Target Particles and Design Flow Rates for Selected Approved Pretreatment Manufactured Treatment Devices.

Device Name (manufacturer)	Model	Published Design Flow Rate (cfs)	Particle Size Captured by MTD (micron)	Design Flow Rate Normalized to 80 Microns (cfs)
CDS Stormwater Treatment Systems (Contech)	CDS2025-5	1.60	172	0.45
	CDS3020-6	2.00	155	0.66
	CDS 3030-6	3.00	210	0.64
	CDS 3035-6	3.80	256	0.62
	CDS 4030-8	4.50	207	0.97
	CDS 4040-8	6.00	261	0.96
	CDS 4045-8	7.50	314	0.95
	CDS 5640-10	9.00	219	1.80
	CDS 5653-10	14.00	319	1.74
	CDS 5668-10	19.00	427	1.68
	CDS 5678-10	25.00	567	1.65
Nutrient Separating Baffle Box (Oldcastle Infrastructure, Inc.)	NSBB-48	4.60	180	1.22
	NSBB-510	8.03	201	1.80
	NSBB-612	12.70	231	2.37
	NSBB-816	26.00	263	4.11
	NSBB-1020	45.40	274	6.82
	NSBB-1224	71.70	300	9.62

E-10.2. Presettling Vault/"Fat Pipe"

A presettling vault is a below-grade vault or tank located inline as part of the upstream conveyance system. The volume provided slows down the water quality flow rate and allows settling to occur. The vaults can be constructed of precast or cast-in-place concrete or can be constructed as a length of oversized pipe with smaller diameter inlet and outlet pipe connections that match at the crowns. This configuration is commonly called a "fat pipe" and is recognized as being a simple and cost-efficient type of presettling vault because the facility utilizes standard materials, and its cylindrical shape is very material efficient. A fat pipe presettling vault is shown in Figure E.9.

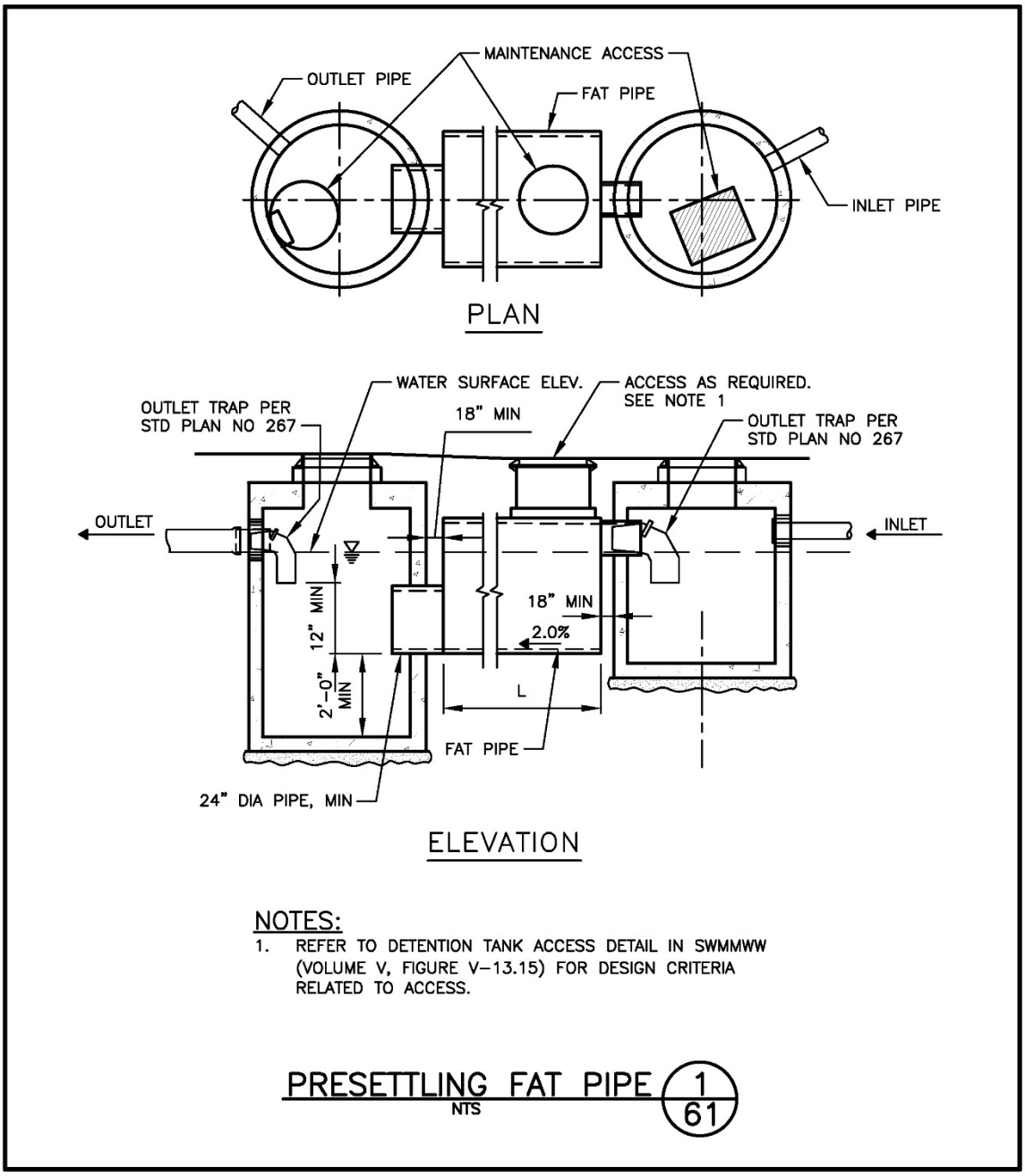

Figure E.9. "Fat Pipe" Presettling Vault.

BMP T6.10 of the 2024 *Stormwater Management Manual for Western Washington* provides design guidance for presettling vaults and recommends that they have a 3:1 (minimum) length-to-width ratio and a minimum depth of 4 feet. When designing a fat pipe, increasing either the diameter or the length of the pipe (while maintaining the minimum length-to-width ratio) improves the settling capability.

To compare the performance of different fat pipe configurations, several small-diameter pipe options were evaluated, each with the lower 12 inches reserved for sediment storage. Once that storage volume is filled, maintenance is required and the sediment must be removed.

The resulting cross-sectional areas and volumes were determined and the settling velocities of particles per modified Stokes' Law (Ferguson and Church 2004) were considered.

Table E.9 shows the design water quality flow rate for fat pipes of various diameters and a constant length of 10 feet that settle 80micron particles. Table E-10 shows the water quality flow rate for fat pipes of varying lengths and a constant diameter of 4 feet which settle the target 80-micron particle. Note that several of the configurations presented in the tables below do not meet the recommended minimum length to diameter ratio but have been included to illustrate how settling performance changes as pipe length and diameter change.

The analysis in Table E.9 and Table E-10 focuses on smaller-diameter storage pipes. Although larger diameter pipe (such as 6-foot diameter) could provide similar performance, a longer pipe would be recommended to maintain the minimum length to diameter ratio.

Table E.9. 10-Foot-Long Fat Pipe Sizing for Various WQ Flow Rates to Settle 80 Micron Particles.

Fat Pipe Diameter (feet)	Design WQ Flow Rate (cfs)
3	0.489
4[a]	0.636
5[a]	0.779

[a] Configuration does not meet the recommended minimum length to width ratio (3:1). Length of these options would need to be adjusted to meet this requirement to be used as a presettling BMP.

Table E-10. 4-Foot-Diameter Fat Pipe Sizing for Various WQ Flow Rates to Settle 80 Micron Particles.

Fat Pipe Length (feet)	Design WQ Flow Rate (cfs)
5[a,b]	0.318
10[a]	0.636
15	0.954
20	1.272
25	1.590

[a] Configuration does not meet the recommended minimum length to width ratio (3:1). Length would need to be adjusted to meet this requirement to be used as a presettling BMP.

[b] A 5-foot-long fat pipe is shown for informational purposes only; the minimum recommended fat pipe length is 10 feet.

To illustrate the expected sizing of a fat pipe for a 6acre residential basin, consisting of 25 percent impervious cover, with generally flat topography and underlain by till soils, MGSFlood was used to estimate the water quality flow rate for the subject basin. The resulting online water quality flow rate is 0.2200 cfs. Per the sizing in Tables E.9 and E.10, presettling requirements could be satisfied using a 3-foot-diameter, 10-foot-long fat pipe.

E-10.3. Extended Sump with Baffle Presettling BMP

Extended sumps help improve the effectiveness of sediment capture in catch basins or maintenance holes by providing additional volume and residence time by deepening the sump. See Figure E.10. Baffles will necessarily inhibit the conveyance capacity of the structure and introduce additional head loss. These losses should be considered during design to verify sufficient conveyance capacity of the proposed drainage system.

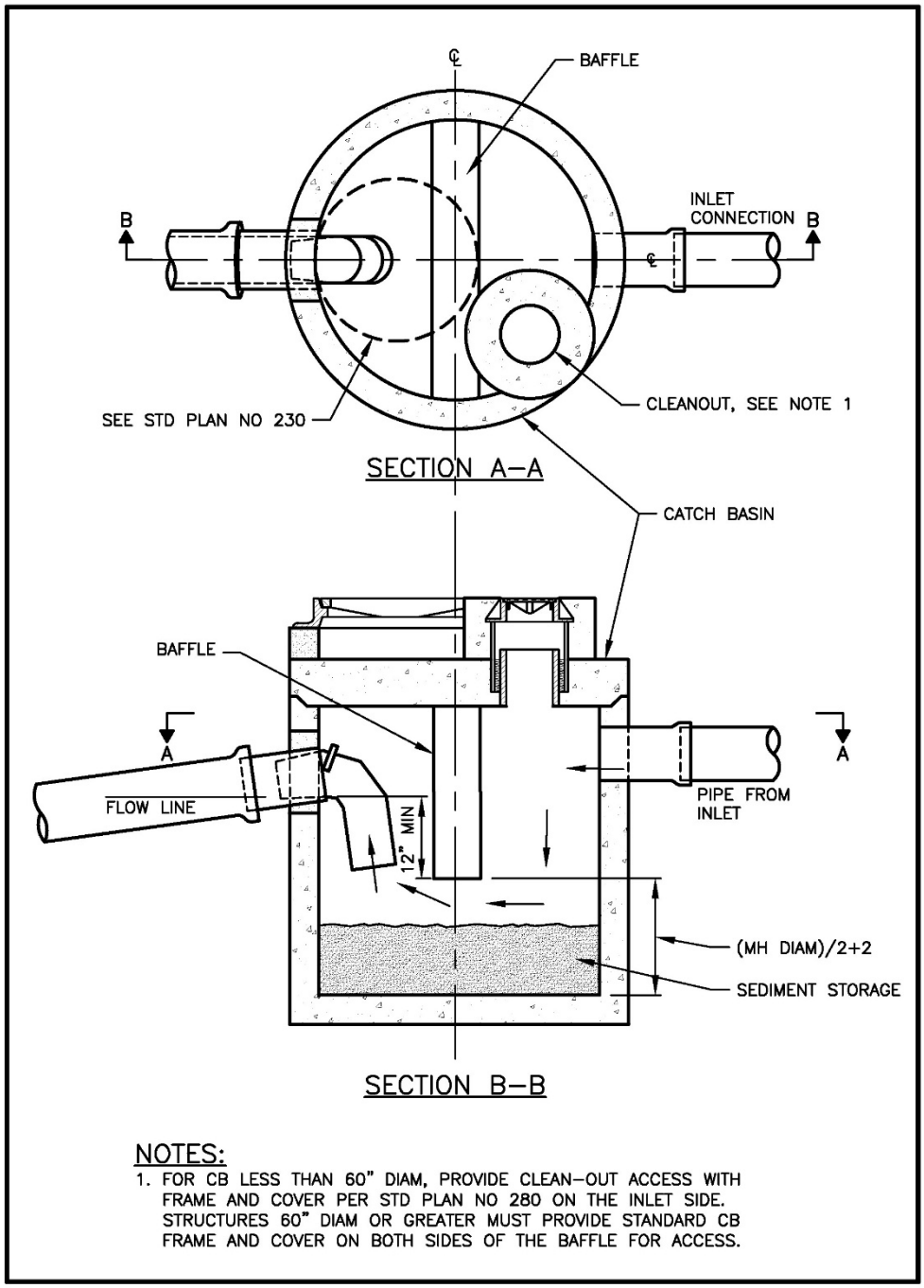

Figure E.10. Catch Basin/Maintenance Hole with an Extended Sump and a Baffle.

Extended sump manholes with various diameters and an extended sump of 4 feet were evaluated for settling 80micron particles; the results are shown in Table E.11. It is intended that the 1 foot of the extended sump would be available for sediment storage. Once the 1 foot is filled, the BMP must be maintained and the sediment removed.

Table E.11shows the water quality design flow rate that would settle an 80micron particle considering the geometry shown in Figure E.10. Due to the small design water quality flow rate capacity of Extended Sumps, these are only expected to be applicable for smaller basins.

Table E.11. Particle Settling Effectiveness for 4-Foot Extended Sumps to Settle 80 Micron Particles.

Catch Basin Diameter (feet)	Design WQ Flow Rate (cfs)
4	0.2871
5	0.3872
6	0.4986
7	0.6214
8	0.7555

To illustrate the expected sizing of an extended sump for a 6acre residential basin, consisting of 25 percent impervious cover, with generally flat topography and underlain by till soils, MGSFlood was used to estimate the water quality flow rate for the subject basin. The resulting online water quality flow rate is 0.2200 cfs. Per the sizing in Table E.11, presettling requirements could be satisfied using a 4-foot-diameter, 4-foot-deep extended sump.

APPENDIX F
Hydrologic Analysis and Design

City of Seattle | Stormwater Manual

July 2026

City of Seattle

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F-1. Introduction

This appendix presents hydrologic modeling concepts to support the design of stormwater best management practices (BMPs) that meet minimum requirements in the Stormwater Code and in *Volume 1 — Project Minimum Requirements*. This appendix includes descriptions of acceptable methods for estimating the quantity and hydrologic characteristics of stormwater runoff, and the assumptions and data requirements of these methods. Specifically, hydrologic tools and methods are presented for the following tasks:

- Calculating runoff hydrographs and time series using single-event and continuous rainfall runoff models.
- Calculating peak flows for conveyance, peak flow detention and retention, and water quality rate treatment BMPs.
- Calculating volumes for detention and retention and water quality volume treatment BMPs.
- Calculating flow durations for flow duration detention- and retention-based requirements.

Flow control and water quality performance standards are presented in *Volume 1*. BMP design requirements and specific modeling methods are provided in *Volume 3, Chapters 4 and 5*. Any request for alternative calculation methods shall follow the principles laid out in this appendix and be approved by the Director.

F-2. Applicability of Hydrologic Analysis Methods

The choice of a hydrologic analysis method depends on the type of facility being designed (conveyance, detention, or water quality) and the required performance standard. The size of the tributary area and watershed characteristics, including backwater effects, should also be considered.

Hydrologic analysis methods may be grouped into three categories:

- **Continuous rainfall-runoff models** use multi-decade precipitation and evaporation time series as input to produce a corresponding multi-decade time series of runoff. Continuous models are used to size stormwater management facilities to meet peak or flow duration performance standards and water quality treatment requirements. Discharge rates computed with continuous models may also be used to size conveyance facilities.
- **Single-event rainfall-runoff models** simulate rainfall-runoff for a single storm, typically 2 hours to 72 hours in length, and usually of a specified exceedance probability (recurrence interval). Single-event methods are applicable for sizing conveyance facilities.
- The **rational method** is appropriate for designing conveyance systems that receive runoff from small, quickly responding areas (less than 10 acres) where short, intense storms generate the highest peak flow. This method only produces a flow peak discharge rate, and routing effects are not included. Advantages of this method are that it is easy to apply and generally produces conservative results. For larger, more complex basins, routing and timing of the flood peaks becomes more important and single-event or continuous rainfall-runoff modeling is required.

The applicability of each method is summarized in Table F.1.

Table F.1. Hydrologic Analysis Method Applicability.

Method	Applicable Models	Constraints	On-site BMP Sizing	FC BMP Sizing	WQ BMP Sizing	Conveyance Sizing	TESC Design Flow Sizing
Continuous Rainfall-runoff Modeling[a]	• MGSFlood • WWHM • Other[b]	Refer to Table F.12 for time step requirements	✓	✓	✓	✓	✓
Single-event Rainfall-runoff Modeling	• NRCS TR-55 • SBUH • StormShed • Corps of Engineers HMS and HEC-1 • EPA SWMM, PCSWMM, and XP-SWMM • Other models approved by the Director	Refer to Table F.14	NA	NA	NA	✓	✓
Rational Method	NA	<10 acres (measured to individual conveyance elements) Upstream of storage routing and backwater effects	NA	NA	NA	✓	✓

[a] Refer to the *Approval Status of Continuous Simulation Models* section of the SWMMWW for a list of currently approved models.

[b] The following continuous hydrologic models may also be used for project-specific situations: HSPF, EPA SWMM5, ModFlow, HMS, PCSWMM, and other models approved by the Director.

BMP – Best Management Practice
FC – Flow Control
HSPF – Hydrologic Simulation Program Fortran (US EPA)
NA – Not Applicable
NRCS – Natural Resources Conservation Service
On-site – On-site Stormwater Management
SBUH – Santa Barbara Urban Hydrograph
SWMM – Storm Water Management Model
TESC – Temporary Erosion and Sediment Control
WQ – Water Quality
WWHM – Western Washington Hydrology Model
✓ = acceptable

F-3. General Modeling Guidance

This section includes general modeling guidance that may apply to all hydrologic analysis methods, including both continuous modeling and single-event modeling using historical precipitation data, watershed characterization, hydrologic soil groups, infiltration equations, and outfalls.

F-3.1. Historical Precipitation Data

Data collected from the Seattle Public Utilities (SPU) rain gauge network may be used in rainfall runoff models to aid in the design process by replicating past floods, to investigate anecdotal flood information, or for use in model calibration. Use of the historical time series is recommended, but is not required, for the design of stormwater BMPs.

Continuous historical precipitation data are available from 17 active and 2 closed rain gauges from January 1978 through the present at a time step of 1 minute. Active and closed gauge names and locations are summarized in Table F.2 and active locations are summarized on Figure F.1. Continuous Rainfall-Runoff Methods (*Section F-4*) and Single-event Rainfall-runoff Methods (*Section F-5*) provide additional detail regarding selection of precipitation data.

Table F.2. City of Seattle Rain Gauge Stations.

Station ID	Station Name	Period of Record	Status
45-S001	Haller Lake Shop	1978 – current	Active
45-S002	Magnusson Park	1978 – current	Active
45-S003	UW Hydraulics Lab	1978 – current	Active
45-S004	Maple Leaf Reservoir	1978 – current	Active
45-S005	Fauntleroy Ferry Dock	1978 – current	Active
45-S007	Whitman Middle School	1978 – current	Active
45-S008	Ballard Locks	1978 – current	Active
45-S009	Woodland Park Zoo	1978 – current	Active
45-S010	Rainier View Elementary	1978 – 2008	Closed
45-S011	Metro-KC Denny Regulating	1978 – current	Active
45-S012	Catherine Blaine Elementary School	1978 – current	Active
45-S014	Lafayette Elementary School	1978 – current	Active
45-S015	Puget Sound Clean Air Monitoring Station	1978 – current	Active
45-S016	Metro-KC E Marginal Way	1978 – current	Active
45-S017	West Seattle Reservoir Treatment Shop	1978 – current	Active
45-S018	Aki Kurose Middle School	1978 – current	Active
45-S020	TT Minor Elementary	1978 – 2010	Closed
RG25	Garfield Community Center	2010 – current	Active
RG30	SPL Rainier Beach Branch	2009 – current	Active

F-3.2. Watershed Characterization

Prior to conducting any detailed stormwater runoff calculations, the overall relationship between the proposed project site and upstream and downstream off-site areas must be considered. The general hydrologic characteristics of the project site dictate the amount of runoff that will occur and where stormwater facilities can be placed. It is important to identify the stormwater destination point, including potential backwater effects. Drainage patterns and contributing areas can be determined from preliminary surveys of the area, available topographic contour maps, and SPU drainage system maps. Note that the drainage systems often cross topographic divides within the City of Seattle. Maps can be obtained from the City's GIS web page (www.seattle.gov/utilities/services/gis).

F-3.3. Calculation of Total Impervious Area

Impervious coverage for proposed development must be estimated. Impervious coverage of streets, sidewalks, hard surface trails, etc., shall be taken from plans of the site. Refer to *Volume 1*, *Appendix A*, and the Stormwater Code for definitions and descriptions of all surfaces that must be considered. Impervious coverage for off-site areas contributing flow to the site can be estimated from orthophotos available through GIS.

F-3.4. Calculation of Effective Impervious Area

Effective impervious surface is the fraction of impervious surface connected to a drainage system and is used in hydrologic simulations to estimate runoff. The effective impervious area is the total impervious area multiplied by the effective impervious fraction. Non-effective impervious surface is assumed to have the same hydrologic response as the immediately surrounding pervious area. For the existing condition modeling, areas with unconnected rooftops may be estimated from visual survey as approved by the Director.

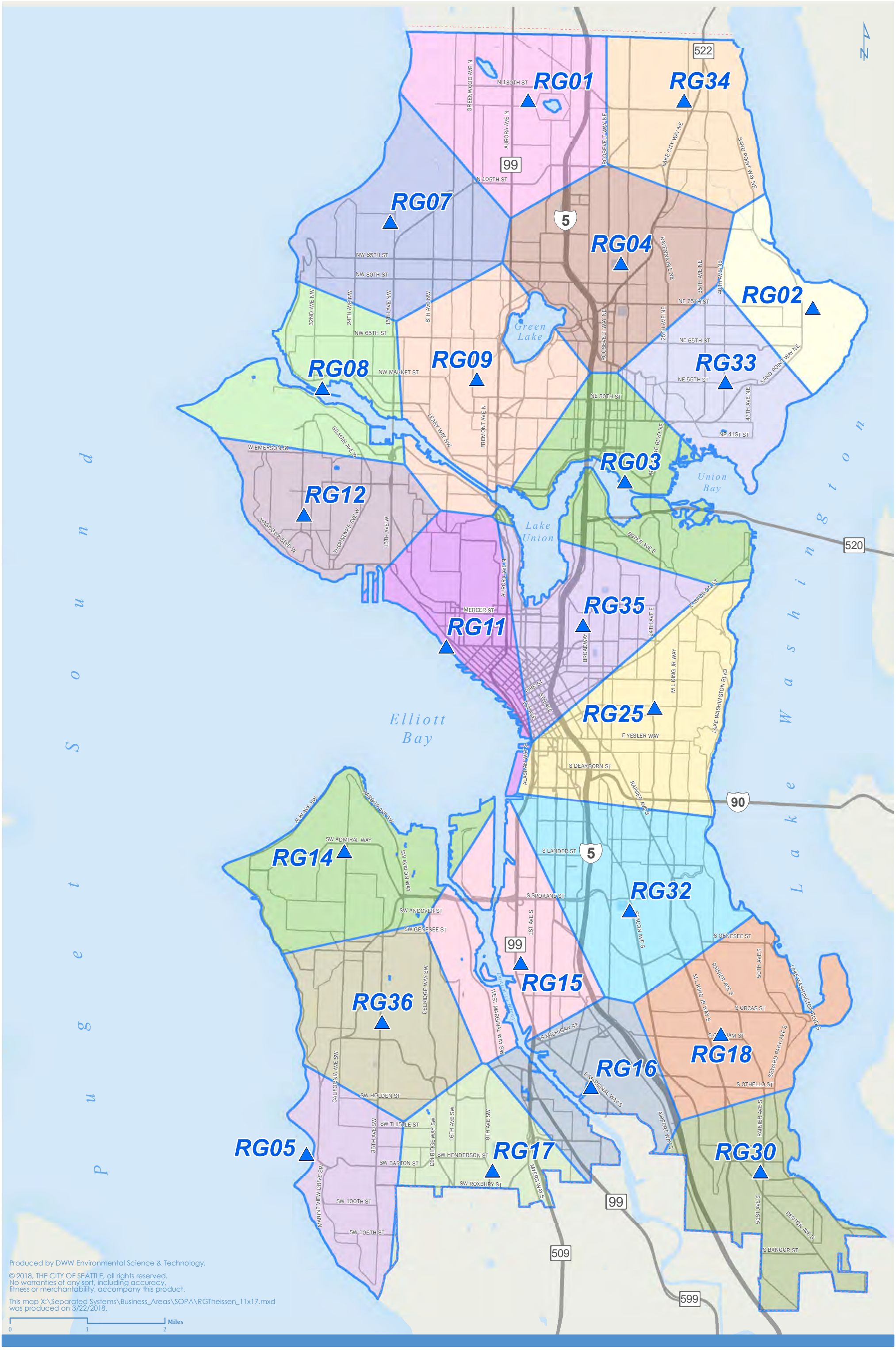

Figure F-1. Active City Rain Gauge Network Stations.

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F-3.5. Soil and Infiltration Parameters

F-3.5.1. Hydrologic Soil Groups

Hydrologic soil groups for common soil types in the Seattle area are listed in Table F.3.

F-3.5.2. Infiltration Equations

When computing runoff in models other than those based on HSPF, an infiltration soil loss method should be used. Examples of infiltration methods include the Green-Ampt (Rawls et al. 1993), Philip (Rawls et al. 1993), and Holtan (Holtan 1961) methods. These methods are incorporated into several commonly available computer programs including StormShed, PCSWMM, HEC HMS, and HEC-1. The City recommends the use of Green-Ampt method; however, the other methods listed above can also be used based on project-specific situations.

Table F.3. Hydrologic Soil Group Definition for Common Soils in King County.

Soil Group	Hydrologic Group	Soil Group	Hydrologic Group
Alderwood	C	Orcas Peat	D
Arents, Alderwood Material	C	Oridia	D
Arents, Everett Material	B	Ovalt	C
Beausite	C	Pilchuck	C
Bellingham	D	Puget	D
Briscot	D	Puyallup	B
Buckley	D	Ragnar	B
Coastal Beaches	Variable	Renton	D
Earlmont Silt Loam	D	Riverwash	Variable
Edgewick	C	Salal	C
Everett	A	Sammamish	D
Indianola	A	Seattle	D
Kitsap	C	Shacar	D
Klaus	C	Si Silt	C
Mixed Alluvial Lan	Variable	Snohomish	D
Nellton	A	Sultan	C
Newberg	B	Tukwila	D
Nooksack	C	Urban	Variable
Normal Sandy Loam	D	Woodinville	D

Table F.3 (continued). Hydrologic Soil Group Definition for Common Soils in King County.

HYDROLOGIC SOIL GROUP CLASSIFICATIONS
A. Low runoff potential: Soils having high infiltration rates, even when thoroughly wetted, and consisting chiefly of deep, well-to-excessively drained sands or gravels. These soils have a high rate of water transmission.
B. Moderately low runoff potential: Soils having moderate infiltration rates when thoroughly wetted, and consisting chiefly of moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission.
C. Moderately high runoff potential: Soils having slow infiltration rates when thoroughly wetted, and consisting chiefly of soils with 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.
D. High runoff potential: Soils having very slow infiltration rates when thoroughly wetted and consisting chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a hardpan or clay later at or near the surface, and shallow soils over nearly impervious material. These soils have a very slow rate of water transmission.

Source: TR-55 (NRCS 1986), Exhibit A-1. Revisions made from Soil Conservation Service (SCS), Soil Interpretation Record, Form #5, September 1988.

Green-Ampt Equation

The Green-Ampt model calculates cumulative infiltration by assuming water flow into a vertical soil profile like a piston flow.

$$f_t = K\left(\frac{\psi\Delta\theta}{F_t} + 1\right) \quad (1)$$

$$F_{t+\Delta t} = F_t + K\Delta t + \psi\Delta\theta \ln\left[\frac{F_{t+\Delta t} + \psi\Delta\theta}{F_t + \psi\Delta\theta}\right] \quad (2)$$

Where:

- f_t = infiltration rate (mm/hr or in/hr)
- ψ = initial matric potential of the soil (mm or inches)
- $\Delta\theta$ = difference of soil water content after infiltration with initial water content
- K = hydraulic conductivity (mm/hr or in/hr)
- F_t = cumulative infiltration at time t (mm or inches)
- $F_{t+\Delta t}$ = cumulative infiltration at time t+ Δt (mm or inches)
- Δt = time incremental (hours)

Equation (1) is used for determining ponding situation and (2) is used for calculating the cumulative infiltration after ponding. Trial and error method is the most popular method to solve equation (2) (Chow et al. 1988). Parameters ψ , $\Delta\theta$, and K were tabulated by Chow et al. (1988) for all soil classes. Chow et al. (1988) developed a procedure to solve infiltration with changing rainfall intensity by Green-Ampt method in a table. However, since it simplifies the water movement as a piston flow, the wetting front is distorted.

Typical values suggested by Rawls, Brakensiek, and Miller (as reflected in Chow et al. 1988) are shown in Table F.4 below.

Table F.4. Green-Ampt Infiltration Parameters.

USDA Soil Classification	Suction Head ψ (mm)	Suction Head ψ (in/hr)	Hydraulic Conductivity *K* (mm/hr)	Hydraulic Conductivity *K* (in/hr)	Porosity η	Effective Porosity θ_e
Sand	49.5	1.95	117.8	4.64	0.437	0.417
Loamy Sand	61.3	2.42	29.9	1.18	0.437	0.401
Sandy Loam	110.1	4.34	10.9	0.43	0.453	0.412
Loam	88.9	3.50	3.4	0.13	0.463	0.434
Silt Loam	166.8	6.57	6.5	0.26	0.501	0.486
Sandy Clay Loam	218.5	8.61	1.5	0.06	0.398	0.330
Clay Loam	208.8	8.23	1.0	0.04	0.464	0.309
Silty Clay Loam	273.0	10.76	1.0	0.04	0.471	0.432
Sandy Clay	239.0	9.42	0.6	0.02	0.430	0.321
Silty Clay	292.2	11.51	0.5	0.02	0.479	0.423
Clay	316.3	12.46	0.3	0.01	0.475	0.385

in/hr – inches per hour
mm – millimeters
mm/hr – millimeters per hour
USDA – United States Department of Agriculture

Holtan's Equation

The empirical infiltration equation devised by Holtan (1961) is explicitly dependent on soil water conditions in the form of available pore space for moisture storage:

$$F = (GI)(AH)\ SMD^{IEXP} + FC \quad (3)$$

Where:

- F = surface infiltration rate at a given time (in/hr)
- GI = Growth Index representing the relative maturity of the ground cover (0 for newly planted, 1 for mature cover)
- AH = constant as specified below
- SMD = soil moisture deficit at a given time (inches)
- IEXP = infiltration exponent (default value is 1.4)
- FC = minimum surface infiltration rate (in/hr) and occurs when SMD equals zero

Parameters GI, AH, FC, and the initial soil moisture deficit (SMD0) are the principal input parameters and can be determined as follows:

- GI is typically set to 1.0 to represent mature ground cover.
- AH can be determined from Table F.5.

- FC can be approximated from Table F.6 or by using the saturated hydraulic conductivity, which is available from soil survey reports.

Table F.5. Estimates of Holtan AH.

Land Use or Cover	Base Area Rating[a] Poor Condition	Base Area Rating[a] Good Condition
Fallow[b]	0.10	0.30
Row crops	0.10	0.20
Small grains	0.20	0.30
Hay (legumes)	0.20	0.40
Hay (sod)	0.40	0.60
Pasture (bunchgrass)	0.20	0.40
Temporary pasture (sod)	0.40	0.60
Permanent pasture (sod)	0.80	1.00
Woods and forests	0.80	1.00

[a] Adjustments needed for "weeds" and "grazing."

[b] For fallow land only, "poor condition" means "after row crop," and "good condition" means "after sod."

Source: Holtan et al. (1975)

Table F.6. Estimates of Holtan FC Values.

NRCS Hydrologic Soil Group	Minimum Infiltration Rates FC (inches/hour)
A	0.30–0.45
B	0.15–0.30
C	0.05–0.15
D	< 0.05

Source: Musgrave (1955)

This equation has been found to be suitable for inclusion in catchment models because of soil water dependence, and satisfactory progress has been reported for runoff predictions (Dunin 1976).

Kostiakov's Equation

Kostiakov (1932) proposed the following equation for estimating infiltration:

$$i(t) = \alpha t^{-\beta} \quad (4)$$

Where: t = time
i = infiltration rate
α= empirical constant (α > 0)
ß= empirical constant (0 < ß < 1)

Upon integration from 0 to t, equation (4) yields equation (5), which is the expression for cumulative infiltration, I(t):

$$I(t) = \frac{\alpha}{1-\beta} t^{(1-\beta)} \tag{5}$$

Where: I(t) = cumulative infiltration

The constants α and ß can be determined by curve-fitting equation (5) to experimental data for cumulative infiltration, I(t). Since infiltration rate (i) becomes zero as $t \to \infty$, rather than approach a constant non-zero value, Kostiakov proposed that equations (4) and (5) be used only for $t < t_{\max}$ where $t_{\max}$ is equal to $(\alpha / K_s)^{(1/\beta)}$, and K_s is the saturated hydraulic conductivity of the soil. Kostiakov's equation describes the infiltration quite well at smaller times, but becomes less accurate at larger times (Philip 1957a and 1957b; Parlange and Haverkamp 1989).

Horton's Equation

Horton (1940) proposed to estimate infiltration in the following manner,

$$i(t) = i_f + (i_0 - i_f) e^{-\gamma t} \tag{6}$$

and

$$I(t) = i_f t + \frac{1}{\gamma}(i_0 - i_f)(1 - e^{-\gamma t}) \tag{7}$$

Where: i_0 = measured infiltration rate
i_f = final infiltration rate
γ = empirical constant

It is readily seen that i(t) is non-zero as t approaches infinity, unlike Kostiakov's equation. It does not, however, adequately represent the rapid decrease of i from very high values at small t (Philip 1957a and 1957b). It also requires an additional parameter over the Kostiakov equation. Parlange and Haverkamp (1989), in their comparison study of various empirical infiltration equations, found the performance of Horton's equation to be inferior to that of Kostiakov's equation.

Mezencev's Equation

In order to overcome the limitations of Kostiakov's equation for large times, Mezencev (Philip 1957a and 1957b) proposed the following as modifications to equations (4) and (5). Mezencev proposed infiltration estimated by:

$$i(t) = i_f + \alpha t^{-\beta} \tag{8}$$

and

$$I(t) = i_f t + \frac{\alpha}{1-\beta} t^{(1-\beta)} \tag{9}$$

Where: i_f = final infiltration rate at steady state

F-3.6. Outfalls

F-3.6.1. Outfalls to Lakes and the Ship Canal

Single-event hydraulic analysis of outfalls that discharge to lakes and the Ship Canal should be performed using high water surface elevation from the observed record. This assumption may lead to conservative results and it is recommended that the designer consider using continuous simulation with a varying receiving water level. Table F.7 shows the maximum observed water levels in Seattle lakes. Water levels may vary from year to year due to sedimentation and season.

For continuous simulations, the designer may choose to use the historical record or the highest observed elevations. Lake Washington and associated waters are controlled at the Hiram M. Chittenden Locks by the US Army Corps of Engineers (USACE). Refer to the USACE Reservoir Control Center website (www.nwd-wc.usace.army.mil/nws/hh/www/index.html) for Lake Washington Ship Canal data and note that elevations given are in USACE datum and should be converted to NAVD88 before use.

Table F.7. Physical Characteristics of Seattle Lakes.

	Bitter Lake	Haller Lake	Green Lake	Lake Union	Lake Washington
Water surface elevation (feet, NAVD88)[a]	434.4	376.9	164.3	18.6	18.6
Maximum depth (feet)[b]	31.0	36.0	30.0	50.0	214
Mean depth (feet)[b]	16.0	16.0	13.0	34.0	108
Area (acres)[b]	19.0	15.0	259	580	21,500

[a] SPU Engineering Support Division – Survey Field Books, measurements were all converted to NAVD88 from the old City of Seattle Vertical Datum based on a conversion factor of 9.7 feet.

[b] Sources: King County (2015) and King County (2016).

Note: Water levels may vary from year to year by as much as 3 feet.

F-3.6.2. Tidal Influence/Sea Level Rise

When utilizing single-event hydraulic analysis of the drainage system or combined sewer system with outfalls that discharge to the tidally influenced Duwamish River or Puget Sound,

the highest observed tide from the observed record shall be used. Match the peak rainfall intensity to a tide cycle simulation with a peak of 12.14 feet (NAVD88). This assumption may lead to conservative results and it is recommended that the designer consider using continuous simulation with a varying receiving water level.

For continuous simulations, the designer should match, by time, the historical tidal record to the historical rainfall record. For rainfall simulations where there is no observed tidal elevation, use of a tide predictor is recommended. Tidal information is available from National Oceanic and Atmospheric Administration (NOAA) (http://tidesandcurrents.noaa.gov) and from the US Army Corps of Engineer's (www.nws.usace.army.mil/About/Offices/Engineering/HydraulicsandHydrology/HistoricalDatumRegions.aspx). The tidal boundary is simulated as a water surface elevation time series computed using astronomical tide theory (NOAA 1995).

Sea level is rising, and for both continuous and single-event modeling, the designer should evaluate the risks depending on the project design life and objectives. Since 1899, the observed trend was a rise of 2.06 mm per year, which is equivalent to 8 inches in 100 years. The effect of climate change on predicted sea level rise is expected to greatly exceed that rate, but there is uncertainty regarding timing and severity. The Washington Costal Resilience Project (Miller et al. 2018) represents the best available science on sea level rise. The report provides local projections at various likelihoods and time frames (see Figure F.2). For Seattle, the central estimate (i.e., 50 percent probability) is 1.9 to 2.3 feet of rise by 2100, and 3.0 to 3.9 feet by 2150. Upper-end estimates (1 percent probability) project 5.1 feet of rise by 2100, and 10.4 feet of rise by 2150.

For design of tidally impacted public drainage system and public combined sewer system, hydraulic analysis of sea level rise is required. For other projects, it is recommended that designers analyze risk by adjusting the tidal record upward by 1 to 4 feet, depending on the design life and risk tolerance of the project. Likewise, designers should look to further mitigate risk by considering current design adjustments or identifying possible future modifications. For design of facilities where water level elevation at the outfall is critical, the City recommends that the designer consider storm surge due to low atmospheric pressure and/or wind and wave action.

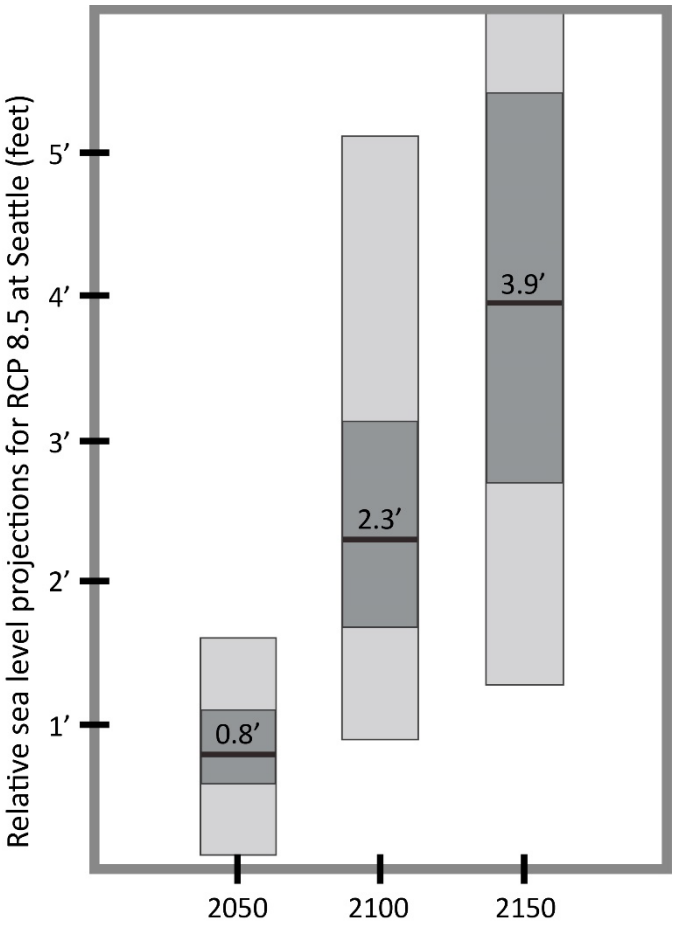


Figure F.2. Projected Sea Level Rise in Washington's Waters Relative to Year 2050.

F-4. Continuous Rainfall-Runoff Methods

This section includes specific modeling guidance that is applicable to continuous rainfall-runoff methods including precipitation input, land cover categorization, soil parameters, infiltration parameters, and modeling guidance.

F-4.1. Precipitation Input

Continuous rainfall-runoff models use multi-year inputs of precipitation and evaporation to compute a multi-year time series of runoff from the site. Using precipitation input that is representative of the site under consideration is critical for the accurate computation of runoff and the design of stormwater facilities.

Two types of precipitation and evaporation data are available for stormwater analysis. The first type is a design precipitation and evaporation time series. The design time series are appropriate for design and analysis of stormwater facilities and were developed by combining and scaling records from distant precipitation stations. The second type of time series is historical precipitation and evaporation time series (described in *Section F-3 — General*

Modeling Guidance). Because the record length of the historical precipitation and evaporation is relatively short, this data should be used for model calibration and not for design.

The City of Seattle Design Time Series consists of a precipitation and evaporation time series that is representative of the climatic conditions in the City of Seattle. The design precipitation time series was developed by combining and scaling precipitation records from widely separated stations to produce an "extended precipitation time series" with a 158year record length (Schaefer and Barker 2002; Schaefer and Barker 2007). The precipitation scaling was performed such that the scaled precipitation record would possess the regional statistics at durations of 5 minutes, 10 minutes, 15 minutes, 20 minutes, 30 minutes, 45 minutes, 60 minutes, 2 hours, 6 hours, 24 hours, 3 days, 10 days, 30 days, 90 days, 6 months, and 12 months (refer to www.seattle.gov/sdci/codes/codes-we-enforce-(a-z)/stormwater-code for modeling resources). The precipitation time series was developed at a 5minute time step. For modeling of the combined sewer system, a shorter precipitation record length may be approved by the Director.

The evaporation time series was developed using a stochastic evaporation generating approach whereby daily evaporation was generated in a manner to preserve the daily and seasonal variability and accounting for differences observed on days with and without rainfall. The evaporation time series was developed from data collected at the Puyallup 2 West Experimental Station (station number 45-6803). Refer to www.seattle.gov/sdci/codes/codes-we-enforce-(a-z)/stormwater-code for modeling resources. The evaporation time series has a 1-hour time step.

F-4.2. Land Cover Categorization

Continuous hydrologic models based on HSPF (e.g., WWHM and MGSFlood) include five land cover types: forest, pasture, lawn (or grass), wetland, and impervious. These cover types shall be applied as specified in Table F.8.

F-4.3. Soil and Infiltration Parameters

F-4.3.1. Soil Mapping

Mapping of soil types by the Natural Resources Conservation Service (NRCS), or the Washington Department of Natural Resources Geologic Information Portal (www.dnr.wa.gov/geologyportal) may be used as a source of soil/geologic information for use in continuous hydrologic modeling. If using NRCS maps, each soil type defined by the NRCS has been classified into one of four hydrologic soil groups; A, B, C, and D. Table F.3 shows hydrologic soil groups for common soil types in King County. As is common practice in hydrologic modeling in western Washington, the soil groups used in the model generally correspond to the hydrologic soil groups as shown in Table F.9.

Table F.8. Continuous Model Land Cover and Areas of Application.

Continuous Model Land Cover	Application Pre-Developed	Application Post-Developed
Forest	All forest/shrub cover, irrespective of age	All permanent (e.g., protected by covenant) onsite forest/shrub cover, irrespective of age planted at densities sufficient to ensure 80%± canopy cover within 5 years.
Pasture	All grassland, pasture land, lawns, and cultivated or cleared area except for lawns in redevelopment areas with pre-development densities greater than 4 DU/GA	● All areas that are amended using implementation options 2, 3, or 4 from *Volume 3, Section 5.1.5.2* may be modeled as pasture rather than lawn (WWHM) or grass (MGSFlood). ● Unprotected forest in rural residential development shall be considered half pasture, half grass.
Lawn (or Grass)	Lawns in redevelopment areas with pre-development densities greater than 4 DU/GA	● All post-development grassland and landscaping that is not amended using implementation options 2, 3, or 4 from *Volume 3, Section 5.1.5.2.* ● All onsite forested land not protected by covenant.
Saturated / Wetland	All delineated saturated or wetland areas	All delineated saturated or wetland areas.
Impervious	● All impervious surfaces, including heavily compacted gravel and dirt roads, parking areas, etc. ● Open receiving waters (ponds and lakes)	● All impervious surfaces (with and without underdrains), including heavily compacted gravel and dirt roads, parking areas, etc. ● Pervious surfaces with underdrains. ● Open receiving waters (ponds, lakes, and onsite detention ponds, and wet ponds).

BMP – Best Management Practice

DU/GA – Dwelling Unit per Gross Acre

Table F.9. Relationship Between Hydrologic Soil Group and Continuous Model Soil Group.

Hydrologic Soil Group	Continuous Model Soil Group
A	Outwash
B	Till or Outwash
C	Till
D	Saturated / Wetland

Type B soils can be classified as either glacial till or outwash depending on the type of soil under consideration. Type B soils underlain by glacial till or bedrock, or with a seasonally high water table, would be classified as till. Conversely, well-drained B type soils would be classified as outwash.

The NRCS maps may not be used for determining infiltration capacity or a design infiltration rate.

F-4.3.2. Infiltration Parameters

The following discussion on HSPF model parameters applies to the use of continuous modeling (e.g., WWHM, MGSFlood). Default model parameters that define interception, infiltration, and movement of moisture through the soil, are based on work by the United States Geological Survey (USGS) (Dinicola 1990, 2001) and King County (2009). Pervious areas have been grouped into three land cover categories (forest, pasture, and lawn) and three soil/geologic categories (till, outwash, and saturated/wetland soil) for a total of seven cover/soil type combinations as shown in Table F.10. The combinations of soil type and land cover are called pervious land segments or PERLNDs. Default runoff parameters for each PERLND are summarized in Table F.11. These parameter values are used automatically by WWHM and MGSFlood programs for each land use type. A complete description of the PERLND parameters can be found in the HSPF User Manual (US EPA 2001). For a general discussion of infiltration equations refer to *Section F-3 — General Modeling Guidance*.

Table F.10. Pervious Land Soil Type/Cover Combinations used with HSPF Model Parameters.

Pervious Land Soil Type/Cover Combinations	
1.	Till/Forest
2.	Till/Pasture
3.	Till/Lawn
4.	Outwash/Forest
5.	Outwash/Pasture
6.	Outwash/Lawn
7.	Saturated Soil/All Cover Groups

F-4.4. Modeling Guidance

F-4.4.1. Computational Time Step Selection

An appropriate computational time step for continuous hydrologic models depends on the type of facility under consideration and the characteristics of the tributary watershed. In general, the design of facilities dependent on peak discharge require a shorter time step than facilities dependent on runoff volume. A longer time step is generally desirable to reduce the overall simulation time provided that computational accuracy is not sacrificed. Table F.12 summarizes the allowable computational time steps for various hydrologic design applications.

F-4.4.2. HSPF Parameter Modification

In HSPF (and MGSFlood and WWHM) pervious land categories are represented by PERLNDs and impervious land categories are represented by IMPLNDs. The only PERLND and IMPLND parameter values that should be adjusted by the user are LSUR (length of surface overland flow plane in feet), SLSUR (slope of surface overland flow plane in feet/feet), and NSUR (roughness of surface overland flow plane). The default HSPF parameter values in MGSFlood and WWHM are appropriate for large sites that are not typical for City of Seattle projects. Users are required to change the values for LSUR, SLSUR, and NSUR per guidance in

Table F.11 or adjust values for LSUR, SLSUR, and NSUR based on site-specific observations. Any changes made to parameter values noted in Table F.11 shall be recorded in the model output report and included with a project submittal.

Table F.11. Required Runoff Parameter Values for Each Pervious Land Segment (PERLND) and Impervious Land Segment (IMPLND).

Parameter	Pervious Land Segment (PERLND) Till Soil Forest	Pervious Land Segment (PERLND) Till Soil Pasture	Pervious Land Segment (PERLND) Till Soil Lawn	Pervious Land Segment (PERLND) Outwash Soil Forest	Pervious Land Segment (PERLND) Outwash Soil Pasture	Pervious Land Segment (PERLND) Outwash Soil Lawn	Pervious Land Segment (PERLND) Saturated Soil Forest, Pasture, or Lawn	Impervious Land Segment (IMPLND)
LZSN	4.5	4.5	4.5	5.0	5.0	5.0	4.0	NA
INFILT	0.08	0.06	0.03	2.0	1.6	0.8	2.0	NA
LSUR[a]	2* √(Contributing Area (square feet))	2* √(Contributing Area (square feet))	2* √(Contributing Area (square feet))	2* √(Contributing Area (square feet))	2* √(Contributing Area (square feet))	2* √(Contributing Area (square feet))	2* √(Contributing Area (square feet))	2* √(Contributing Area (square feet))
SLSUR[a]	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
KVARY	0.5	0.5	0.5	0.3	0.3	0.3	0.5	NA
AGWRC	0.996	0.996	0.996	0.996	0.996	0.996	0.996	NA
INFEXP	2.0	2.0	2.0	2.0	2.0	2.0	10.0	NA
INFILD	2.0	2.0	2.0	2.0	2.0	2.0	2.0	NA
BASETP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	NA
AGWETP	0.0	0.0	0.0	0.0	0.0	0.0	0.7	NA
CEPSC	0.2	0.15	0.1	0.2	0.15	0.1	0.1	NA
UZSN	0.5	0.4	0.25	0.5	0.5	0.5	3.0	NA
NSUR[a]	0.35	0.3	0.25	0.35	0.3	0.25	0.5	0.02
INTFW	6.0	6.0	6.0	0.0	0.0	0.0	1.0	NA
IRC	0.5	0.5	0.5	0.7	0.7	0.7	0.7	NA
LZETP	0.7	0.4	0.25	0.7	0.4	0.25	0.8	NA
RETSC	NA	NA	NA	NA	NA	NA	NA	0.1

[a] LSUR, SLSUR, and NSUR parameter values shall be adjusted based on site-specific observations.

LZSN = lower zone storage nominal (inches)
INFILT = infiltration capacity (in/hr)
LSUR = length of surface overland flow plane (feet)
SLSUR = slope of surface overland flow plane (feet/feet)
KVARY = groundwater exponent variable (inch -1)
AGWETP = active groundwater evapotranspiration (fraction)
CEPSC = Interception storage (inches)
UZSN = upper zone storage nominal (inches)
NSUR = roughness of surface overland flow plane (Manning's n)
INTFW = interflow index

AGWRC = active groundwater recession constant (day -1)
INFEXP = infiltration exponent
INFILD = ratio of maximum to mean infiltration
BASETP = base flow evapotranspiration (fraction)
IRC = interflow recession constant (day $^{-1}$)
LZETP = lower zone evapotranspiration (fraction)
RETSC = retention storage capacity (in)
NA = not applicable

Table F.12. Required Continuous Simulation Model Computational Time Step for Various Stormwater Facilities.

Type of Analysis	Maximum Time Step
Conveyance Sizing (Off-site)	5 minutes[a]
Conveyance Sizing Upstream of Stormwater Detention Facility (On-site), TESC Design Flows	5 minutes[a]
Conveyance Sizing Downstream of Stormwater Detention Facility (On-site), TESC Design Flows	15 minutes
Downstream Analysis, Off-site	5 minutes[a]
Flow Control (Detention and/or Infiltration) Facility and On-site BMP Sizing	5 minutes[a]
Water Quality Design Flow Rate	15 minutes
Water Quality Design Flow Volumes/Pollutant Loading	1 hour

[a] A 15-minute time step may be used if the time of concentration computed is 30 minutes or more (refer to *Time of Concentration Estimation* in *Section F-5.3*).

F-4.4.3. Steps for Hydrologic Design Using Continuous Rainfall-Runoff Models

This section presents the general process involved in conducting hydrologic analyses using continuous models. The actual design process will vary considerably depending on the project scenario, the applicable requirements, the facility being designed, and the environmental conditions.

Step #	Procedure
C-1	Review all minimum requirements that apply to the proposed project (*Volume 1*)
C-2	Review applicable site assessment requirements (*Volume 1, Chapter 2.4)*
C-3	Identify and delineate the overall drainage basin for each discharge point from the development site under existing conditions: ● Identify existing land use ● Identify existing soil types using onsite evaluation, NRCS soil survey, or mapping performed by the University of Washington (http://geomapnw.ess.washington.edu) ● Convert hydrologic soil types to HSPF soil classifications (till, outwash, or wetland) ● Identify existing drainage features such as streams, conveyance systems, detention facilities, ponding areas, depressions, etc.
C-4	Select and delineate pertinent subbasins based on existing conditions: ● Select homogeneous subbasin areas ● Select separate subbasin areas for on-site and off-site drainage ● Select separate subbasin areas for major drainage features
C-5	Determine hydrologic parameters for each subbasin under existing conditions, if required: ● Determine appropriate rainfall time series. For most design applications, the City of Seattle Design Time Series will be required. ● Categorize soil types and land cover ● Determine total and effective impervious areas within each subbasin ● Determine areas for each soil/cover type in each subbasin ● Select the required computational time step according to Table F.12
C-6	Compute runoff for the pre-developed condition. The continuous hydrologic model will utilize the selected precipitation time series, compute runoff from each subbasin, and route the runoff through the defined network. Flood-frequency and flow duration statistics will subsequently be computed at points of interest in the study area by the model.

Step #	Procedure
C-7	Determine hydrologic parameters for each subbasin under developed conditions: ● Utilize rainfall time series selected for existing conditions ● Categorize soil types and land cover ● Determine total and effective impervious areas within each subbasin ● Determine areas for each soil/cover type in each subbasin ● Utilize computational time step selected for existing conditions
C-8	Compute runoff for the developed condition. The continuous hydrologic model will utilize the selected precipitation time series, compute runoff from each subbasin, and route the runoff through the defined network. Flood-frequency and flow duration statistics will subsequently be computed at points of interest in the study area by the model.

Additional design steps specific to flow control and water quality treatment facility design are described below.

F-4.4.4. Flow Control Facility Design

Peak Standard

Peak flow control-based standards require that the stormwater facilities be designed such that the post-development runoff peak discharge rate is controlled to one or more discharge rates, usually at specified recurrence intervals. An example of this type of standard is the Peak Flow Control Standard.

Flood-frequency analysis seeks to determine the flood flow or water surface elevation with a probability (p) of being equaled or exceeded in any given year. Return period (T_r) or recurrence interval is often used in lieu of probability to describe the frequency of exceedance of a flood of a given magnitude. Return period and annual exceedance probability are reciprocals (equation 10). Flood-frequency analysis is most commonly conducted for flood peak discharge and peak water surface elevation but can also be computed for maximum or minimum values for various durations. Flood-frequency analysis as used here refers to analysis of flood peak discharge or peak water surface elevation.

$$\mathrm{Tr} = \frac{1}{\mathrm{p}} \tag{10}$$

Where: T_r = average recurrence interval in years
p = the annual exceedance probability

The annual exceedance probability of flow (or water surface elevation) may be estimated using the Gringorten (1963) plotting position formula (equation 11), which is a non-parametric approach.

$$Tr = \frac{N + 0.12}{i - 0.44} \tag{11}$$

Where: T_r = recurrence interval of the peak flow or peak elevation in years
i = rank of the annual maxima peak flow from highest to lowest
N = total number of years simulated

A probability distribution, such as the Generalized Extreme Value or Log-Pearson III (Interagency Advisory Committee on Water Data 1981), is not recommended for estimating the frequency characteristics.

Flood frequency analyses are used in continuous flow simulations to determine the effect of land use change and assess the effectiveness of flow control facilities. Flow control facilities are designed such that the post-developed peak discharge rate is at or below a target pre-developed peak discharge rate at one or more recurrence intervals. For example, Figure F.3 shows pre-developed and post-developed flood frequency curves for a stormwater pond designed to control peak discharges at the 2-year and 10-year recurrence intervals. Continuous simulation hydrologic models perform the frequency calculations and present the results in graphical and tabular form.

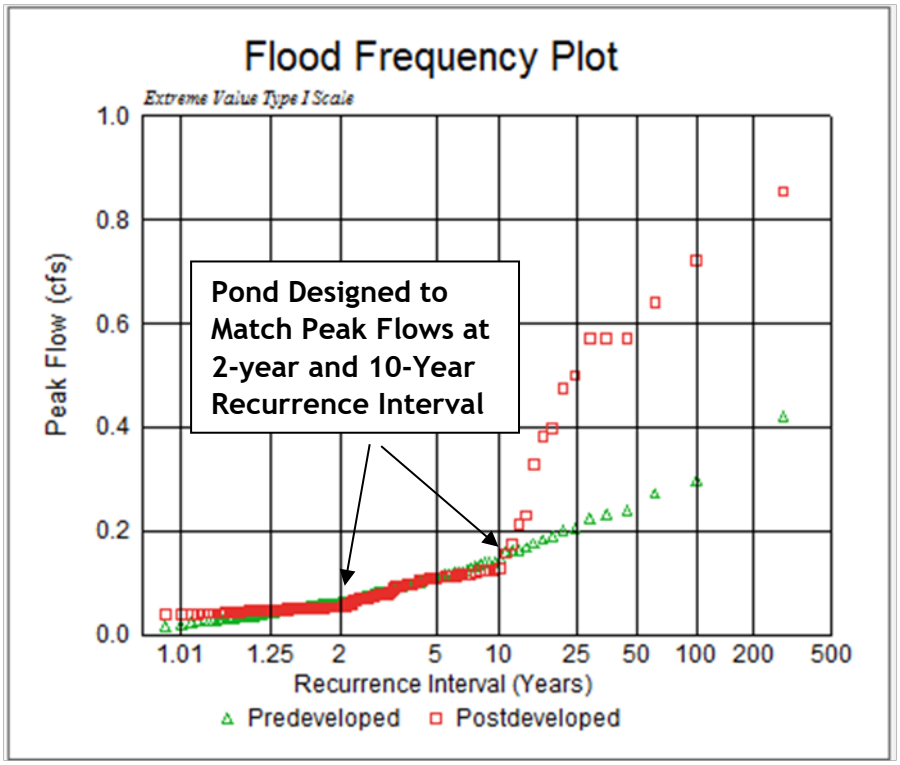


Figure F.3. Example Flood-Frequency Curves for a Stormwater Pond Designed to Control Post-developed Peak Discharge Rates to Pre-developed Levels at the 2-Year and 10-Year Recurrence Interval.

Flow Duration Standard

Flow duration statistics provide a convenient tool for characterizing stormwater runoff computed with a continuous hydrologic model. Examples of this type of standard are the Pre-developed Forest Standard and the Pre-developed Pasture Standard. Evaluation of a flow duration design standard requires continuous simulation to compute the pre-development and post-development runoff record. Duration statistics are computed by tracking the fraction of total simulation time that a specified flow rate is equaled or exceeded. Continuous rainfall-runoff models do this by dividing the range of flows simulated into discrete increments, and

then tracking the fraction of time that each flow is equaled or exceeded. For example, Figure F.4 shows a 1-year flow time series computed at hourly time steps from a 10-acre forested site and Figure F.5 shows the flow duration curve computed from this time series.

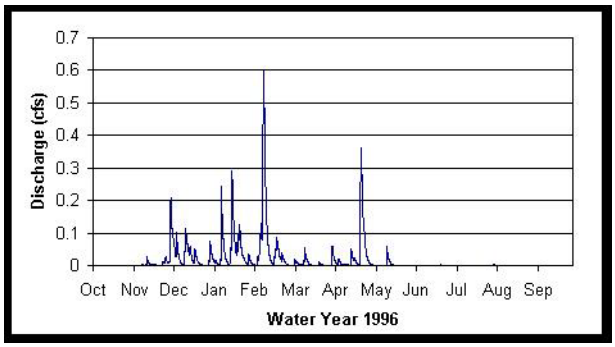


Figure F.4. Runoff from 10-acre Forested Site.

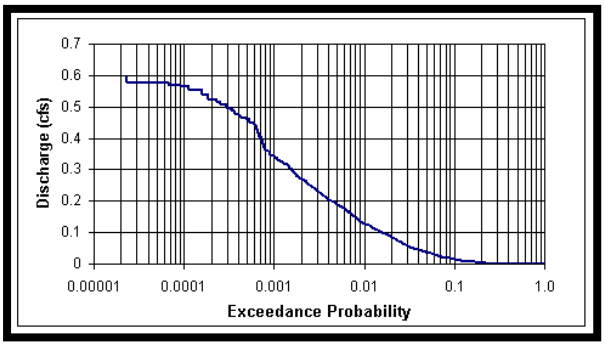


Figure F.5. Flow Duration Curve Computed Using Time Series in Figure F.4.

The fraction of time is termed "exceedance probability" because it represents the probability that a particular flow rate will be equaled or exceeded. It should be noted that exceedance probability for duration statistics is different from the "annual exceedance probability" associated with flood frequency statistics and there is no practical way of converting/relating annual exceedance probability statistics to flow duration statistics.

The flow duration standard can be viewed graphically as shown in Figure F.6. The flow duration curve for the site under pre-developed conditions is computed and is the target to which the post-developed flow duration curve is compared. The flow duration curve for the pond discharge must match the applicable pre-developed curve between 50 percent of the pre-developed 2-year (0.5 Q_2) and an upper limit, either the 2-year (Q_2) or the 50-year (Q_{50}) depending on the flow duration design standard for the facility.

Specified flow levels for the Pre-developed Forest Standard are typically 50 percent of the pre-developed 2-year peak flow (0.5 Q_2), the pre-developed 2-year peak flow (Q_2), and the pre-developed 50-year peak flow (Q_{50}) plus 97 other incremental flow values between 0.5 Q_2 and Q_{50}. Specified flow levels for the Pre-developed Pasture Standard are typically 50 percent of the pre-developed 2-year peak flow (0.5 Q_2) and the pre-developed 2-year peak flow (Q_2) plus 98 other incremental flow values between 0.5 Q_2 and Q_2.

Depending on the flow duration design standard applicable to the stormwater facility, three criteria are evaluated to determine if the standard has been met.

1. Post-development flow duration values may not exceed the pre-development flow duration values between 50 percent of the pre-developed 2-year peak flow (0.5 Q_2) and the pre-developed 2-year peak flow (Q_2).
2. Post-development flow duration values may not exceed pre-development flow duration values between the pre-developed 2-year peak flow (Q_2) and the pre-developed 50-year peak flow (Q_{50}) by more than 10 percent, i.e., a post-development flow duration value may be up to 110 percent of the corresponding pre-development flow duration value.

3. Post-development flow duration values may not exceed pre-development flow duration values for more than 50 percent of flow duration levels, i.e., not more than half of the post-development flow duration values may exceed 100 percent of the corresponding pre-development flow duration value.

General guidance for adjusting the geometry and outlets of stormwater ponds to meet the duration standard were developed by King County (1999) and are summarized in Figure F.7 and described below. Refinements should be made in small increments with one refinement at a time. In general, the recommended approach is to analyze the duration curve from bottom to top, and adjust orifices from bottom to top. Inflection points in the outflow duration curve occur when additional structures (e.g., orifices, notches, overflows) become active. Refer to *Volume 3, Chapter 5* for complete facility design and sizing requirements.

Step #	Parameter	Procedure
P-1	Bottom Orifice Size	Adjust the bottom orifice to control the bottom arc of the post-developed flow duration curve. Reducing the bottom orifice discharge lowers and shortens the bottom arc while increasing the bottom orifice raises and lengthens the bottom arc.
P-2	Height of Second Orifice	The invert elevation of the second orifice affects the point on the flow duration curve where the transition (break in slope) occurs from the curve produced by the low-level orifice. Lower the invert elevation of the second orifice to move the transition point to the right on the lower arc. Raise the height of the second orifice to move the transition point to the left on the lower arc.
P-3	Second Orifice Size	The upper arc represents the combined discharge of both orifices. Adjust the second orifice size to control the arc of the curve for post-developed conditions. Increasing the second orifice raises the upper arc while decreasing the second orifice lowers the arc.
P-4	Pond Volume	Adjust the pond volume to control the upper end of the duration curve. Increase the pond volume to move the entire curve down and to the left to control riser overflow conditions. Decrease the pond volume to move the entire curve up and to the right to ensure that the outflow duration curve extends up to the riser overflow.

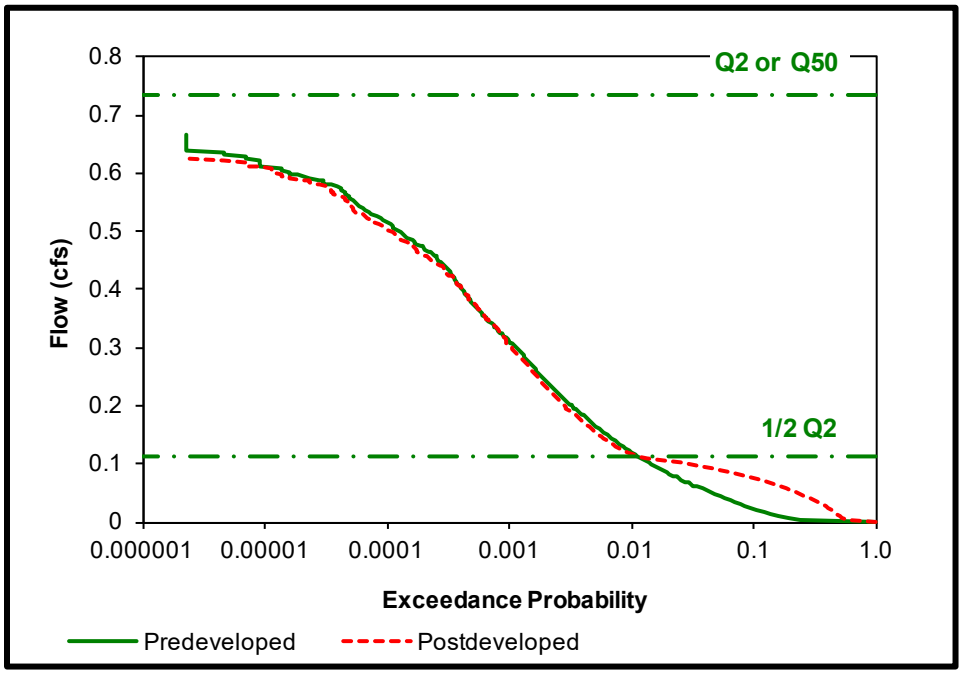


Figure F.6. Comparison of Pre-developed and Post-developed Flow Duration Curves.

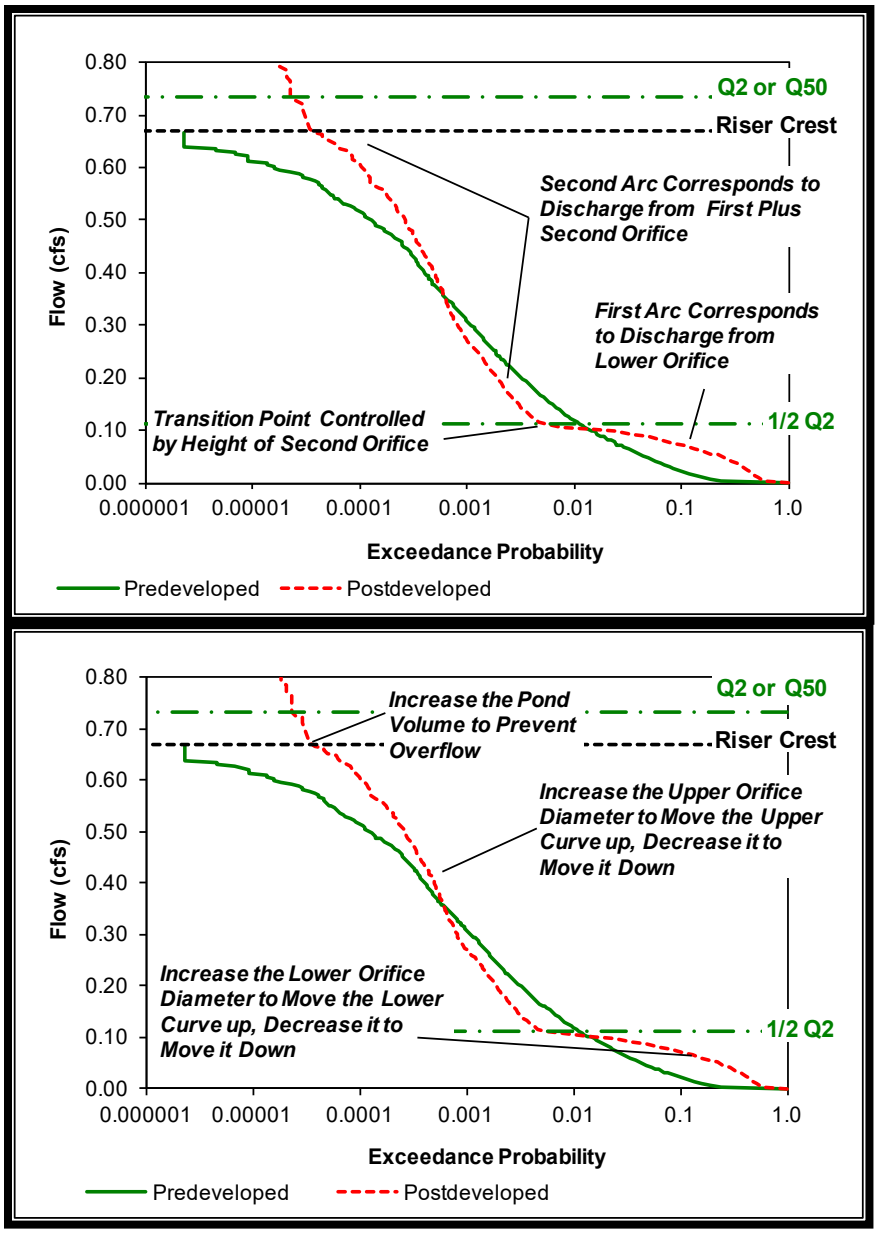


Figure F.7. General Guidance for Adjusting Pond Performance.

On-site Performance Standard BMP Design

This section provides guidance for sizing BMPs to meet the On-site Performance Standard. If the applicant chooses to use the On-site List Approach, modeling is typically not required (refer to sizing requirements in Chapter 5 of Volume 3). If the applicant chooses to use the On-site Performance Standard, the modeling procedures will depend upon the applicable target (i.e., forest or pasture). See Volume 1, Section 5.2.1 to determine the target based on the percent of existing hard surface and the type of drainage basin.

If the project discharge durations must match pre-developed forest flow durations from 8 percent to 50 percent of the 2-year pre-developed flow, the procedures outlined above in the *Flow Duration Standard* subsection are generally applicable (with duration bounds revised

to 8 percent to 50 percent of the 2-year flow). Both WWHM and MGSFlood have the capability to evaluate (and report "pass" and "fail") for this standard.

If the project discharge durations must match pre-developed pasture flow durations for the range of pre-developed discharge rates between the 1 percent and 10 percent exceedance values, the procedures outlined in this section are applicable.

The "frequency of exceedance" or "percent exceedance" (as referenced in the Stormwater Code), is the percent of time, over the simulation period (e.g., 158 years), that a given flow is equaled or exceeded. MGSFlood and WWHM both report "exceedance probability"— the decimal equivalent of "percent exceedance." For example, the 1 to 10 percent exceedance range corresponds to the 0.01 and 0.1 exceedance probabilities displayed on the flow duration curves (see Figure F.7a). The standard is achieved if the post-developed flows are less than the pre-developed flows for the 1 to 10 percent exceedance range (red line is beneath the green line for the shaded range of exceedance values).

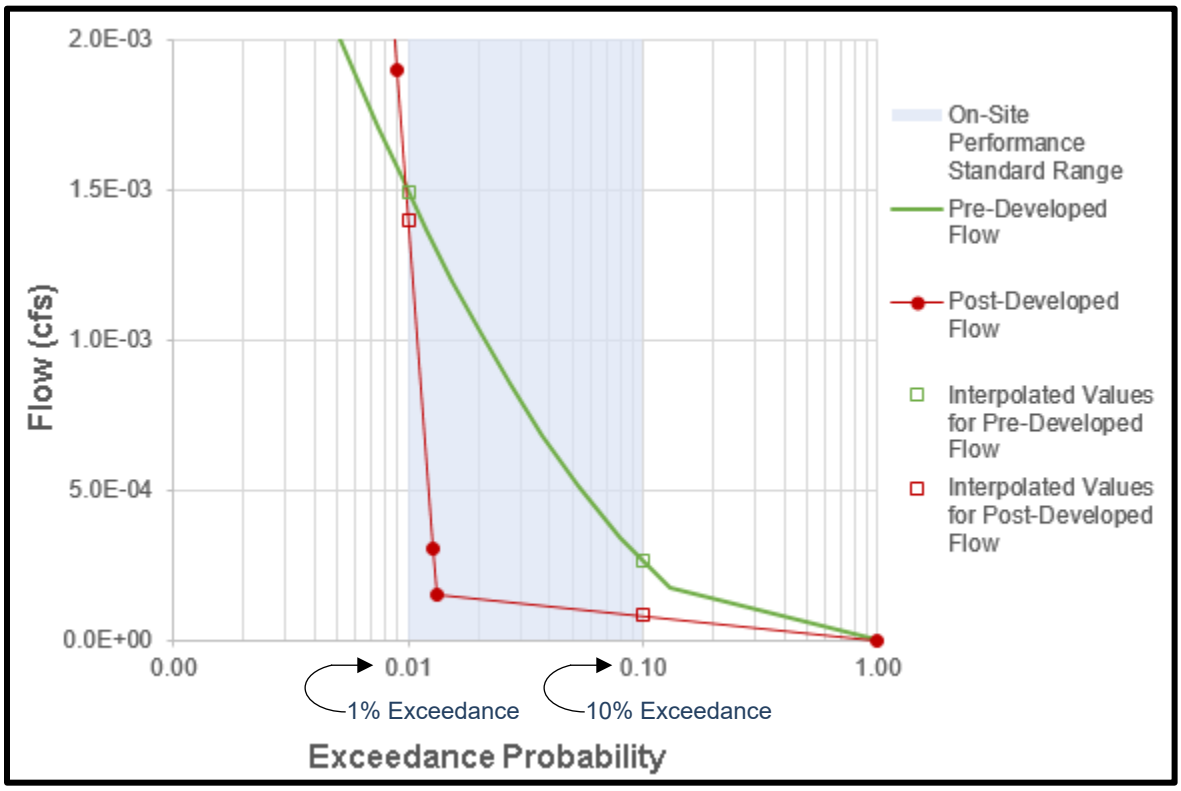


Figure F.7a. On-site Performance Standard Duration Curve.

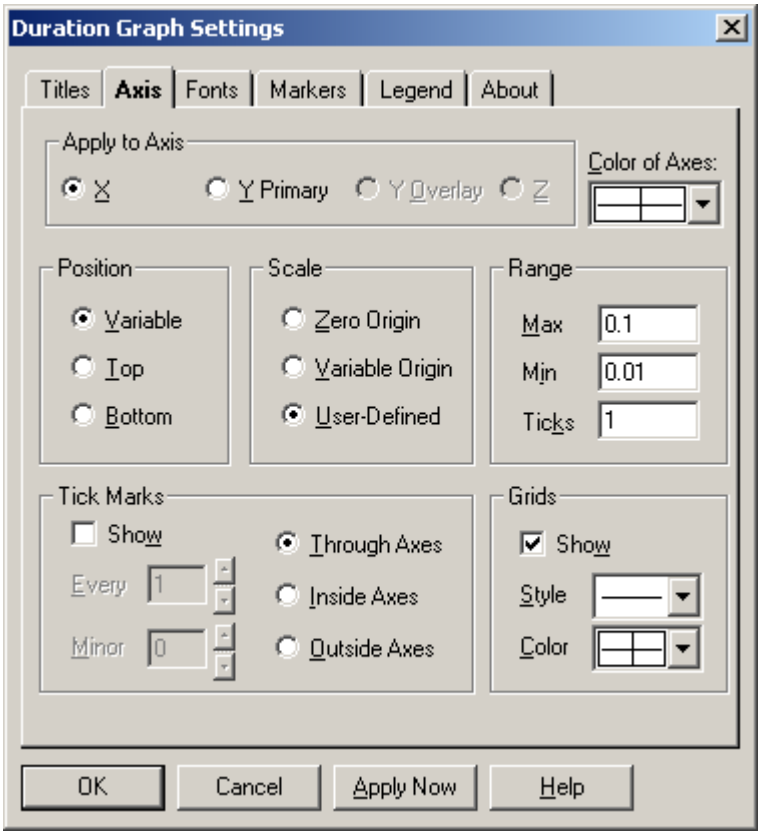
The latest versions of MGSFlood (Version 4.5.6 or later) include the option to conduct a flow duration analysis based on the 1 to 10 percent exceedance standard. An MGSFlood user can select the option on the LID Duration tab in the Options menu. MGSFlood will then report "pass" or "fail" for the 1 to 10 percent exceedance standard. WWHM does not explicitly report "pass" or "fail" for the 1 to 10 percent exceedance standard. However, WWHM allows the user to define the bounds of duration analysis in term of flow rate (cubic feet per second). A user can calculate the pre-developed pasture 1 and 10 percent exceedance flow rates using the software and manually enter them as the bounds for the flow duration analysis

on the Duration Criteria tab in the Options menu. WWHM will then report “pass” or “fail” for the 1 to 10 percent exceedance standard. For users with different or older software, the following procedures may be used to determine compliance with Seattle Stormwater Code. Details are provided for determining compliance with both MGSFlood and WWHM but similar procedures may be applicable to other software programs.

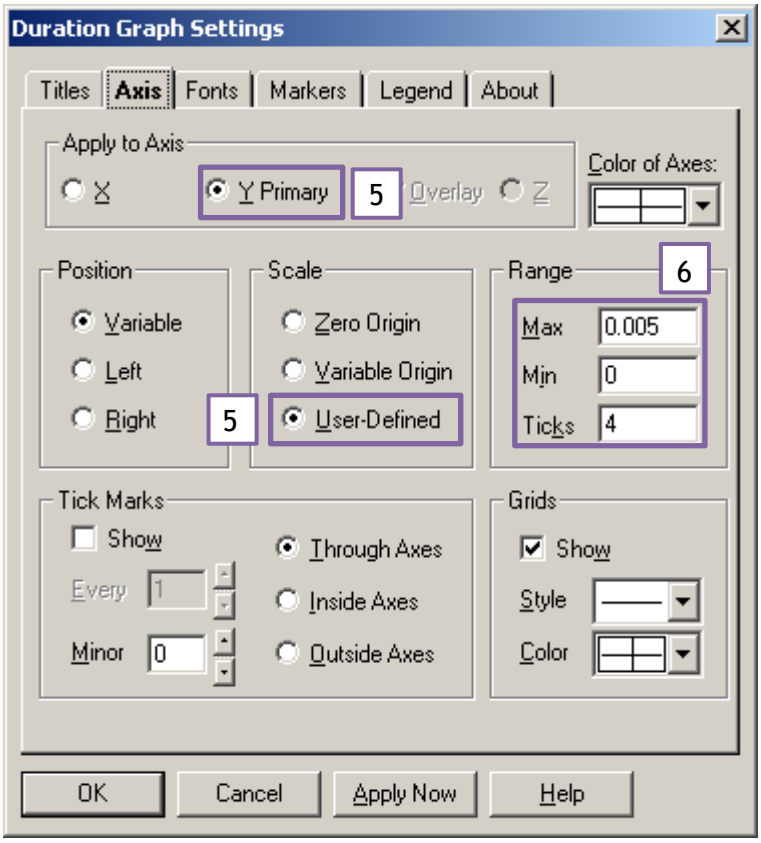
Visual Evaluation of On-site Performance Standard in MGSFlood (Versions prior to 4.5.6)

For versions of MGSFlood released prior to Version 4.5.6, evaluation of the 1 to 10 percent exceedance standard is not automated and must be confirmed by visually observing the MGSFlood Flow Duration Plot. The axes on the plot may be adjusted to clearly display the duration curve from 1 to 10 percent exceedance. Step-by-step instructions are provided below.

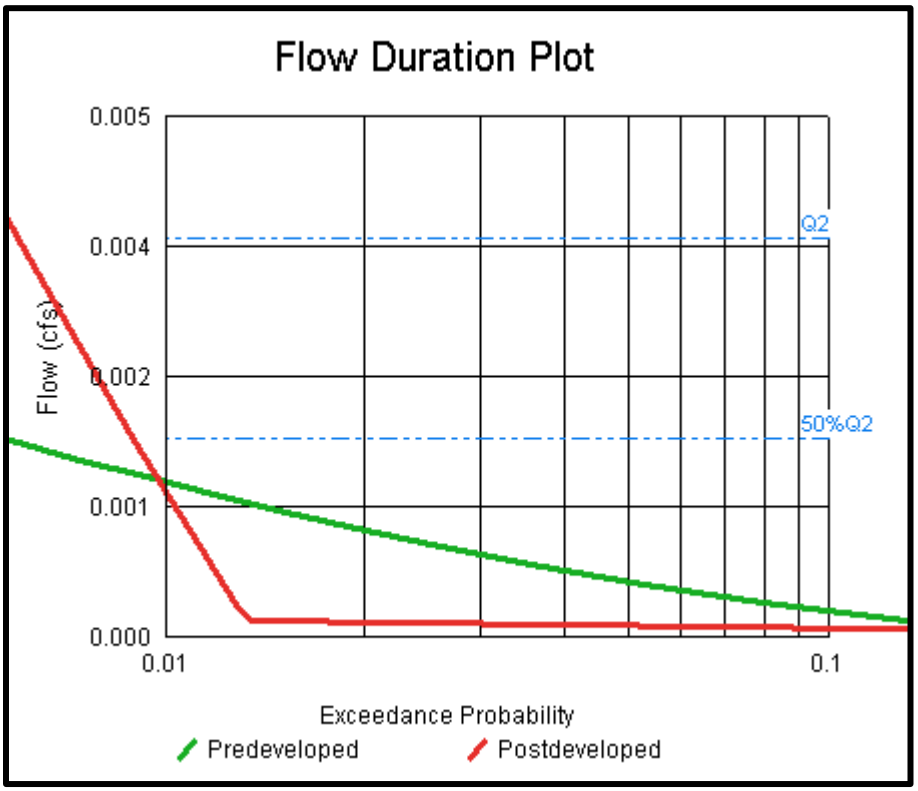
1. Right click on the Flow Duration Plot to open Duration Graph Settings
2. Select “Axis” tab
3. Edit x-axis scale (select “X”, “User Defined”)
4. Update x-axis range of values as follows:
   a. Max = 0.1
   b. Min = 0.01
   c. Ticks = 1



5. Edit y-axis scale (select “Y Primary,” “User Defined”)
6. Update y-axis range of values. Values will vary depending on size of contributing area.



7. Visually inspect to confirm that the post-developed flows are less than the pre-developed flows for the 1 to 10 percent exceedance range (red line is beneath the green line for the range plotted).



Quantitative Evaluation of the On-site Performance Standard in MGSFlood (Versions prior to 4.5.6)

For versions of MGSFlood released prior to Version 4.5.6, BMP sizes must be fully optimized for the 1 to 10 percent exceedance standard by conducting calculations outside of the model. Step-by-step procedures are provided below with an example:

1. Build and run the model
2. View report file (File>View Report)
3. Select “Full Output” to get full detailed report and click “Refresh”
4. Navigate to “Point of Compliance Flow Duration Data”
5. Determine pre-developed flows associated with 1 percent and 10 percent exceedance probability using the steps below. Note that a higher probability of exceedance corresponds to lower, more frequent, flows.

a. Identify the exceedance probability values immediately higher and immediately lower than the 1 percent exceedance. Record the exceedance probabilities and the associated flows as shown in the example below:

	Pre-development Runoff Discharge (cfs)	Exceedance Probability
Higher than 1%	1.37E-03	1.19%
Lower than 1%	1.54E-03	0.94%

6. Identify the exceedance probability values immediately higher and immediately lower than the 10 percent exceedance. Record the exceedance probabilities and the associated flows as shown in the example below:

	Pre-development Runoff Discharge (cfs)	Exceedance Probability
Higher than 10%	1.71E-04	13.15%
Lower than 10%	3.42E-04	7.97%

7. Logarithmically interpolate flows associated with the 1 and 10 percent exceedance probabilities using equation (12) and equation (13), respectively.

$$Flow_{1\%} = Flow_{lower} + \frac{Flow_{lower} - Flow_{higher}}{\log(Exceedance_{lower}) - \log(Exceedance_{higher})} \times [log(1\%) - log(Exceedance_{lower})] \quad (12)$$

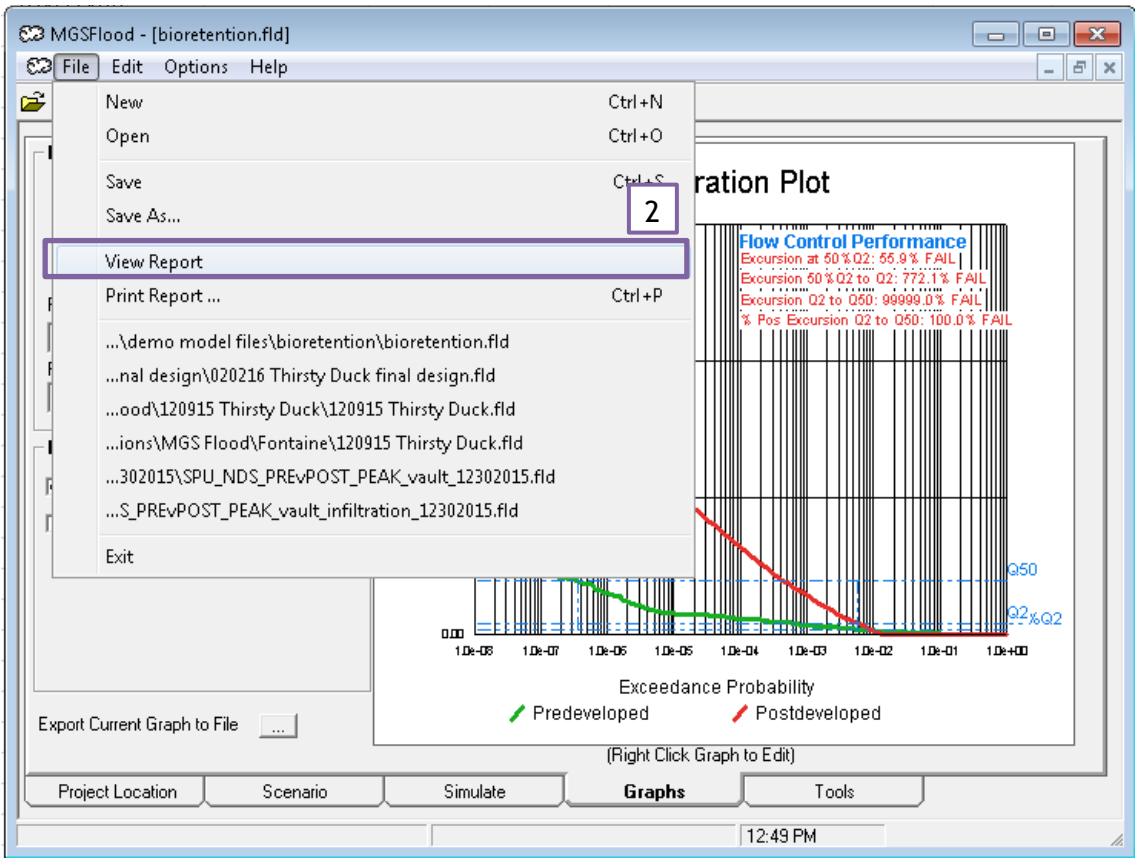
$$Flow_{10\%} = Flow_{lower} + \frac{Flow_{lower} - Flow_{higher}}{\log(Exceedance_{lower}) - \log(Exceedance_{higher})} \times [log(10\%) - log(Exceedance_{lower})] \quad (13)$$

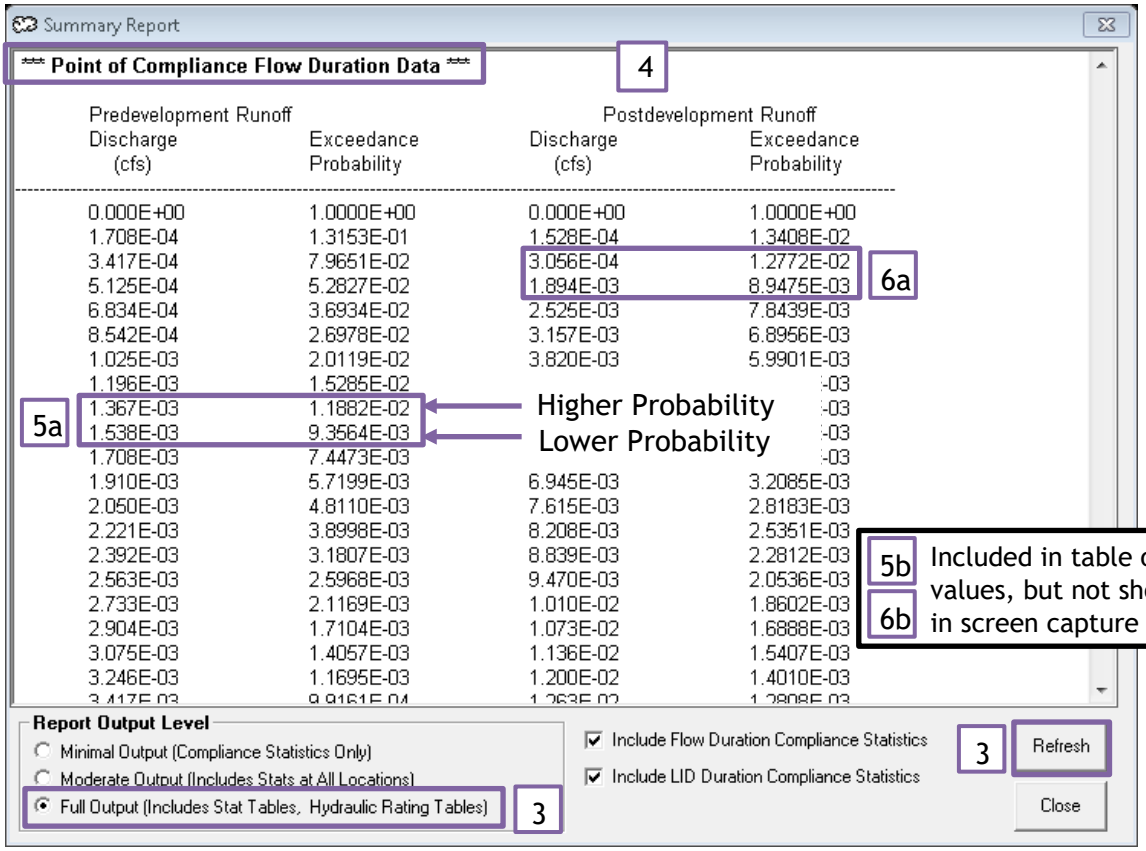
Results for this example are shown below:

	Pre-development Runoff Discharge (cfs)	Exceedance Probability
Interpolated flows at 1%	1.49E-03	1.00%
Interpolated flows at 10%	2.64E-04	10.00%

8. Determine post-developed flows associated with 1 percent and 10 percent exceedance probability. Repeat Steps 5a, 5b, and 5c using post-developed flows.

	Post-development Runoff Discharge (cfs)	Exceedance Probability
Interpolated flows at 1%	1.40E-03	1.00%
Interpolated flows at 10%	8.16E-05	10.00%


MGSFlood - [bioretention.fld]
File
Edit
Options
Help
New Ctrl+N
Open Ctrl+O
Save
Save As...
2
View Report
Print Report ... Ctrl+P
...\demo model files\bioretention\bioretention.fld
...nal design\020216 Thirsty Duck final design.fld
...ood\120915 Thirsty Duck\120915 Thirsty Duck.fld
...ions\MGS Flood\Fontaine\120915 Thirsty Duck.fld
...302015\SPU_NDS_PREvPOST_PEAK_vault_12302015.fld
...S_PREvPOST_PEAK_vault_infiltration_12302015.fld
Exit
ration Plot
Flow Control Performance
Excursion at 50%Q2: 55.9% FAIL
Excursion 50%Q2 to Q2: 772.1% FAIL
Excursion Q2 to Q50: 99999.0% FAIL
% Pos Excursion Q2 to Q50: 100.0% FAIL
Q50
Q2
%Q2
0.00
1.0e-08
1.0e-07
1.0e-06
1.0e-05
1.0e-04
1.0e-03
1.0e-02
1.0e-01
1.0e+00
Exceedance Probability
Predeveloped
Postdeveloped
(Right Click Graph to Edit)
Export Current Graph to File
...
Project Location
Scenario
Simulate
Graphs
Tools
12:49 PM


Summary Report
*** Point of Compliance Flow Duration Data ***
4
Predevelopment Runoff
Discharge (cfs)
Exceedance Probability
Postdevelopment Runoff
Discharge (cfs)
Exceedance Probability
0.000E+00 1.0000E+00 0.000E+00 1.0000E+00
1.708E-04 1.3153E-01 1.528E-04 1.3408E-02
3.417E-04 7.9651E-02 3.056E-04 1.2772E-02
5.125E-04 5.2827E-02 1.894E-03 8.9475E-03
6.834E-04 3.6934E-02 2.525E-03 7.8439E-03
8.542E-04 2.6978E-02 3.157E-03 6.8956E-03
1.025E-03 2.0119E-02 3.820E-03 5.9901E-03
1.196E-03 1.5285E-02 -03
1.367E-03 1.1882E-02 -03
1.538E-03 9.3564E-03 -03
1.708E-03 7.4473E-03 -03
1.910E-03 5.7199E-03 6.945E-03 3.2085E-03
2.050E-03 4.8110E-03 7.615E-03 2.8183E-03
2.221E-03 3.8998E-03 8.208E-03 2.5351E-03
2.392E-03 3.1807E-03 8.839E-03 2.2812E-03
2.563E-03 2.5968E-03 9.470E-03 2.0536E-03
2.733E-03 2.1169E-03 1.010E-02 1.8602E-03
2.904E-03 1.7104E-03 1.073E-02 1.6888E-03
3.075E-03 1.4057E-03 1.136E-02 1.5407E-03
3.246E-03 1.1695E-03 1.200E-02 1.4010E-03
6a
5a
Higher Probability
Lower Probability
5b
6b
Included in table of values, but not shown in screen capture
Report Output Level
Minimal Output (Compliance Statistics Only)
Moderate Output (Includes Stats at All Locations)
Full Output (Includes Stat Tables, Hydraulic Rating Tables)
3
Include Flow Duration Compliance Statistics
Include LID Duration Compliance Statistics
3
Refresh
Close

9. Compare pre-developed flows and post-developed flows at 1 and 10 percent exceedance probabilities and visually confirm, from the flow duration curves in the model, that the post-developed flows are smaller than the pre-developed flows. If post-developed flows at the 1 or 10 percent exceedance probability are higher than the pre-developed flows, or if the post developed flows appear to exceed the pre-developed flows for the 1 to 10 percent exceedance range of the duration curve (refer to procedures for visual observation, above), increase the BMP size(s), run the model, and repeat Steps 2 through 9.

See Figure F.7a for a comparison of pre-and post-developed flow duration curves for the target exceedance probability range. Figure F.7a also includes the interpolated data points described above, shown as hollow squares on the graph. If post-developed flows (shown in red) are smaller than pre-developed flows (shown in green) for the target exceedance probability range (grey hatch), the project satisfies the On-site Performance Standard.

Visual Evaluation of On-site Performance Standard in WWHM

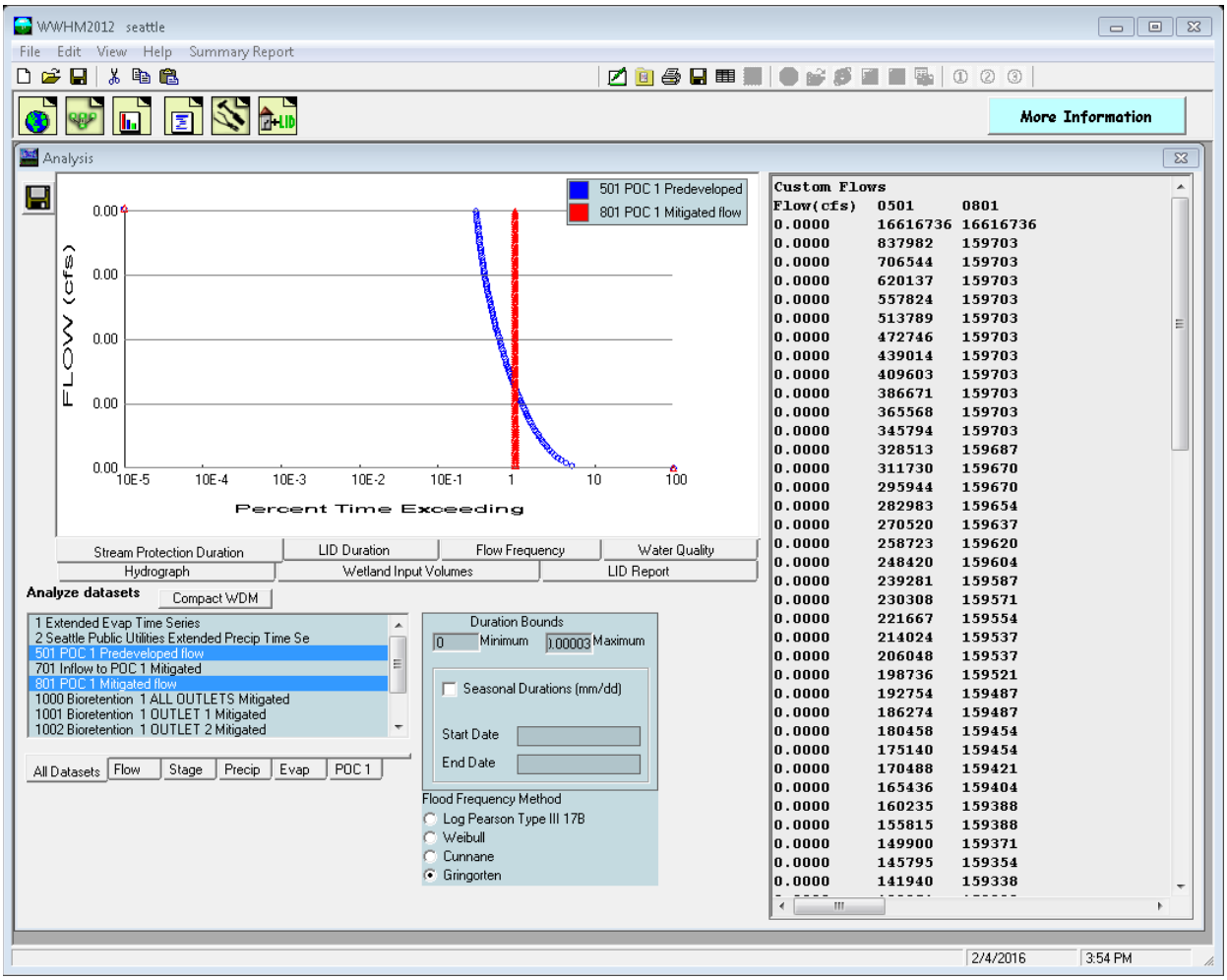
Compliance with the 1 to 10 percent exceedance standard may be estimated by visually observing the WWHM Stream Protection Duration Plot. The axes on the plot must be adjusted and manually evaluated to more clearly display the duration curve from 1 to 10 percent exceedance. Because the graphs are difficult to accurately read, the facility may need to be somewhat oversized to visually confirm compliance. Step-by-step instructions are provided below:

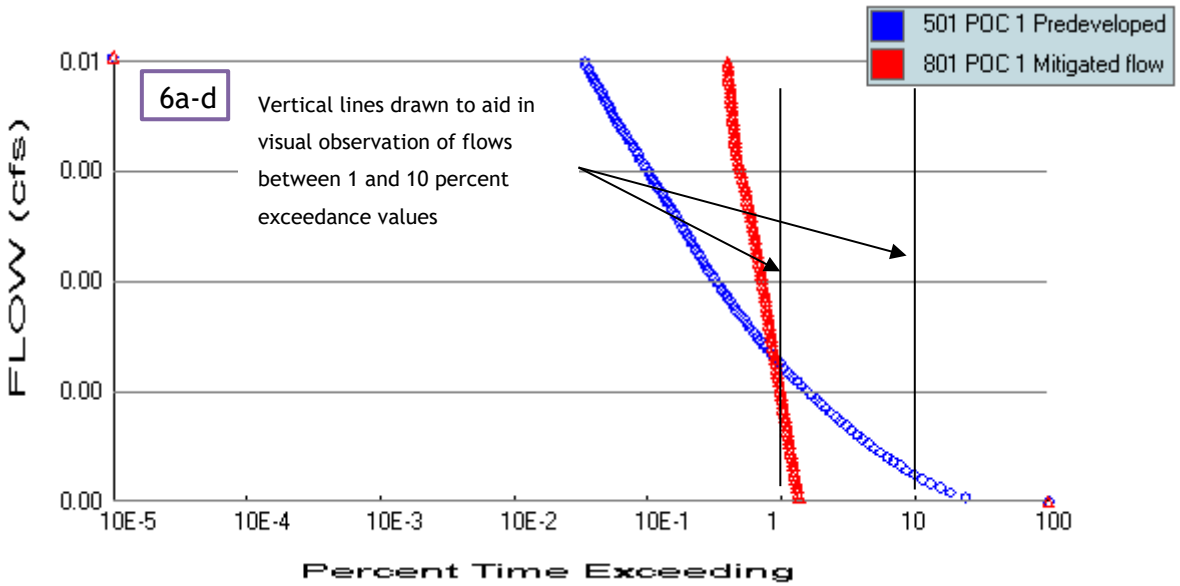
1. Build and run the model
2. View the “Stream Protection Duration” results in the Analysis tab window
3. Select the appropriate points of compliance for the pre-developed scenario and the mitigated (i.e., post-developed) scenario under “All Datasets” (hold CTRL to select more than one)

   501 POC 1 Predeveloped flow
   801 POC 1 Mitigated flow

4. Modify the “Duration Bounds” to include the 1 and 10 percent exceedance values
   a. Minimum = 0 cfs
   b. Maximum = established by trial and error until the pre-developed flows corresponding to the 1 percent exceedance are visible on the graph. To optimize the facility size(s), set the maximum value slightly above the pre-developed flow that is exceeded 1 percent of the time. This value can be approximated as the contributing area in acres times 0.00025 cfs per acre.
5. Select the “Stream Protection Duration” tab to re-calculate the results with the new duration bounds

6. Visually inspect the duration plot to confirm that the mitigated flows are smaller than the pre-developed flows for the 1 to 10 percent exceedance range. Because the plots are difficult to accurately read, the following steps are required to confirm compliance with the 1 to 10 percent exceedance standard:
   a. Take a screenshot of the flow duration curve
   b. Paste the screenshot into a word processing software, e.g., Microsoft Word
   c. Overlay two vertical lines at the 1% and 10% tick marks
   d. Confirm the mitigated flows (red line) are below the pre-developed flows (blue line) within the range of the two horizontal lines. Note: to visually ensure compliance, the facility may need to be somewhat oversized (the screenshot shown below is 10 percent larger than required when quantitatively evaluated using the procedure provided below).


WWHM2012 seattle
File Edit View Help Summary Report
More Information
Analysis
501 POC 1 Predeveloped
801 POC 1 Mitigated flow
FLOW (cfs)
Percent Time Exceeding
Stream Protection Duration
LID Duration
Flow Frequency
Water Quality
Hydrograph
Wetland Input Volumes
LID Report
Analyze datasets
Compact WDM
1 Extended Evap Time Series
2 Seattle Public Utilities Extended Precip Time Se
501 POC 1 Predeveloped flow
701 Inflow to POC 1 Mitigated
801 POC 1 Mitigated flow
1000 Bioretention 1 ALL OUTLETS Mitigated
1001 Bioretention 1 OUTLET 1 Mitigated
1002 Bioretention 1 OUTLET 2 Mitigated
All Datasets Flow Stage Precip Evap POC 1
Duration Bounds
Minimum
Maximum
Seasonal Durations (mm/dd)
Start Date
End Date
Flood Frequency Method
Log Pearson Type III 17B
Weibull
Cunnane
Gringorten
Custom Flows
Flow(cfs) 0501 0801
2/4/2016
3:54 PM


501 POC 1 Predeveloped
801 POC 1 Mitigated flow
6a-d
Vertical lines drawn to aid in visual observation of flows between 1 and 10 percent exceedance values
FLOW (cfs)
Percent Time Exceeding

Evaluation of the On-site Performance Standard in WWHM

To quantitatively evaluate and fully optimize BMP sizes for the 1 to 10 percent exceedance standard, values must be calculated and evaluated outside of the model. Step-by-step procedures are provided below with an example:

1. Build and run the model
2. View the "Stream Protection Duration" results in the Analysis tab window
3. Select the appropriate points of compliance for the pre-developed scenario and the mitigated (i.e., post-developed) scenario under "All Datasets" (hold CTRL to select more than one)

   501 POC 1 Predeveloped flow
   801 POC 1 Mitigated flow

4. Modify the "Duration Bounds" to include the 1 and 10 percent exceedance values
   a. Minimum = 0 cfs
   b. Maximum = established by trial and error until the pre-developed flows corresponding to the 1 percent exceedance are visible on the graph. To optimize the facility size(s), set the maximum value slightly above the pre-developed flow that is exceeded 1 percent of the time. This value can be approximated as the contributing area in acres times 0.00025 cfs per acre.

      0.12 acres x 0.00025 cfs/acre = 0.00003

5. Select the "Stream Protection Duration" tab to re-calculate the results with the new duration bounds
6. Determine the total number of timesteps calculated by the model. Refer to the first line in the "Custom Flows" table (i.e., number of timesteps associated with a flow of zero cfs [flow at every timestep is greater than or equal to zero cfs]).

Custom Flows		
Flow(cfs)	0501	0801
0.0000	16616736	16616736

7. Calculate the number of timesteps that correspond to the 1 percent and 10 percent exceedance values using equations (14) and (15)

$$1\ \text{Percent of Timesteps} = \text{Total number of Timesteps} \times 0.01 \quad (14)$$

$$10\ \text{Percent of Timesteps} = \text{Total number of Timesteps} \times 0.1 \quad (15)$$

   1 Percent of Timesteps = 16,616,736 x 0.01 = 166,167
   10 Percent of Timesteps = 16,616,736 x 0.1 = 1,661,674

8. Compare pre-developed flows and post-developed (i.e., mitigated) flows at the 1 percent exceedance probability. While the flow values themselves are often too small to display in the "Custom Flows" table in WWHM, the number of timesteps a given flow is exceeded can be used to evaluate facility performance relative to the pre-developed condition. For the On-site Performance standard, all flows with a probability of exceedance from 1 to 10 percent should be exceeded at the same

frequency, or less frequently than the predeveloped condition. In other words, for a given flow in the target range, the number of timesteps that flow is exceeded should be fewer in the mitigated scenario than the pre-developed scenario. To compare the pre-developed and mitigated flows:

a. Identify the flow values immediately higher and immediately lower than the target 1 percent of timesteps (as determined in Step 7) for the pre-developed scenario
b. Compare the number of timesteps these flow values are exceeded in the mitigated scenario to the pre-developed scenario.
c. If the pre-developed scenario is exceeded less frequently than the mitigated scenario, increase facility size and repeat Step 8.
d. Proceed to Step 9.

Custom Flows		
Flow(cfs)	0501	0801
0.0000	170488	159421
0.0000	165436	159404

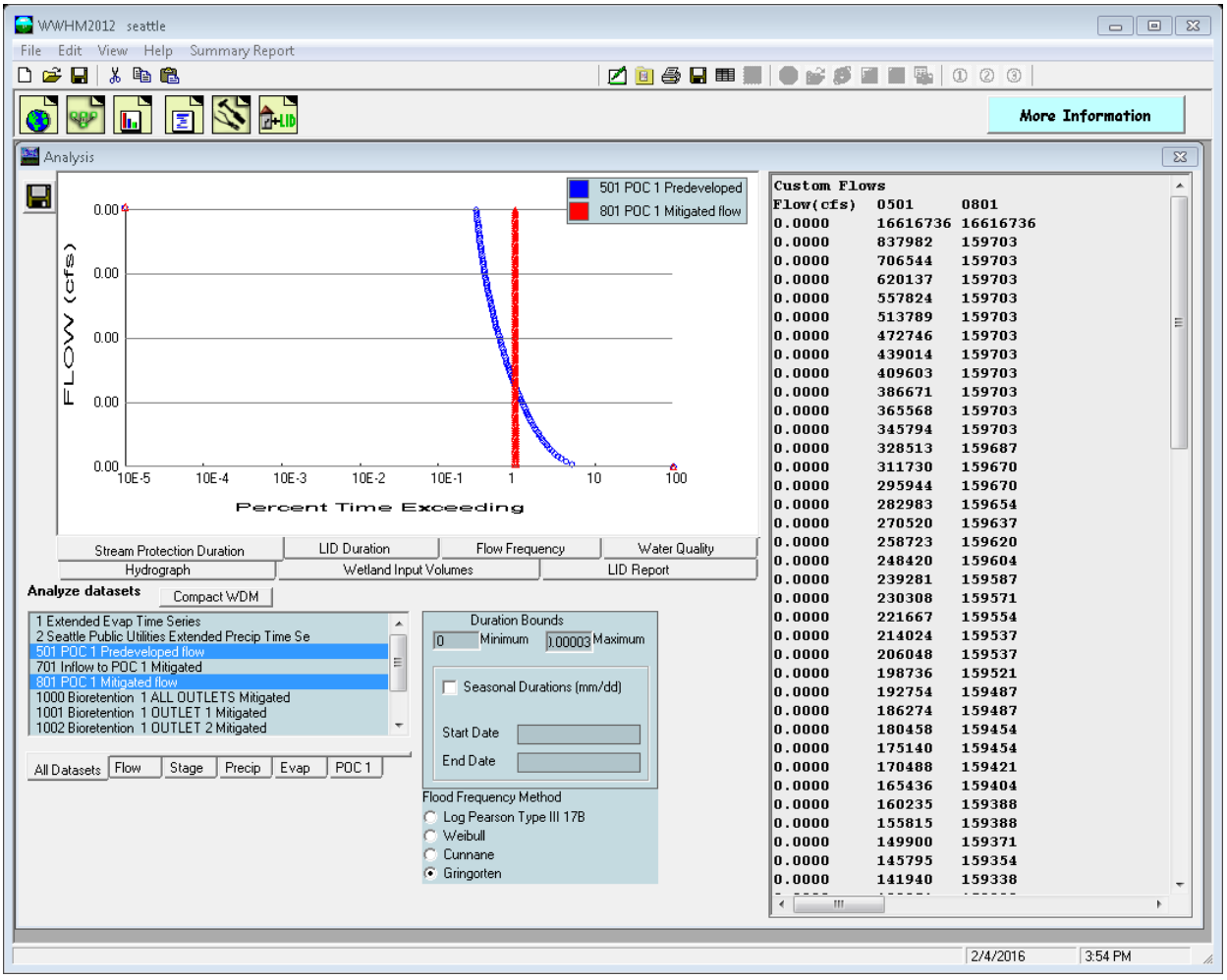
The first flow is exceeded for 170,488 timesteps (170,488/16,616,736 = 1.03%) in the pre-developed condition. The second flow is exceeded for 165,436 timesteps (165,436/16,616,736 = 0.996%) in the pre-developed condition. For these flows, the mitigated scenario is exceeded for a fewer number of timesteps than the pre-developed scenario, therefore the mitigated condition meets the On-site Performance Standard at the 1 percent exceedance value.

9. Compare pre-developed flows and post-developed (i.e., mitigated) flows at the 10 percent exceedance probability:
   a. Identify the flow values immediately higher and immediately lower than the target 10 percent of timesteps (as determined in Step 7) for the pre-developed scenario.
   b. Compare the number of timesteps these flow values are exceeded in the mitigated scenario to the pre-developed scenario.
   c. If the pre-developed scenario is exceeded less frequently than the mitigated scenario, increase facility size and repeat Step 9.
   d. Proceed to Step 10.

Custom Flows		
Flow(cfs)	0501	0801
0.0000	16616736	16616736
0.0000	837982	159703

The first flow is exceeded for 16,616,736 timesteps (16,616,736/16,616,736 = 100%) for both the pre-developed scenario and the mitigated scenario. The second flow is exceeded for 837,982 timesteps (837,982/16,616,736 = 5.04%) in the pre-developed condition and is exceeded for 21,134 timesteps in the mitigated condition. Therefore, the mitigated condition meets the on-site standard at the 10 percent exceedance value.

10. Visually confirm, from the flow duration curves in the model, that the mitigated flows are smaller than the pre-developed flows for the 1 to 10 percent exceedance range. If the post developed flows appear to exceed the pre-developed flows for the 1 to 10 percent exceedance range of the duration curve, increase the BMP size(s) and repeat Steps 8 through 10.



F-4.4.5. Water Quality Treatment BMP Design

Water Quality Design Volume

The water quality design volume for sizing wet ponds is computed as the daily runoff volume that is greater than or equal to 91 percent of all daily values in the simulation period. The continuous model develops a daily runoff time series from the pond inflow time series and scans the computed daily time series to determine the 24-hour volume that is greater than or equal to 91 percent of all daily values in the time series. This value is then used as the volume for a “Basic Wet Pond” and 1.5 times this value is used for sizing a “Large Wet Pond."

The water quality design volume is defined as the daily runoff volume at which 91 percent of the total runoff volume is produced by smaller daily volumes. The procedure can be visualized using Figure F.8 below. The bars on the graph represent daily inflow volume for the

entire simulation. The time span along the x-axis in Figure F.8 is for 105 days, but in practice, this would include the entire simulated inflow time series (e.g., 158 years).

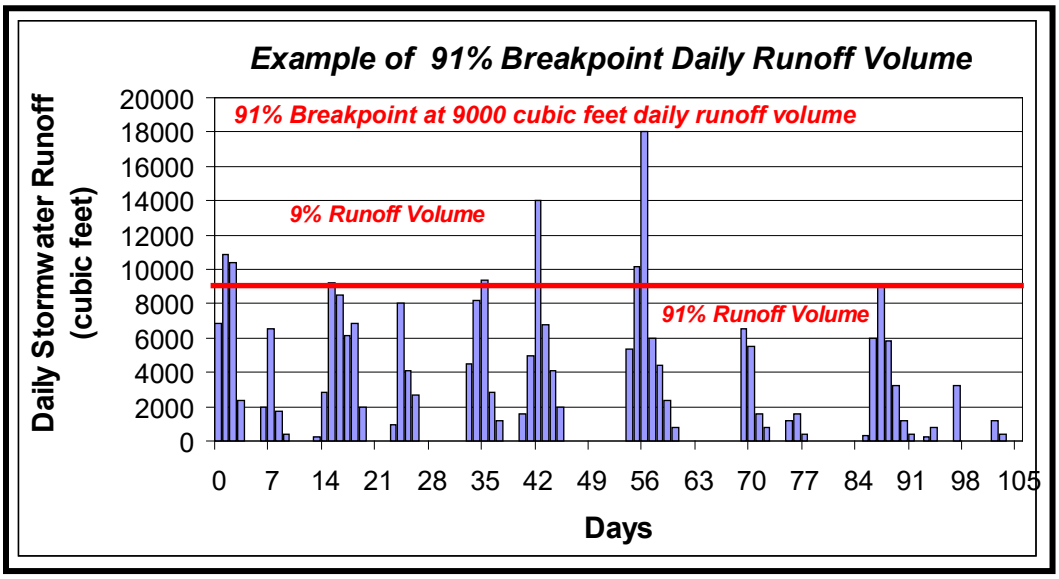


Figure F.8. Example of Portion of Time-Series of Daily Runoff Volume and Depiction of Water Quality Design Volume.

The horizontal line represents the water quality design volume. Its value is calculated such that 91 percent of the total daily runoff volume for the entire simulation resides below this line and 9 percent of the total daily runoff volume for the entire simulation exceeds the water quality design volume. Stated another way, if you total the daily runoff volumes that exceed the 9,000 cubic foot water quality design volume, they represent 9 percent of the total runoff volume.

The process for computing this water quality design volume may vary among continuous simulation models. An example of a typical approach used to compute the water quality design volume (WQDV) is summarized below.

Step #	Procedure
WQDV-1	Compute daily volume to the pond using the inflow time (convert the inflow rate to inflow volume on a midnight-to-midnight basis using a 1-hour or less time step).
WQDV-2	Compute the total inflow volume by summing all of the daily inflow volume values for the entire simulation.
WQDV-3	Compute a breakpoint value by multiplying the total runoff volume computed in Step WQDV-2 by 9 percent.
WQDV-4	Sort the daily runoff values from Step WQDV-1 in descending order (highest to lowest).
WQDV-5	Sum the sorted daily volume values until the total equals the 9 percent breakpoint. That is, the largest volume is added to the second largest, which is added to the third largest, etc., until the total equals the 9 percent breakpoint.
WQDV-6	The last daily value added to match the 9 percent breakpoint is defined as the water quality design volume.

Water Quality Treatment Design Flow Rate

The flow rate used to design flow-rate-dependent treatment facilities depends on whether or not the treatment is located upstream of a stormwater detention facility and whether it is an on-line or off-line facility (Figure F.9).

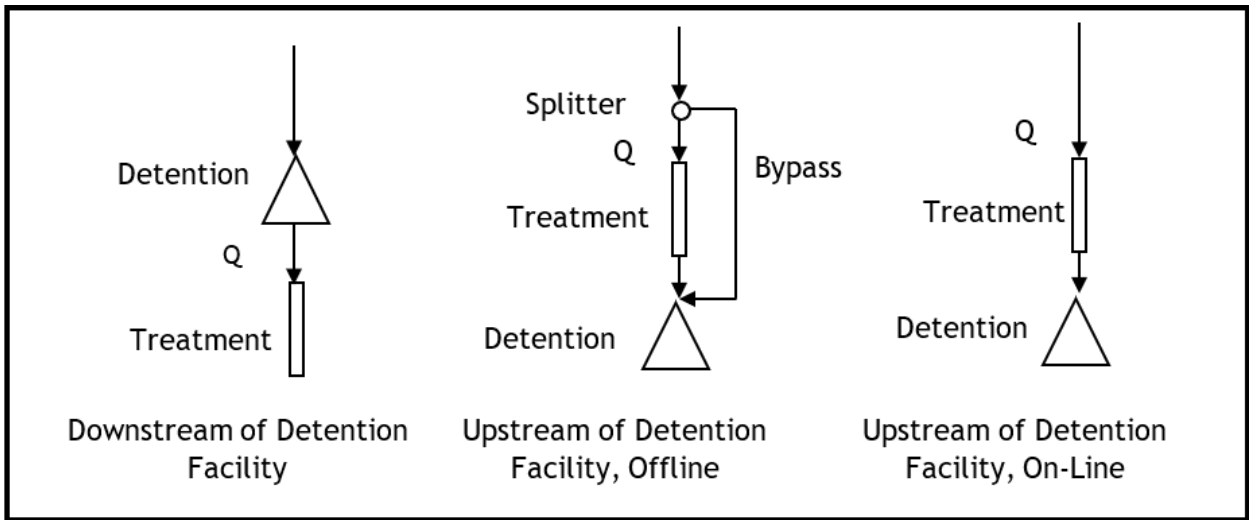


Figure F.9. Water Quality Treatment and Detention Definition.

Downstream of Detention Facilities: If the treatment facility is located downstream of a stormwater detention facility, then the water quality design flow rate is the release rate from the detention facility that has a 50 percent annual probability of occurring in any given year (2-year recurrence interval).

Upstream of Detention Facilities, Off-line: Off-line water quality treatment located upstream of the detention facility includes a high-flow bypass that routes the incremental flow in excess of the water quality design rate around the treatment facility. It is assumed that flows from the bypass enter the system downstream of the treatment facility but upstream of the detention facility. The continuous model determines the water quality treatment design flow rate as the rate corresponding to the runoff volume that is greater than or equal to 91 percent of the 15-minute runoff volume entering the treatment facility (Figure F.10). If runoff is computed using the City of Seattle Design Time Series with a time step of 15 minutes or less, then no time step adjustment factors are needed for the water quality design discharge.

Upstream of Detention Facilities, On-line: On-line water quality treatment does not include a high-flow bypass for flows in excess of the water quality design flow rate and all runoff is routed through the facility. The continuous model determines the water quality treatment design flow rate as the rate corresponding to the runoff volume that is greater than or equal to 91 percent of the 15minute runoff volume entering the treatment facility. However, those flows that exceed the water quality design flow are not counted as treated in the calculation (Figure F.11). Therefore, the design flow rate for on-line facilities is higher than for off-line facilities. If runoff is computed using the City of Seattle Design Time Series with a time step of 15 minutes or less, then no time step adjustment factors are need for the water quality design discharge.

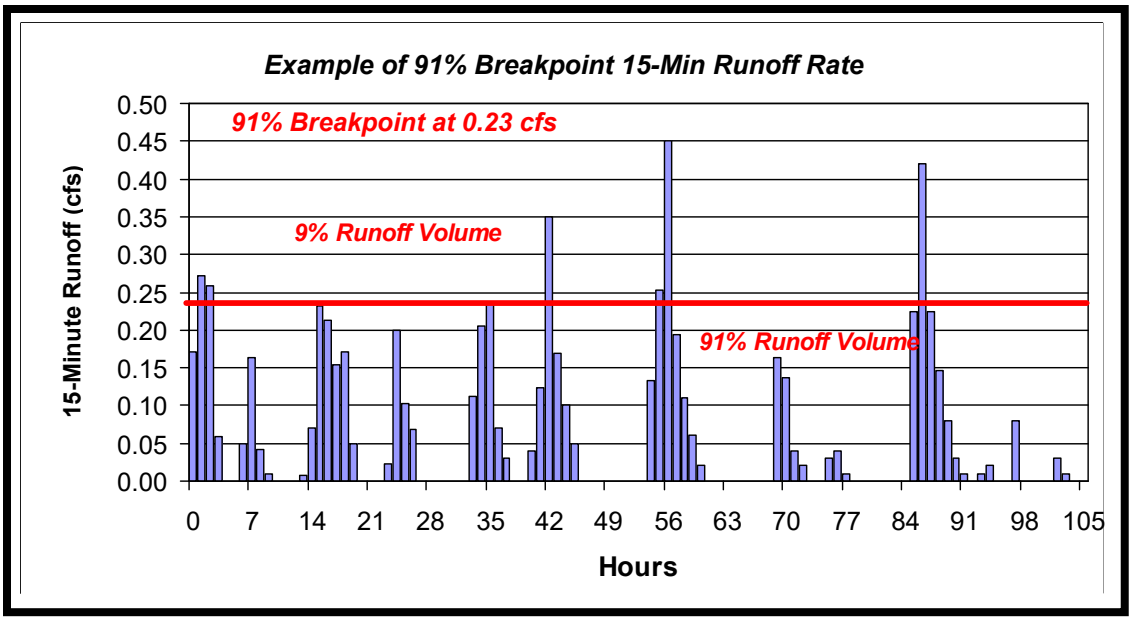


Figure F.10. Off-line Water Quality Treatment Discharge Example.

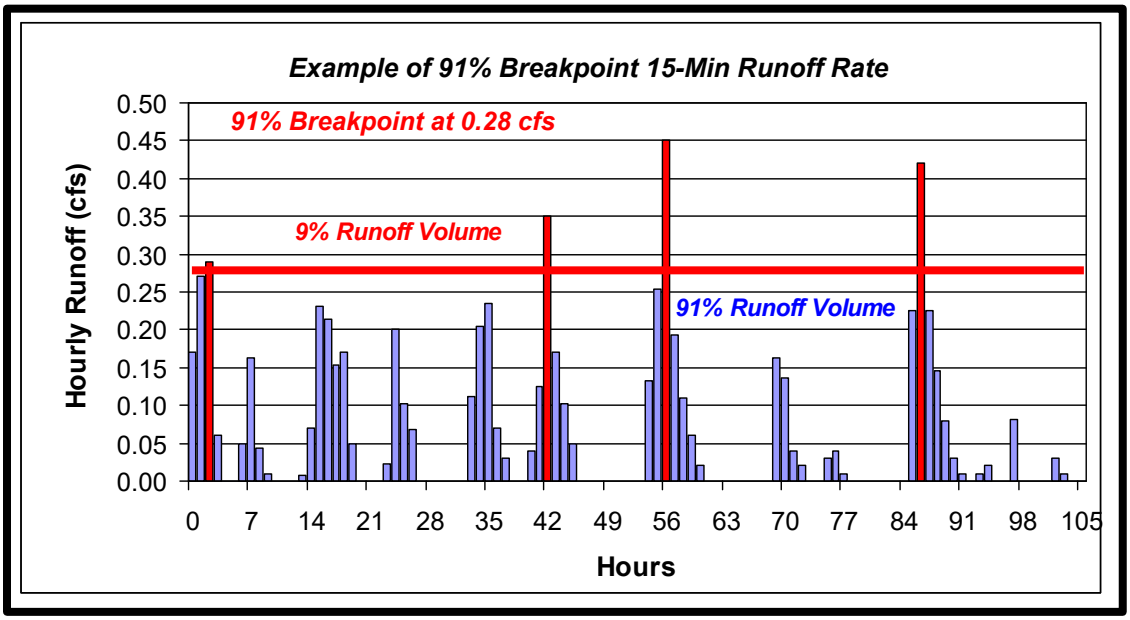


Figure F.11. On-Line Water Quality Treatment Discharge Example.

Infiltration Facilities Providing Water Quality Treatment: Infiltration facilities designed for water quality treatment must infiltrate 91 percent of the total runoff volume through soil meeting the treatment soils requirements outlined in *Volume 3, Section 4.5.2*. The procedure is the same as for designing infiltration for flow control, except that the target is to infiltrate 91 percent of the runoff file without overflow (refer to *Volume 3, Section 4.5.1*). In addition, to prevent the onset of anaerobic conditions, an infiltration facility designed for water quality treatment purposes must be designed to drain the water quality design volume within 48 hours. Drain time can be calculated by using a horizontal projection of the infiltration basin mid-depth dimensions and the design infiltration rate.

Stormwater Conveyance

Storms that produce the highest rates of runoff from developed areas are typically shorter in duration and are characterized by brief periods of high intensity rainfall. A 5minute time step (refer to Table F.12) is required to adequately simulate the runoff peak discharge and hydrograph shape resulting from these high-intensity storms. A 15minute time step may be used if the time of concentration computed is 30 minutes or more. Follow the modeling steps outlined in *Subsection F-4.4.3 Steps for Hydrologic Design Using Continuous Models*, and for conveyance-specific designs also perform the following:

Step #	Procedure
SC-1	Identify downstream hydraulic controls, such as outfalls (refer to Outfalls in *Section F-3.6*), known flooding locations, receiving pipe hydraulic grade line (HGL), pump station, regulator station, weirs, or orifices. Determine if backwater calculations or a dynamic hydraulic routing model are required. Refer to 2021 King County Surface Water Design Manual guidelines, Section 4.2.1 for backwater analysis methods.
SC-2	Analyze flood frequencies and select the flows representing the level of conveyance service and/or flood protection required.
SC-3	Utilize the peak flows to size or assess the capacity of pipe systems, culverts, channels, spillways and overflow structures.
SC-4	Perform a capacity analysis to verify that there is sufficient capacity in the public drainage system or the public combined sewer system. Refer to *Volume 3, Section 4.3* and SMC, Section 22.805.020.H for specific requirements.
SC-5	Size the pipe to convey the selected peak flows.

Using Continuous Simulation Hydrographs with Dynamic Routing Models

Continuous hydrologic models based on the HSPF program utilize hydrologic (also known as lumped) routing routines to determine the time and magnitude of flow of a watercourse. Because of this, these models cannot simulate complex hydraulics such as where the flow reverses direction or where a downstream channel or pipe influences another upstream in a time dependent way.

For simulation of complex hydraulics in pipe systems or tidally influenced boundaries, a dynamic routing hydraulic program, such as the SWMM Extran routine, may be necessary to accurately determine the discharge rate and the water surface elevation or hydraulic grade line (HGL). Flows simulated using the continuous hydrologic model may be exported and used as input to the dynamic routing hydraulic model.

Dynamic routing models solve the full unsteady flow equations using numeric approximation methods. These methods typically require computational time steps that are relatively short to maintain numerical stability, and it may not be practical to attempt routing of multi-year sequences of runoff produced by the continuous hydrologic model. To reduce the simulation time, flow hydrographs from specific storms of interest computed using the continuous flow model may be used rather than the entire simulated flow time series.

To utilize a dynamic routing model to route hydrographs computed with the continuous hydrologic model, the procedure described in *Subsection F-4.4.3 Steps for Hydrologic Design*

Using Continuous Models should be followed to create the runoff time series. The following additional steps should be followed to identify storms of a particular recurrence interval, export them from the continuous model, and import them into SWMM (or other dynamic routing model):

Step #	Procedure
DR-1	Delineate the watershed with subbasin outlets (runoff collection points) corresponding to the main inflows to the pipe system.
DR-2	Run the continuous hydrologic model for the full period of record. For most design applications, the City of Seattle Design Time Series should be used. The routing effects of the pipe or other conveyance system to be analyzed should not be included in the continuous hydrologic model.
DR-3	Use flood peak discharge statistics computed by the continuous model to identify when floods of various recurrence intervals occur in the simulated time series. Export hydrographs with peak discharge rates corresponding to desired recurrence intervals in a format that can be read by the hydraulic model.

For example, Table F.13 shows flood peak discharge-frequency results for a subbasin. If hydrographs corresponding to the 100-year, 25-year, and 10-year recurrence intervals were needed for conveyance design purposes, then simulated hydrographs with recurrence intervals closest to those required would be exported from the continuous hydrologic model as indicated in the right column of the table. The hydrograph duration would include a period antecedent to the flood peak (typically several days to a week) and several days following the flood peak.

F-5. Single-Event Rainfall–Runoff Methods

Single-event models simulate rainfall-runoff processes for a single-storm, typically 2 hours to 72 hours in length and usually of a specified exceedance probability. Because the primary interest is the flood hydrograph, calculation of evapotranspiration, soil moisture changes between storms, and base flow processes are typically not needed. This is in contrast to continuous rainfall-runoff models (*Section F-4*) where multi-decade precipitation and evaporation time series are used as input to produce a corresponding multi-decade time series of runoff.

Precipitation input to single-event models can include either historical data recorded from a rain gauge or a synthetic design storm hyetograph. This section describes the use of both types of precipitation input.

F-5.1. Design Storm Hyetographs

Design storm hyetographs were developed using noteworthy storms that were recorded by the City of Seattle gauging network. NOAA Atlas 2 precipitation-frequency (isopluvial) maps published in the early 1970s have historically been used in hydrologic analysis and design. These maps are replaced in this manual by precipitation magnitude-frequency estimates more specific to the City of Seattle. These estimates are based on a regional analysis using data from the SPU Rain Gauge Network and gauges from the NOAA national cooperative gaging network in western Washington. The most recent analysis included data from 1940 to 2003. Attachment 2 provides the precipitation data based on the SPU Rain Gauge Network.

Table F.13. Example Simulated Peak Discharge Frequency Table and Hydrographs Exported to SWMM or Other Hydraulic Model for Desired Recurrence Intervals.

Flood Peak Recurrence Interval (years)	Date of Peak[a]	Peak Discharge Rate (cfs)	Desired Recurrence Interval for Analysis
282	06/10/2010	7.62	
101	**11/04/1998**	**6.11**	**100-year**
62	06/29/1952	6.06	
44	02/03/2062	5.38	
35	07/18/2043	4.71	
28	10/06/1981	4.64	
24	**03/03/1950**	**4.54**	**25-year**
21	01/09/1990	4.40	
18	09/30/2011	4.40	
17	11/24/1990	4.27	
15	08/24/2077	4.25	
14	05/03/2002	4.25	
13	10/27/2054	4.15	
12	10/26/1986	4.03	
11	09/01/2061	3.93	
10	**01/20/2013**	**3.92**	**10-year**
9.6	08/23/1968	3.92	
9.0	01/14/2040	3.76	

[a] Simulation was performed using SPU Design Time Series, which is 158 years in length, and has dates spanning 10/1/1939 through 9/30/2097. (Note: This table may be revised in a future version of the 2026 Seattle Stormwater Manual.)

Statistical analyses were conducted for the storm characteristics and dimensionless design storms were developed for short, intermediate, and long duration storm events (Schaefer 2004). The short, intermediate, and long duration design storms can be scaled to any site-specific recurrence interval using precipitation magnitudes at the 2-hour, 6-hour, and 24-hour duration.

Table F.14 summarizes the applicability of the four City design storms. If multiple storm types are listed for a particular application, then all applicable storm types should be considered candidates and used in the hydrologic model. The candidate storm that produces the most severe hydrologic loading and most conservative design is then adopted as the design storm. Note that this table does not override the modeling requirements for specific facilities outlined in *Volume 3*, *Chapters 4* and *5*, or Table F.1. Table F.14 is for general guidance and applicability only.

Table F.14. Applicability of Storm Types for Hydrologic Design Applications.

Storm Type	Description	Applicability	Total Storm Duration	Precipitation from SPU Rain Gauges
Short-duration	• Typically occurs in late spring through early fall • High intensity • Limited volume	• Conveyance (storm drains, ditches, culverts, and other hydraulic structures) • Flow Control	3 hours	2 hours
Intermediate Duration	• Typically occurs in fall through early winter • Low intensity • High volume	• Conveyance (storm drains, ditches, culverts, and other hydraulic structures) • Flow Control	18 hours	6 hours
Seattle 24-hour	NA	Volume-based BMPs	24 hours	24 hours
Long-duration – Front and Back Loaded	• Typically occurs in late fall through early spring • Low intensity • High volume	Flow Control	64 hours	24 hours

NA – not applicable

F-5.1.1. Short-Duration Storm (3-hour)

Short-duration design storms are used for design situations where peak discharge is of primary interest. The storm temporal pattern is shown in Figure F.12 as a dimensionless unit hyetograph. Tabular values for this hyetograph are listed in Attachment 1. The total storm precipitation is 1.06 times the 2-hour precipitation amount.

Use the following steps to utilize the short-duration storm in hydrologic analyses.

Step #	Procedure
SD-1	Obtain the 2-hour precipitation amount for the recurrence interval of interest (refer to Table 2 in Attachment 2). Note that the 2-hour precipitation values for short-duration storms do not vary across the City.
SD-2	Multiply the 5-minute incremental ordinates of the dimensionless short-duration design storm (Attachment 1, Table 1) by the 2-hour value from Step SD-1. Note that the resulting storm has a duration of 3 hours and the total storm amount will be 1.06 times the volume of the 2-hour precipitation (refer to the SDCI SPU Stormwater webpage for modeling resources).
SD-3	Input the resulting storm hyetograph into the hydrologic model. The resultant incremental precipitation ordinates have units of inches. To obtain the corresponding intensities (in/hr), multiply the precipitation increments by 12.

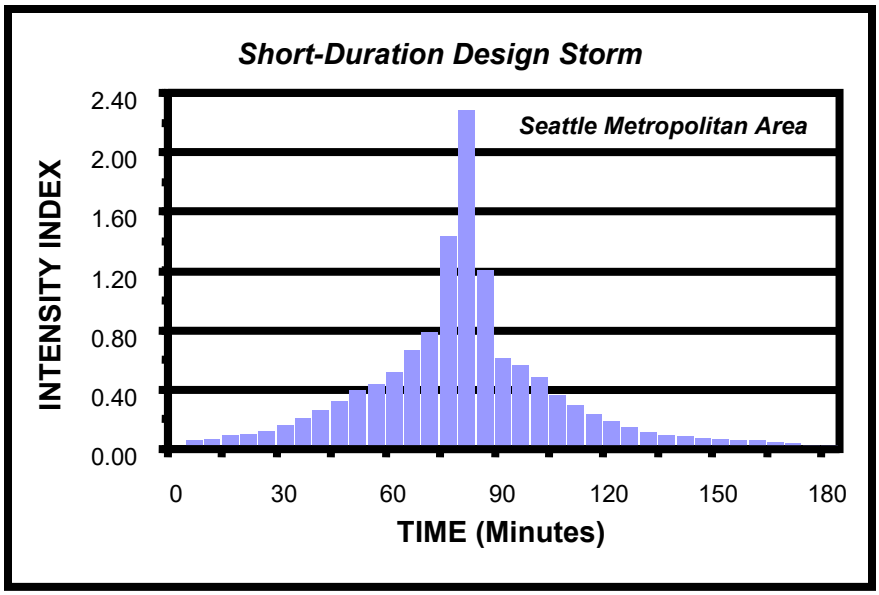


Figure F.12. Dimensionless Short-duration (3-hour) Design Storm, Seattle Metropolitan Area.

F-5.1.2. Intermediate-Duration Storm (18 hour)

Intermediate-duration design storms are used in design applications where both peak discharge and runoff volume are important considerations and there is a need for a runoff hydrograph. The storm temporal pattern is shown in Figure F.13 as a dimensionless unit hyetograph. Tabular values for this hyetograph are listed in Attachment 1. The total storm precipitation is 1.51 times the 6hour precipitation amount.

The following steps describe how to utilize the intermediate-duration storm in hydrologic analyses.

Step #	Procedure
ID-1	Obtain the 6-hour precipitation amount for the recurrence interval of interest for the watershed (refer to Attachment 2 for data from the SPU Gauge(s) of interest).
ID-2	Multiply the 10-minute incremental ordinates of the dimensionless intermediate-duration and long-duration design storms (Attachment 1, Tables 2 and 4) by the 6-hour value from Step ID-1. Note that the resulting storm has a duration of 18 hours and the total storm amount will be 1.51 times the volume of the 6-hour precipitation (refer to the SDCI SPU Stormwater webpage for modeling resources).
ID-3	Input the resulting storm hyetograph into the hydrologic model. The resultant incremental precipitation ordinates have units of inches. To obtain the corresponding intensities (in/hr), multiply the precipitation increments by 6.

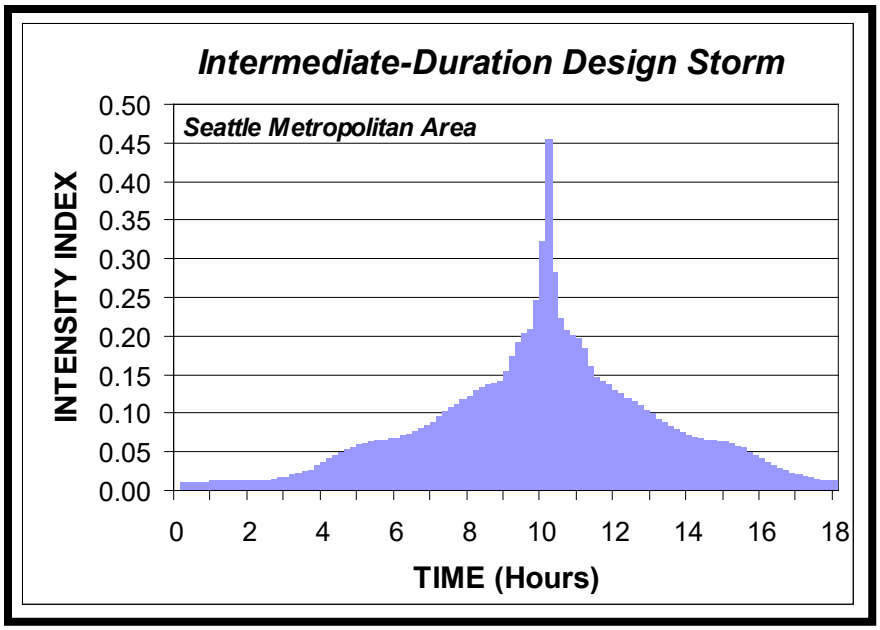


Figure F.13. Dimensionless Intermediate-duration (18-hour) Design Storm, Seattle Metropolitan Area.

F-5.1.3. 24-Hour Dimensionless Design Storm

Some specific volume-based stormwater facilities require or allow the use of a 24-hour design storm. To meet this need, the 24-hour dimensionless design storm was developed based on the maximum 24-hour period of precipitation within the long-duration design storm. It should be noted that the 24-hour dimensionless design storm has the same temporal shape and ordinates as the period of maximum 24-hour precipitation within the front-loaded and back-loaded long-duration dimensionless design storms. The City of Seattle 24-hour design storm is shown in Figure F.14.

Use the following steps to utilize the 24-hour design storm in hydrologic analyses:

Step #	Procedure
DD-1	Obtain the 24-hour precipitation amount for the recurrence interval of interest for the watershed (refer to Attachment 2 for data from the SPU Gauge(s) of interest).
DD-2	Multiply the 10-minute incremental ordinates of the dimensionless 24-hour duration design storm (Attachment 1, Table 5) by the 24-hour value from Step DD-1 (refer to the SDCI SPU Stormwater webpage for modeling resources).
DD-3	Input the resulting storm hyetograph into the hydrologic model. The resultant incremental precipitation ordinates have units of inches. To obtain the corresponding intensities (in/hr), multiply the precipitation increments by 6.

F-5.1.4. Long-Duration Storm (64 hour)

Long-duration design storms are primarily used in design of stormwater detention facilities and other projects where runoff volume is a primary consideration. Long-duration storms occur primarily in the late fall into early spring.

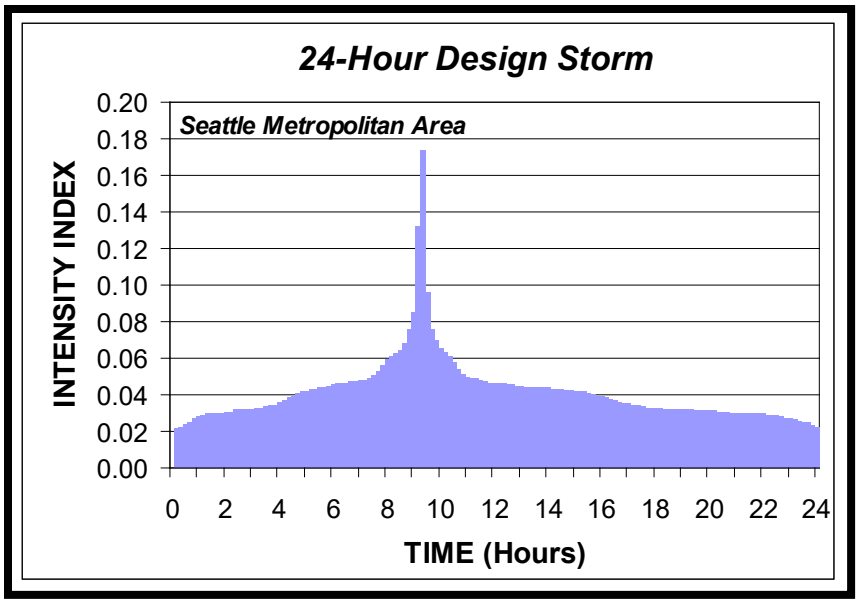


Figure F.14. Dimensionless 24-Hour Design Storm for Seattle Metropolitan Area.

Two long-duration dimensionless design storms are provided: a front-loaded design storm with the highest intensities at the beginning of the storm, and a back-loaded storm with the higher intensities nearer the end of the storm period. Characteristics of the front-loaded design storm have been observed more frequently, and this storm would be expected to produce more "typical" runoff conditions. The back-loaded storm occurs less often and is typically a more conservative event for drainage control facility design.

The long-duration storm hyetographs are 64 hours in duration. The storm temporal patterns for the front loaded and back loaded storms are shown in Figures F.15 and F.16, respectively. Tabular values for these storms are listed in Attachment 1. The total storm precipitation is 1.29 times the 24hour precipitation amount for both the front and back loaded long-duration storm.

Use the following steps to utilize the long-duration storm in hydrologic analyses.

Step #	Procedure
LD-1	Obtain the 24-hour precipitation amount for the recurrence interval of interest for the watershed (refer to Attachment 2 for data from the SPU Gauge(s) of interest).
LD-2	Multiply the 10-minute incremental ordinates of the dimensionless long-duration design storm (Attachment 1, Table 3 or 4) by the 24-hour value from Step LD-1. Note that the resulting storm has a duration of 64 hours and the total storm amount will be 1.29 times the volume of the 6-hour precipitation (refer to the SDCI SPU Stormwater webpage for modeling resources).
LD-3	Input the resulting storm hyetograph into the hydrologic model. The resultant incremental precipitation ordinates have units of inches. To obtain the corresponding intensities (in/hr), multiply the precipitation increments by 6.

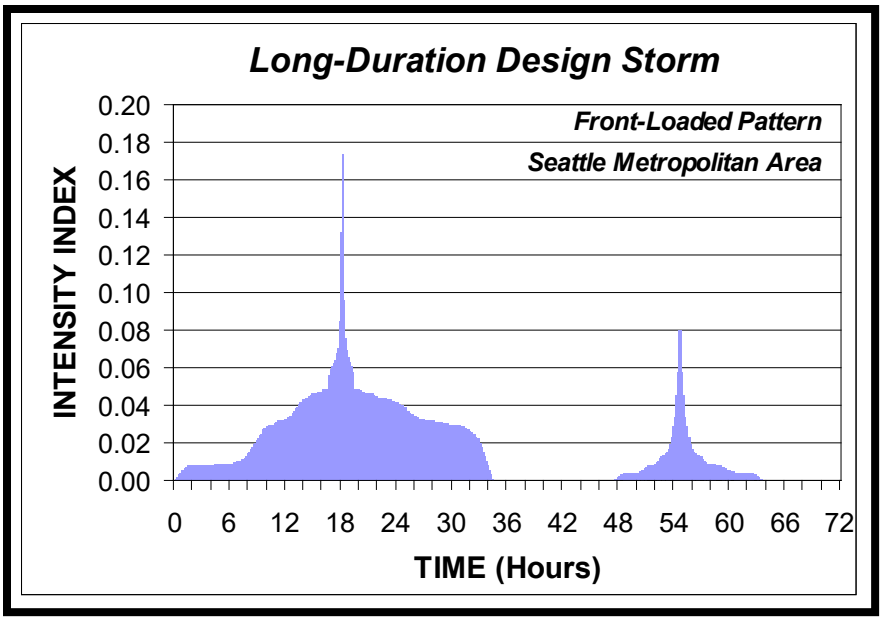


Figure F.15. Dimensionless Front-loaded Long-duration (64-hour) Design Storm for the Seattle Metropolitan Area.

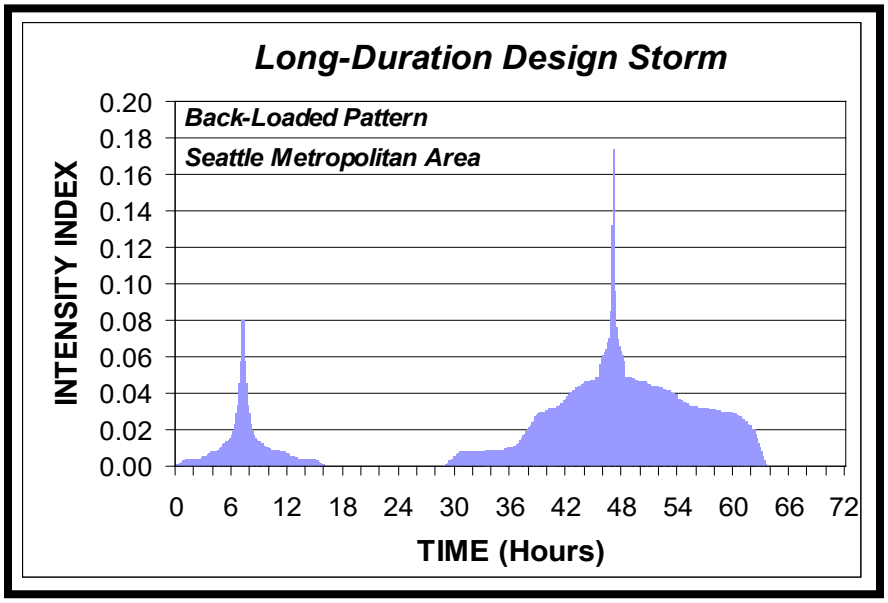


Figure F.16. Dimensionless Back-loaded Long-duration (64-hour) Design Storm for the Seattle Metropolitan Area.

F-5.2. Curve Number Equation and Infiltration Parameters

The Curve Number method may be used when computing runoff using the Long-duration storms (24 hours or 66 hours in length). The NRCS developed relationships between land use, soil type, vegetation cover, interception, infiltration, surface storage, and runoff. These relationships have been characterized by a single runoff coefficient called a "curve number" (CN). The National Engineering Handbook — Part 630: Hydrology (NRCS 1997) contains a detailed description of the development and use of the curve number method.

The CN is related to the runoff potential of a watershed according to equations (16) and (17).

$$Q_d = \frac{(P - 0.2\,SMD_{MAX})^2}{(P + 0.8\,SMD_{MAX})} \tag{16}$$

$$SMD_{MAX} = \frac{1000}{CN} - 10 \tag{17}$$

Where: Q_d = runoff depth (inches)
P = precipitation depth (inches)
SMD_{MAX} = maximum soil moisture deficit (inches)
CN = Curve Number for the soil (Table F.15)

The CN is a combination of a hydrologic soil group and land cover with higher CNs resulting in higher runoff. CN values for combinations of land cover and hydrologic soil group are listed in Table F.15. Refer to Table F.3 in General Modeling Guidance (*Section F-3*) for information on soil groups in King County.

Table F.15. Post-Development Runoff Curve Numbers for Selected Agricultural, Suburban, and Urban Areas.

Land Cover Type	Hydrologic Condition	Curve Numbers by Hydrologic Soil Group: A	Curve Numbers by Hydrologic Soil Group: B	Curve Numbers by Hydrologic Soil Group: C	Curve Numbers by Hydrologic Soil Group: D
Pasture, grassland, or range-continuous forage for grazing	Fair Condition (ground cover 50% to 75% and not heavily grazed)	49	69	79	84
	Good Condition (ground cover >75% and lightly or only occasionally grazed)	39	61	74	80
Woods	Fair Condition (woods are grazed but not burned, and some forest litter covers the soil)	36	60	73	79

Table F.15 (continued). Post-Development Runoff Curve Numbers for Selected Agricultural, Suburban, and Urban Areas.

Land Cover Type	Hydrologic Condition	Curve Numbers by Hydrologic Soil Group: A	Curve Numbers by Hydrologic Soil Group: B	Curve Numbers by Hydrologic Soil Group: C	Curve Numbers by Hydrologic Soil Group: D
Woods	Good Condition (woods are protected from grazing, and litter and brush adequately cover the soil)	30	55	70	77
Open space (Lawns, parks, golf courses, cemeteries, landscaping, etc.)	Fair Condition (grass cover on 50 to 75% of the area)	77	85	90	92
	Good Condition (grass cover on greater than 75% of the area)	68	80	86	90
Impervious areas	Open receiving waters (lakes, wetlands, ponds, etc.)	100	100	100	100
	Paved surfaces (roads, roofs, driveways, etc.)	98	98	98	98
	Gravel roads and parking lots	76	85	89	91
	Dirt roads and parking lots	72	82	87	89
Permeable pavement	Porous asphalt, porous concrete, or grid/lattice systems (without underlying perforated drain pipes to collect stormwater)	77	85	90	92
	Paving blocks (without underlying perforated drain pipes to collect stormwater)	87	91	94	96
	All permeable pavement types (with underlying perforated drain pipes to collect stormwater)	98	98	98	98

F-5.3. Time of Concentration Estimation

The time of concentration for the various surfaces and conveyances should be computed using the following methods, which are based on Chapter 3 of TR-55 (NRCS 1986).

Travel time (T_t) is the time it takes water to travel from one location to another in a watershed. T_t is a component of time of concentration (T_c), which is the time for runoff to travel from the hydraulically most distant point of the watershed. T_c is computed by summing all the travel times for consecutive components of the drainage conveyance system.

Water is assumed to move through a watershed as sheet flow, shallow concentrated flow, open channel flow, or some combination of these. The type that occurs is best determined by field inspection. The time of concentration (T_c) is the sum of T_t values for the various consecutive flow segments.

$$T_c = T_1+T_2+T_3+\ldots T_n \quad (18)$$

Where:
- T_c = time of concentration (minutes)
- $T_{1,2,3,n}$ = time for consecutive flow path segments with different land cover categories or flow path slope

Travel time for each segment is computed using the following equation:

$$T_t = \frac{L}{60V} \quad (19)$$

Where:
- T_t = travel time (minutes)
- L = length of flow across a given segment (feet)
- V = average velocity across the land segment (ft/sec)

Sheet Flow: Sheet flow is flow over plane surfaces. Sheet flow travel time is computed using equation (20). This equation is applicable for relatively impervious areas with shallow flow depths up to about 0.1 foot and for travel lengths up to 300 feet. Modified Manning's effective roughness coefficients (n_s) are summarized in Table F.16. These n_s values are applicable for shallow flow depths up to about 0.1 foot and for travel lengths up to 300 feet.

$$T_t = 0.42 * (n_s * L)^{0.8} / ((P_{24})^{0.5} * (S_o)^{0.4}) \quad (20)$$

Where:
- T_t = travel time (minutes)
- n_s = sheet flow Manning's effective roughness coefficient from Table F.16
- L = overland flow length (feet)
- P_{24} = 2-year, 24-hour rainfall (inches)
- S_o = slope of hydraulic grade line or land slope (feet/feet)

Shallow Concentrated Flow: After a maximum of 300 feet, sheet flow is assumed to become shallow concentrated flow. The average velocity for this flow can be calculated using the ks values from Table F.16 in which average velocity is a function of watercourse slope and type of channel. After computing the average velocity using the velocity equation (21), the travel time (T_t) for the shallow concentrated flow segment can be computed using the travel time equation (19).

Velocity Equation: A commonly used method of computing average velocity of flow, once it has measurable depth, is the following equation:

$$V = k_s \sqrt{S_o} \tag{21}$$

Where: k_s = velocity factor (Table F.16)
S_0 = slope of flow path (feet/feet)

"k" values in Table F.16 have been computed for various land covers and channel characteristics with assumptions made for hydraulic radius using the following rearrangement of Manning's equation:

$$k = (1.49\ (R)\ 0.667)/n \tag{22}$$

Where: R = assumed hydraulic radius
n = Manning's roughness coefficient for open channel flow, from Tables F.16 or F.17

Open Channel Flow: Open channels are assumed to begin where flow enters ditches or pipes, where surveyed cross section information has been obtained, where channels are visible on aerial photographs, or where lines indicating streams appear (in blue) on USGS quadrangle sheets. The k_c values from Table F.16 used in velocity equation (21) or water surface profile information can be used to estimate average flow velocity. Average flow velocity is usually determined for bank-full conditions. The travel time (T_t) for the channel segment can be computed using travel time equation (19).

Lakes or Wetlands: Sometimes it is necessary to estimate the velocity of flow through a lake or wetland at the outlet of a watershed. This travel time is normally very small and can be assumed as zero. Where significant attenuation may occur due to storage effects, the flows should be routed using the "level-pool routing" technique described in the *Level-Pool Routing Method* section.

Limitations: The following limitations apply in estimating travel time (T_t):

- Manning's kinematic solution should not be used for sheet flow longer than 300 feet.
- In watersheds with drainage systems, carefully identify the appropriate hydraulic flow path to estimate T_c. Drainage systems generally handle only a small portion of a large event. The rest of the peak flow travels by streets, lawns, and other surfaces, to the outlet. Consult a standard hydraulics textbook (e.g., Gray 1961; Linsley et al. 1975; Pilgrim and Cordery 1993; Viessman et al. 1977) to determine average velocity in pipes for either pressure or non-pressure flow.
- A culvert or bridge can act as a reservoir outlet if there is significant storage behind it. A hydrograph should be developed to this point and the "level pool routing" technique should be used to determine the outflow rating curve through the culvert or bridge.

Table F.16. Values of "n" and "k" for use in Computing Time of Concentration.

FOR SHEET FLOW	n_s
Smooth surfaces (concrete, asphalt, gravel, or bare hard soil)	0.011
Fallow fields of loose soil surface (no vegetal residue)	0.05
Cultivated soil with crop residue (slope < 0.20 ft/ft)	0.06
Cultivated soil with crop residue (slope > 0.20 ft/ft)	0.17
Short prairie grass and lawns	0.15
Dense grass	0.24
Bermuda grass	0.41
Range, natural	0.13
Woods or forest, poor cover	0.40
Woods or forest, good cover	0.80
FOR SHALLOW, CONCENTRATED FLOW	**k_s**
Forest with heavy ground litter and meadows (n = 0.10)	3
Brushy ground with some trees (n = 0.06)	5
Fallow or minimum tillage cultivation (n = 0.04)	8
High grass (n = 0.035)	9
Short grass, pasture and lawns (n = 0.04)	11
Newly bare ground (n = 0.025)	13
Paved and gravel areas (n = 0.012)	27
CHANNEL FLOW (INTERMITTENT, R = 0.2)	**k_c**
Forested swale with heavy ground litter (n = 0.10)	5
Forested drainage course/ravine with defined channel bed (n = 0.050)	10
Rock-lined waterway (n = 0.035)	15
Grassed waterway (n = 0.030)	17
Earth-lined waterway (n = 0.025)	20
CMP pipe (n = 0.024)	21
Concrete pipe (n = 0.012)	42
Other waterways and pipes	0.508/n
CHANNEL FLOW (CONTINUOUS STREAM, R = 0.4)	**k_c**
Meandering stream with some pools (n = 0.040)	20
Rock-lined stream (n = 0.035)	23
Grassed stream (n = 0.030)	27
Other streams, man-made channels and pipe	0.807/n

Source: USDA (1986).

Table F.17. Other Values of the Roughness Coefficient "n" for Channel Flow.

Type of Channel and Description	Manning's "n"*
A. Constructed Channels	
a. Earth, straight and uniform	
1. Clean, recently completed	0.018
2. Gravel, uniform selection, clean	0.025
3. With short grass, few weeds	0.027
b. Earth, winding and sluggish	
1. No vegetation	0.025
2. Grass, some weeds	0.030
3. Dense weeds or aquatic plants in deep channels	0.035
4. Earth bottom and rubble sides	0.030
5. Stony bottom and weedy banks	0.035
6. Cobble bottom and clean sides	0.040
c. Rock lined	
1. Smooth and uniform	0.035
2. Jagged and irregular	0.040
d. Channels not maintained, weeds and brush uncut	
1. Dense weeds, high as flow depth	0.080
2. Clean bottom, brush on sides	0.050
3. Same, highest stage of flow	0.070
4. Dense brush, high stage	0.100
B. Natural Streams	
B-1 Minor streams (top width at flood stage <100 ft.)	
a. Streams on plain	
1. Clean, straight, full stage no rifts or deep pools	0.030
2. Same as above, but more stones and weeds	0.035
3. Clean, winding, some pools and shoals	0.040
4. Same as above, but some weeds	0.040
5. Same as 4, but more stones	0.050
6. Sluggish reaches, weedy deep pools	0.070
7. Very weedy reaches, deep pools, or floodways with heavy stands of timber and underbrush	0.100
b. Mountain streams, no vegetation in channel, banks usually steep, trees and brush along banks submerged at high stages	
1. Bottom: gravel, cobbles, and few boulders	0.040
2. Bottom: cobbles with large boulders	0.050

Table F.17 (continued). Other Values of the Roughness Coefficient "n" for Channel Flow.

Type of Channel and Description	Manning's "n"*
B-2 Flood plains	
a. Pasture, no brush	
1. Short grass	0.030
2. High grass	0.035
b. Cultivated areas	
1. No crop	0.030
2. Mature row crops	0.035
3. Mature field crops	0.040
c. Brush	
1. Scattered brush, heavy weeds	0.050
2. Light brush and trees	0.060
3. Medium to dense brush	0.070
4. Heavy, dense brush	0.100
d. Trees	
1. Dense willows, straight	0.150
2. Cleared land with tree stumps, no sprouts	0.040
3. Same as above, but with heavy growth of sprouts	0.060
4. Heavy stand of timber, a few down trees, little undergrowth, flood stage below branches	0.100
5. Same as above, but with flood stage reaching branches	0.120

F-5.4. Single-Event Routing Methods Overview

In the United States, the majority of single-event models for computation of runoff hydrographs are based on unit hydrographs. Most commercial software packages utilize unit hydrographs for making the transformation from computation of runoff volume to generation of the runoff hydrograph. This may require direct input of the ordinates of the unit hydrograph or the unit hydrograph may be computed internally based on watershed characteristics provided by the user. Notable exceptions include event-based models that utilize linear reservoir concepts, such as the Santa Barbara Urban Hydrograph model (SBUH), event-based models that utilize kinematic wave approaches, and continuous flow simulation models such as HSPF.

The *Unit Hydrograph Routing Methods* Section F-5.4.1 describes rainfall-runoff modeling based on unit hydrograph concepts. The reader is referred to any standard hydrology textbook (e.g., Gray 1961; Linsley et al. 1975; Pilgrim and Cordery 1993; Viessman et al. 1977) for a detailed discussion of unit hydrograph theory. The *SBUH Routing Method* Section F-5.4.2 includes a discussion of runoff hydrographs developed using the SBUH model. The *Level-Pool Routing Method* Section F-5.4.3 provides a discussion on the level-pool method, which is appropriate for routing hydrographs through lakes, wetlands, and other areas of standing water.

F-5.4.1. Unit Hydrograph Routing Methods

The unit hydrograph is defined as the time-distribution of runoff (Figure F.17) measured at the watershed outlet as produced by 1 inch of runoff uniformly generated over the watershed during a specified period of time. Thus, a 10-minute unit hydrograph would be the runoff hydrograph (cfs) observed at the watershed outlet as generated by 1 inch of runoff uniformly produced over the watershed in a 10-minute period.

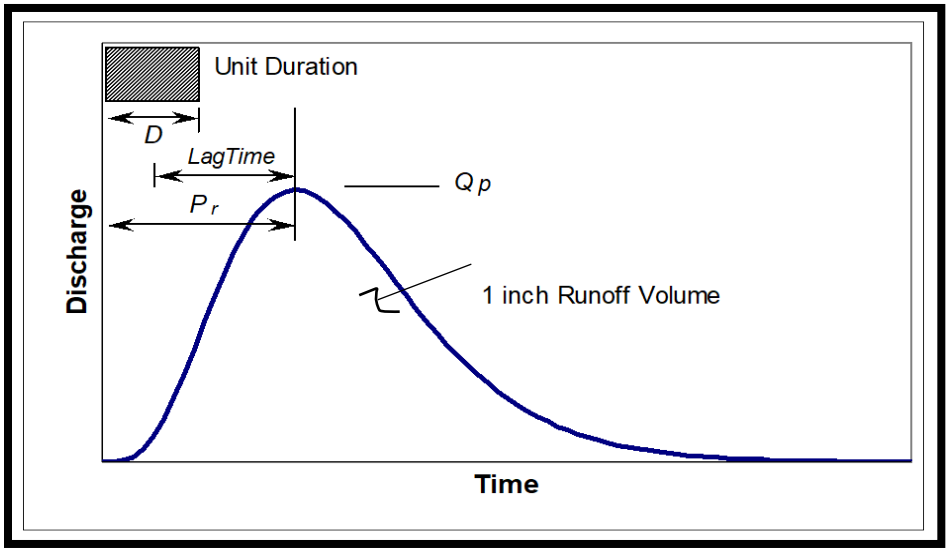


Figure F.17. Characteristics of Unit Hydrographs.

In computation of the runoff hydrograph, the unit hydrograph is scaled by the runoff in each D-minute period, and the resultant hydrographs for each D-minute period are added by superposition to yield the runoff hydrograph from the watershed.

Relationship of Computational Time Step to Time Lag (Lag Time). As indicated above, the ordinates of the unit hydrograph are specified on intervals equal to the computational time step. Recognizing that the time step and unit duration are equal ($\Delta t = D$), the unit duration must be chosen small enough to allow reasonable definition of the rising limb of the unit hydrograph. This is required to provide for adequate definition of the resultant runoff hydrograph in the vicinity of the runoff peak discharge. In addition, the value of D should be an integer multiple of the period of rise P_r so that the computational time step (Δt) falls on the peak discharge of the unit hydrograph.

Selection of Time Step (Δt) Based on Time of Concentration (T_c). The time-of concentration of the watershed (T_c) is often taken to be the elapsed time from the end of the unit duration (D) to the inflection point on the recession limb of the unit hydrograph (NRCS 1997). When the runoff hydrograph is computed based on unit hydrograph concepts utilizing time of concentration, the computational time step should be:

$$\Delta t < T_c/5 \qquad (23)$$

To enhance compatibility with the City of Seattle design storms, the computational time step for runoff computations should be a multiple of the time step used to describe the

design storm. The short-duration design storm is described in 5-minute intervals and the intermediate and long-duration design storms are described in 10-minute intervals. Therefore, the following additional criteria are required for selection of the time step for use with the short-duration design storm:

$$\Delta t = 5/n \quad (24)$$

And, for use with the intermediate and long-duration design storms:

$$\Delta t = 10/n \quad (25)$$

Where: n = integer greater than or equal to one

The above information should be particularly helpful for use with computer software that allows output of the runoff hydrograph on a time interval other than that used for internal computation of the runoff hydrograph. For those cases, the user may be unaware of the unit duration (D) and internal time step (Δt) being used by the computer program.

F-5.4.2. SBUH Routing Method

The SBUH method is an adaptation of standard hydrologic routing methods that employ the principle of conservation of mass. The routing equation for the SBUH method may be derived from linear reservoir concepts (Linsley et al. 1975; Fread 1993) where storage is taken to be a linear function of discharge.

The SBUH method uses two steps to synthesize the runoff hydrograph:

Step 1 — Compute the instantaneous hydrograph
Step 2 — Compute the runoff hydrograph

The instantaneous hydrograph is computed as follows:

$$I(t) = 60.5\ R(t)\ A/\Delta t \quad (26)$$

Where:
- $I(t)$ = instantaneous hydrograph at each time step (Δt) (cfs)
- $R(t)$ = total runoff depth (both impervious and pervious) at time increment Δt (inches)
- A = area (acres)
- Δt = computational time step (minutes)

The runoff hydrograph is then obtained by routing the instantaneous hydrograph through an imaginary reservoir with a time delay equal to the time of concentration of the drainage basin. The following equation estimates the routed flow:

$$Q(t+1) = Q(t) + w[I(t) + I(t+1) - 2Q(t)] \quad (27)$$

$$w = \Delta t\ /(2T_c + \Delta t) \quad (28)$$

Where:
- $Q(t)$ = runoff hydrograph or routed flow (cfs)
- T_c = time of concentration (minutes)
- Δt = computational time step (minutes)

Selection of Time Step (Δt) Based on Time of Concentration (T_c). Equation (27) requires that the computational time step be sufficiently short that the change in inflow, outflow, and storage during the time step can be treated as linear. For the case of very small urban watersheds, the low to moderate intensities in the long-duration design storm would typically generate runoff over a longer period than the time of concentration of the watershed. As a result, the elapsed time of the rising limb of the runoff hydrograph (T_r) would likewise be much longer than the time of concentration of the watershed. In addition, the computational time step for routing should be a multiple of the time step used to describe the design storm. Therefore, for intermediate and long-duration storms, the computational time step should satisfy equations (29) and (30):

$$\Delta t < T_c \tag{29}$$

$$\Delta t = 10/n \tag{30}$$

Where: Δt = computational time step (minutes)
T_c = time of concentration (minutes)
n = an integer greater than or equal to one

For short duration design storms, the flood peak of the runoff hydrograph may be quite flashy and produced by high-intensity precipitation during a limited portion of the storm. For this case, the elapsed time for the rising limb of the runoff hydrograph may be similar in magnitude to that of the time-of-concentration of the watershed. In this situation, the time step should be smaller than the time of concentration. In addition, the computational time step for routing should be a multiple of the time step used to describe the design storm. Therefore, for the short-duration storm, the computational time step should satisfy equations (31) and (32):

$$\Delta t < T_c/5 \tag{31}$$

$$\Delta t = 5/n \tag{32}$$

Where: Δt = computational time step (minutes)
T_c = time of concentration (minutes)
n = an integer greater than or equal to one

F-5.4.3. Level-Pool Routing Method

This section presents a general description of the methodology for routing a hydrograph through a retention/detention facility, closed depression, or wetland. Note that the City does not allow the use of single-event models for retention/detention facility design. The information presented in this section is for informational purposes only. The level pool routing technique (Fread 1993) is based on the continuity equation:

Inflow-outflow=change in storage

$$\left[\frac{I_1 + I_2}{2} - \frac{O_1 + O_2}{2}\right] = \frac{\Delta S}{\Delta t} = S_2 - S_1 \tag{33}$$

rearranging:

$$I_1 + I_2 + 2S_1 - O_1 = O_2 + 2S_2 \quad (34)$$

Where:
I = inflow at time 1 and time 2
O = outflow at time 1 and time 2
S = storage at time 1 and time 2
Δt = computational time step (minutes)

The time step (Δt) must be consistent with the time interval used in developing the inflow hydrograph.

The following summarizes the steps required in performing level-pool hydrograph routing:

- Develop stage-storage-discharge relationship, which is a function of pond/wetland geometry and outflow
- Route the inflow hydrograph through the structure by applying equation (34) at each time step, where the inflow hydrograph supplies values of I, the stage-storage relationship supplies values of S, and the stage discharge relationship provides values of O.

Commercially available hydrologic computer models perform these calculations automatically.

F-5.5. Modeling Guidance

The following sections present the general process involved in conducting a hydrologic analysis using single-event hydrograph methods to evaluate or design stormwater conveyance systems. Applicability of single-event methods and design standard requirements are discussed in *Section F-2*.

F-5.5.1. Steps for Hydrologic Design Using Single-Event Methods

The following summarizes the process for conducting hydrologic analyses using single-event models.

Step #	Procedure
SE-1	Review all minimum requirements that apply to the proposed project (*Volume 1*)
SE-2	Review applicable site definition and mapping requirements (*Volume 1*)
SE-3	Identify and delineate the overall drainage basin for each discharge point from the development site under existing conditions: ● Identify existing land use ● Identify existing soil types using on-site evaluation, NRCS soil survey, or mapping performed by the University of Washington (http://geomapnw.ess.washington.edu) ● Identify existing drainage features such as streams, conveyance systems, detention facilities, ponding areas, depressions, etc.
SE-4	Select and delineate pertinent subbasins based on existing conditions: ● Select homogeneous subbasin areas ● Select separate subbasin areas for on-site and off-site drainage ● Select separate subbasin areas for major drainage features.

F-5.5.2. Stormwater Conveyance

Existing and proposed stormwater conveyance facilities may be analyzed and designed using peak flows from hydrographs derived from single-event approaches described in this appendix. In addition to the steps listed in the *Steps for Hydrologic Design Using Single-event Methods* Section F-5.5.1, the following steps should be followed for designing/analyzing conveyance facilities:

Step #	Procedure
SC-1	Determine runoff parameters for each subbasin
SC-2	Identify pervious and impervious areas ● The short- or intermediate-duration design storm generally governs the design of conveyance facilities. Both storm durations should be treated as candidate design storms and the one that produces the more conservative design (higher peak discharge rates) used as the design storm (refer to Design Storm Hyetograph Section F-5.1). ● Select runoff parameters per the Infiltration Equation section. ● Compute time of concentration per the Time of Concentration Estimation section.
SC-3	Identify downstream hydraulic controls, such as outfalls (refer to Outfalls in *Section F-3.6*), known flooding locations, receiving pipe HGL, pump station, regulator station, weirs or orifice. Determine if backwater calculations or a dynamic hydraulic routing model are required. Refer to 2021 King County Surface Water Design Manual guidelines, Section 4.2.1 for backwater analysis methods.
SC-4	Compute runoff for the drainage system and determine peak discharge at the outlet of each subbasin for the design storm of interest
SC-5	Perform a capacity analysis to verify that there is sufficient capacity in the public drainage system or the public combined sewer system. Refer to *Volume 3, Section 4.3* and SMC, Section 22.805.020.H for specific requirements.
SC-6	Size the pipe based on the designated level of service.

F-6. Rational Method

The rational method is based on the assumption that rainfall intensity for any given duration is uniform over the entire tributary watershed. The rational formula relates peak discharge from the site of interest to rainfall intensity times a coefficient:

$$Q = CiA \tag{35}$$

Where:
- Q = peak discharge from the site of interest
- C = dimensionless runoff coefficient
- i = rainfall intensity for a given recurrence interval (in/hr)
- A = tributary area (acres)

The rainfall intensity (i) is determined from Figure F.18 or Table F.18 for the precipitation recurrence interval of interest and duration corresponding to the calculated time of concentration (refer to *Time of Concentration Estimation* section below).

F-6.1. Peak Rainfall Intensity-Duration-Frequency (IDF curves)

Rainfall intensity-duration-frequency (IDF) curves allow calculation of average design rainfall intensity for a given exceedance probability (recurrence interval) over a range of durations. Precipitation-frequency statistics presented in this appendix were analyzed using data from the City's 17gauge precipitation measurement network within the City of Seattle, and the national NOAA cooperative gauge network 13. Durations of 5 minutes, 10 minutes, 15 minutes, 20 minutes, 30 minutes, 45 minutes, 60 minutes, 2 hours, 3 hours, 6 hours, 12 hours, 24 hours, 48 hours, 72 hours, and 7 days were analyzed to develop the IDF curves. IDF curves for storm durations up to 3 hours and applicable to sites within Seattle are shown in Figure F.18.

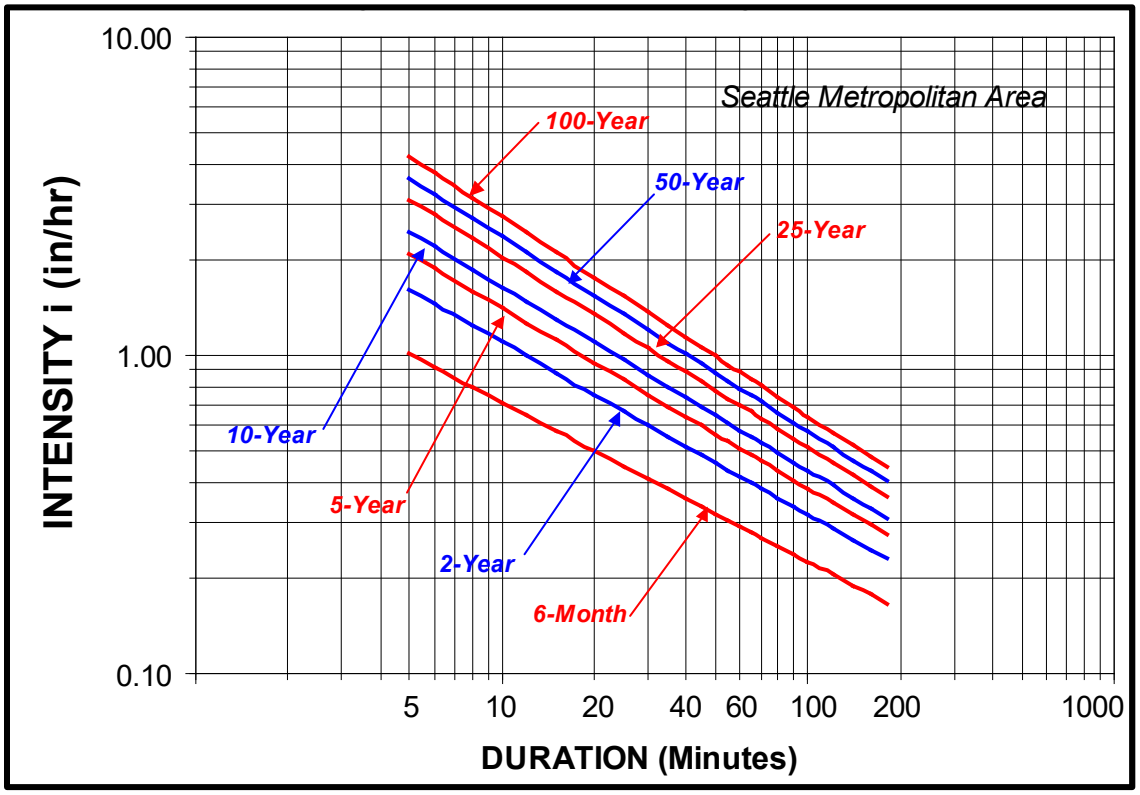


Figure F.18. Intensity-Duration-Frequency Curves for the City of Seattle.

Table F.18. Intensity-Duration-Frequency Values for 5- to 180-Minute Durations for Selected Recurrence Intervals for the City of Seattle.

Duration (minutes)	Precipitation Intensities (in/hr) for 6-month Recurrence Interval	Precipitation Intensities (in/hr) for 2-year Recurrence Interval	Precipitation Intensities (in/hr) for 5-year Recurrence Interval	Precipitation Intensities (in/hr) for 10-year Recurrence Interval	Precipitation Intensities (in/hr) for 20-year Recurrence Interval	Precipitation Intensities (in/hr) for 25-year Recurrence Interval	Precipitation Intensities (in/hr) for 50-year Recurrence Interval	Precipitation Intensities (in/hr) for 100-year Recurrence Interval
5	1.01	1.60	2.08	2.45	2.92	3.08	3.61	4.20
6	0.92	1.45	1.87	2.21	2.62	2.76	3.23	3.75
8	0.80	1.24	1.59	1.87	2.21	2.32	2.71	3.13
10	0.71	1.10	1.40	1.64	1.93	2.03	2.36	2.72
12	0.65	1.00	1.27	1.48	1.74	1.82	2.11	2.43
15	0.58	0.88	1.12	1.30	1.52	1.60	1.84	2.11
20	0.50	0.75	0.95	1.10	1.28	1.34	1.54	1.76
25	0.45	0.67	0.84	0.97	1.12	1.18	1.35	1.53
30	0.41	0.61	0.76	0.87	1.01	1.05	1.21	1.37
35	0.38	0.56	0.69	0.80	0.92	0.96	1.10	1.24
40	0.35	0.52	0.64	0.74	0.85	0.89	1.01	1.14
45	0.33	0.49	0.60	0.69	0.79	0.83	0.94	1.06
50	0.32	0.46	0.57	0.65	0.74	0.78	0.88	0.99
55	0.30	0.44	0.54	0.61	0.70	0.73	0.83	0.94
60	0.29	0.42	0.51	0.58	0.67	0.70	0.79	0.89
65	0.28	0.40	0.49	0.56	0.64	0.66	0.75	0.84
70	0.27	0.38	0.47	0.53	0.61	0.64	0.72	0.80
80	0.25	0.36	0.43	0.49	0.56	0.59	0.66	0.74
90	0.24	0.33	0.41	0.46	0.52	0.55	0.62	0.69
100	0.22	0.32	0.38	0.43	0.49	0.51	0.58	0.64
120	0.20	0.29	0.35	0.39	0.44	0.46	0.52	0.57
140	0.19	0.26	0.32	0.36	0.40	0.42	0.47	0.52
160	0.18	0.24	0.29	0.33	0.37	0.39	0.43	0.48
180	0.17	0.23	0.27	0.31	0.35	0.36	0.40	0.45

F-6.2. Runoff Coefficients

Runoff coefficients vary with the tributary land cover and, to a certain extent, the total depth and intensity of the rainfall. The storm depth and intensity are typically neglected, and the runoff coefficient is based on land cover only (Table F.19). For watersheds containing several land cover types, an aggregate runoff coefficient can be developed by computing the area weighted average from all cover types present (equation 36):

$$C_c = (C_1A_1 + C_2A_2 + C_3A_3 + \ldots + C_nA_n)/A_t \qquad (36)$$

Where:
- C_c = composite runoff coefficient for the site
- $C_{1, 2,,\ldots n}$ = runoff coefficient for each land cover type
- $A_{1, 2,,\ldots n}$ = area of each land cover type (acres)
- A_t = total tributary area (acres)

Table F.19. Rational Equation Runoff Coefficients.

Land Cover	Runoff Coefficient (C)
Dense Forest	0.10
Light Forest	0.15
Pasture	0.20
Lawns	0.25
Gravel Areas	0.80
Pavement and Roofs	0.90
Open Water (Ponds Lakes and Wetlands)	1.00

F-6.3. Time of Concentration Estimation

Time of concentration (T_c) is defined as the time it takes for runoff to travel from the most hydraulically distant point of the drainage area to the outlet. T_c is computed by summing all the travel times for consecutive components of the drainage conveyance system.

$$T_c = T_1 + T_2 + T_3 + \ldots T_n \qquad (37)$$

Where:
- T_c = time of concentration (minutes)
- $T_{1,2,3,\ldots n}$ = time for consecutive flow path segments with different land cover categories or flow path slope

Travel time for each segment is computed using the following equation:

$$T_t = L / V$$

Where:
- T_t = travel time (minutes)
- L = length of flow across a given segment (feet)
- V = average velocity across the land segment (ft/sec)

$$V = k_r\sqrt{S_o} \qquad (38)$$

Where:
- k_r = Velocity factor (Table F.20)
- S_0 = Slope of flow path (feet/feet)

Table F.20. Coefficients for Average Velocity Equation.

Land Cover	Velocity Factor (k_r)
Forest with Heavy Ground Cover and Meadow	2.5
Grass, Pasture, and Lawns	7.0
Nearly Bare Ground	10.1
Grassed Swale or Channel	15.0
Paved Areas	20.0

F-7. Risk-Based Hydrologic Design Concepts

Risk-based concepts and analytical approaches are being used more frequently in hydrologic design. A risk-based approach focuses on evaluating the two components of risk: the probability and consequences of failure. Failure may be broadly defined and includes failure to meet a project goal, failure to meet a regulatory requirement, or the physical failure of a project element. Consequences of failure vary with the project type and features and may include economic, life safety, environmental, and political consequences.

Risk can be described qualitatively or quantitatively. For example, qualitative risk is often expressed as low, moderate, high, or very high, based on various combinations of the probability of failure and the consequences of failure. Quantitative risk assessment requires more detailed analysis to provide numerical measures of the probability of failure and consequences of failure. Quantitative units of measure for risk include loss of life per year for life safety risk, and dollars per year for consequences that can be expressed in economic terms.

Risk concepts are often used in design where the design target, level-of-service, etc., is based on the consequences of failure or upon some adopted level of qualitative or quantitative risk. The design targets and level of conservatism of design are typically set based on the tolerable level of risk for a given project type or consideration of the regulatory requirements.

When applying a risk-based approach, engineers and hydrologists primarily evaluate the probability of failure (or probability of being in compliance) and may assess how and which uncertainties affect the probability of failure (or probability of being in compliance). Application of hydrologic computer models and detailed numerical descriptions of hydrologic/hydraulic system components are an integral part of assessing the probability of being in compliance.

F-7.1. Uncertainty

Historically, uncertainty in hydrologic simulation analyses and the consequences for analysis results are rarely quantified as part of stormwater engineering design. Factors of safety have typically been applied at the end of a hydrologic analysis to account for uncertainties in the analysis. The same factor of safety is typically used regardless of the level of uncertainty or the confidence in the hydrologic model's ability to realistically simulate runoff. For many projects, the fixed safety factor approach is adequate. However, for projects where the consequences of failure (an erroneous design) are large, quantifying the analysis uncertainty and risk of not meeting the design standard may be beneficial in selecting an appropriate level of design conservatism.

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Attachment 1

Design Storm Dimensionless Hyetograph Ordinates

Attachment 1 – Design Storm Dimensionless Hyetograph Ordinates

Table 1. Dimensionless Ordinates of the Short-duration Design Storm.

ELAPSED TIME (min)	INCREMENTAL ORDINATES	CUMULATIVE ORDINATES
0	0.0000	0.0000
5	0.0045	0.0045
10	0.0055	0.0100
15	0.0075	0.0175
20	0.0086	0.0261
25	0.0102	0.0363
30	0.0134	0.0497
35	0.0173	0.0670
40	0.0219	0.0889
45	0.0272	0.1161
50	0.0331	0.1492
55	0.0364	0.1856
60	0.0434	0.2290
65	0.0553	0.2843
70	0.0659	0.3502
75	0.1200	0.4702
80	0.1900	0.6602
85	0.1000	0.7602
90	0.0512	0.8114
95	0.0472	0.8586
100	0.0398	0.8984
105	0.0301	0.9285
110	0.0244	0.9529
115	0.0195	0.9724
120	0.0153	0.9877
125	0.0125	1.0002
130	0.0096	1.0098
135	0.0077	1.0175
140	0.0068	1.0243
145	0.0062	1.0305
150	0.0056	1.0361
155	0.0050	1.0411
160	0.0044	1.0455
165	0.0038	1.0493
170	0.0032	1.0525
175	0.0026	1.0551
180	0.0020	1.0571

Table 2. Dimensionless Ordinates of the Intermediate-duration Design Storm.

ELAPSED TIME (Hr)	INCRM ORDINATE	SUM ORDINATE	ELAPSED TIME (Hr)	INRM ORDINATE	SUM ORDINATE	ELAPSED TIME (Hr)	INCRM ORDINATE	SUM ORDINATE
0.00	0.0000	0.0000	6.17	0.0118	0.1972	12.17	0.0210	1.1731
0.17	0.0020	0.0020	6.33	0.0123	0.2095	12.33	0.0201	1.1932
0.33	0.0020	0.0040	6.50	0.0129	0.2224	12.50	0.0193	1.2125
0.50	0.0020	0.0060	6.67	0.0136	0.2360	12.67	0.0184	1.2309
0.67	0.0020	0.0080	6.83	0.0142	0.2502	12.83	0.0176	1.2485
0.83	0.0020	0.0100	7.00	0.0150	0.2652	13.00	0.0168	1.2653
1.00	0.0021	0.0121	7.17	0.0163	0.2815	13.17	0.0154	1.2807
1.17	0.0021	0.0142	7.33	0.0171	0.2986	13.33	0.0147	1.2954
1.33	0.0021	0.0163	7.50	0.0180	0.3166	13.50	0.0140	1.3094
1.50	0.0021	0.0184	7.67	0.0188	0.3354	13.67	0.0132	1.3226
1.67	0.0021	0.0205	7.83	0.0197	0.3551	13.83	0.0127	1.3353
1.83	0.0022	0.0227	8.00	0.0205	0.3756	14.00	0.0121	1.3474
2.00	0.0022	0.0249	8.17	0.0215	0.3971	14.17	0.0116	1.3590
2.17	0.0023	0.0272	8.33	0.0224	0.4195	14.33	0.0113	1.3703
2.33	0.0023	0.0295	8.50	0.0229	0.4424	14.50	0.0111	1.3814
2.50	0.0024	0.0319	8.67	0.0232	0.4656	14.67	0.0109	1.3923
2.67	0.0025	0.0344	8.83	0.0237	0.4893	14.83	0.0107	1.4030
2.83	0.0028	0.0372	9.00	0.0257	0.5150	15.00	0.0105	1.4135
3.00	0.0030	0.0402	9.17	0.0290	0.5440	15.17	0.0103	1.4238
3.17	0.0034	0.0436	9.33	0.0320	0.5760	15.33	0.0098	1.4336
3.33	0.0038	0.0474	9.50	0.0338	0.6098	15.50	0.0093	1.4429
3.50	0.0042	0.0516	9.67	0.0349	0.6447	15.67	0.0085	1.4514
3.67	0.0046	0.0562	9.83	0.0411	0.6858	15.83	0.0078	1.4592
3.83	0.0054	0.0616	10.00	0.0540	0.7398	16.00	0.0070	1.4662
4.00	0.0062	0.0678	10.17	0.0760	0.8158	16.17	0.0062	1.4724
4.17	0.0070	0.0748	10.33	0.0470	0.8628	16.33	0.0054	1.4778
4.33	0.0079	0.0827	10.50	0.0372	0.9000	16.50	0.0049	1.4827
4.50	0.0085	0.0912	10.67	0.0347	0.9347	16.67	0.0044	1.4871
4.67	0.0090	0.1002	10.83	0.0337	0.9684	16.83	0.0039	1.4910
4.83	0.0095	0.1097	11.00	0.0330	1.0014	17.00	0.0035	1.4945
5.00	0.0100	0.1197	11.17	0.0308	1.0322	17.17	0.0032	1.4977
5.17	0.0104	0.1301	11.33	0.0269	1.0591	17.33	0.0029	1.5006
5.33	0.0107	0.1408	11.50	0.0247	1.0838	17.50	0.0026	1.5032
5.50	0.0109	0.1517	11.67	0.0237	1.1075	17.67	0.0024	1.5056
5.67	0.0110	0.1627	11.83	0.0228	1.1303	17.83	0.0024	1.5080
5.83	0.0113	0.1740	12.00	0.0218	1.1521	18.00	0.0023	1.5103
6.00	0.0114	0.1854						

Table 3. Dimensionless Ordinates of Front-loaded Long-duration Design Storm.

ELAPSED TIME (Hr)	INCRM ORDINATE	SUM ORDINATE	ELAPSED TIME (Hr)	INRM ORDINATE	SUM ORDINATE	ELAPSED TIME (Hr)	INCRM ORDINATE	SUM ORDINATE
0.00	0.0000	0.0000	7.17	0.0018	0.0569	14.17	0.0072	0.2570
0.17	0.0001	0.0001	7.33	0.0019	0.0588	14.33	0.0073	0.2643
0.33	0.0003	0.0004	7.50	0.0019	0.0607	14.50	0.0074	0.2717
0.50	0.0005	0.0009	7.67	0.0020	0.0627	14.67	0.0075	0.2792
0.67	0.0007	0.0016	7.83	0.0022	0.0649	14.83	0.0076	0.2868
0.83	0.0009	0.0025	8.00	0.0024	0.0673	15.00	0.0077	0.2945
1.00	0.0010	0.0035	8.17	0.0026	0.0699	15.17	0.0078	0.3023
1.17	0.0011	0.0046	8.33	0.0028	0.0727	15.33	0.0078	0.3101
1.33	0.0012	0.0058	8.50	0.0030	0.0757	15.50	0.0078	0.3179
1.50	0.0013	0.0071	8.67	0.0032	0.0789	15.67	0.0079	0.3258
1.67	0.0013	0.0084	8.83	0.0034	0.0823	15.83	0.0079	0.3337
1.83	0.0013	0.0097	9.00	0.0036	0.0859	16.00	0.0079	0.3416
2.00	0.0013	0.0110	9.17	0.0038	0.0897	16.17	0.0081	0.3497
2.17	0.0013	0.0123	9.33	0.0040	0.0937	16.33	0.0082	0.3579
2.33	0.0013	0.0136	9.50	0.0042	0.0979	16.50	0.0082	0.3661
2.50	0.0014	0.0150	9.67	0.0045	0.1024	16.67	0.0093	0.3754
2.67	0.0014	0.0164	9.83	0.0047	0.1071	16.83	0.0099	0.3853
2.83	0.0014	0.0178	10.00	0.0048	0.1119	17.00	0.0102	0.3955
3.00	0.0014	0.0192	10.17	0.0049	0.1168	17.17	0.0104	0.4059
3.17	0.0014	0.0206	10.33	0.0049	0.1217	17.33	0.0107	0.4166
3.33	0.0014	0.0220	10.50	0.0049	0.1266	17.50	0.0114	0.4280
3.50	0.0014	0.0234	10.67	0.0050	0.1316	17.67	0.0118	0.4398
3.67	0.0014	0.0248	10.83	0.0051	0.1367	17.83	0.0142	0.4540
3.83	0.0014	0.0262	11.00	0.0051	0.1418	18.00	0.0220	0.4760
4.00	0.0014	0.0276	11.17	0.0053	0.1471	18.17	0.0290	0.5050
4.17	0.0014	0.0290	11.33	0.0053	0.1524	18.33	0.0160	0.5210
4.33	0.0015	0.0305	11.50	0.0054	0.1578	18.50	0.0127	0.5337
4.50	0.0015	0.0320	11.67	0.0054	0.1632	18.67	0.0116	0.5453
4.67	0.0015	0.0335	11.83	0.0054	0.1686	18.83	0.0110	0.5563
4.83	0.0015	0.0350	12.00	0.0055	0.1741	19.00	0.0106	0.5669
5.00	0.0015	0.0365	12.17	0.0055	0.1796	19.17	0.0102	0.5771
5.17	0.0015	0.0380	12.33	0.0056	0.1852	19.33	0.0096	0.5867
5.33	0.0015	0.0395	12.50	0.0057	0.1909	19.50	0.0082	0.5949
5.50	0.0015	0.0410	12.67	0.0058	0.1967	19.67	0.0082	0.6031
5.67	0.0015	0.0425	12.83	0.0060	0.2027	19.83	0.0082	0.6113
5.83	0.0015	0.0440	13.00	0.0062	0.2089	20.00	0.0081	0.6194
6.00	0.0015	0.0455	13.17	0.0064	0.2153	20.17	0.0080	0.6274
6.17	0.0015	0.0470	13.33	0.0066	0.2219	20.33	0.0079	0.6353
6.33	0.0015	0.0485	13.50	0.0068	0.2287	20.50	0.0079	0.6432

Table 3 (continued). Dimensionless Ordinates of Front-loaded Long-duration Design Storm.

ELAPSED TIME (Hr)	INCRM ORDINATE	SUM ORDINATE	ELAPSED TIME (Hr)	INRM ORDINATE	SUM ORDINATE	ELAPSED TIME (Hr)	INCRM ORDINATE	SUM ORDINATE
6.50	0.0016	0.0501	13.67	0.0069	0.2356	20.67	0.0078	0.6510
6.67	0.0016	0.0517	13.83	0.0070	0.2426	20.83	0.0078	0.6588
6.83	0.0017	0.0534	14.00	0.0072	0.2498	21.00	0.0077	0.6665
7.00	0.0017	0.0551						
21.17	0.0077	0.6742	30.17	0.0050	1.0069	39.17	0.0000	1.0984
21.33	0.0077	0.6819	30.33	0.0049	1.0118	39.33	0.0000	1.0984
21.50	0.0077	0.6896	30.50	0.0049	1.0167	39.50	0.0000	1.0984
21.67	0.0076	0.6972	30.67	0.0049	1.0216	39.67	0.0000	1.0984
21.83	0.0075	0.7047	30.83	0.0049	1.0265	39.83	0.0000	1.0984
22.00	0.0075	0.7122	31.00	0.0048	1.0313	40.00	0.0000	1.0984
22.17	0.0074	0.7196	31.17	0.0048	1.0361	40.17	0.0000	1.0984
22.33	0.0074	0.7270	31.33	0.0048	1.0409	40.33	0.0000	1.0984
22.50	0.0073	0.7343	31.50	0.0047	1.0456	40.50	0.0000	1.0984
22.67	0.0073	0.7416	31.67	0.0046	1.0502	40.67	0.0000	1.0984
22.83	0.0073	0.7489	31.83	0.0045	1.0547	40.83	0.0000	1.0984
23.00	0.0072	0.7561	32.00	0.0044	1.0591	41.00	0.0000	1.0984
23.17	0.0072	0.7633	32.17	0.0043	1.0634	41.17	0.0000	1.0984
23.33	0.0072	0.7705	32.33	0.0042	1.0676	41.33	0.0000	1.0984
23.50	0.0071	0.7776	32.50	0.0041	1.0717	41.50	0.0000	1.0984
23.67	0.0071	0.7847	32.67	0.0039	1.0756	41.67	0.0000	1.0984
23.83	0.0070	0.7917	32.83	0.0038	1.0794	41.83	0.0000	1.0984
24.00	0.0070	0.7987	33.00	0.0037	1.0831	42.00	0.0000	1.0984
24.17	0.0069	0.8056	33.17	0.0033	1.0864	42.17	0.0000	1.0984
24.33	0.0068	0.8124	33.33	0.0029	1.0893	42.33	0.0000	1.0984
24.50	0.0067	0.8191	33.50	0.0025	1.0918	42.50	0.0000	1.0984
24.67	0.0067	0.8258	33.67	0.0021	1.0939	42.67	0.0000	1.0984
24.83	0.0066	0.8324	33.83	0.0017	1.0956	42.83	0.0000	1.0984
25.00	0.0065	0.8389	34.00	0.0013	1.0969	43.00	0.0000	1.0984
25.17	0.0062	0.8451	34.17	0.0009	1.0978	43.17	0.0000	1.0984
25.33	0.0062	0.8513	34.33	0.0005	1.0983	43.33	0.0000	1.0984
25.50	0.0060	0.8573	34.50	0.0001	1.0984	43.50	0.0000	1.0984
25.67	0.0059	0.8632	34.67	0.0000	1.0984	43.67	0.0000	1.0984
25.83	0.0059	0.8691	34.83	0.0000	1.0984	43.83	0.0000	1.0984
26.00	0.0058	0.8749	35.00	0.0000	1.0984	44.00	0.0000	1.0984
26.17	0.0057	0.8806	35.17	0.0000	1.0984	44.17	0.0000	1.0984
26.33	0.0056	0.8862	35.33	0.0000	1.0984	44.33	0.0000	1.0984
26.50	0.0055	0.8917	35.50	0.0000	1.0984	44.50	0.0000	1.0984
26.67	0.0055	0.8972	35.67	0.0000	1.0984	44.67	0.0000	1.0984

Table 3 (continued). Dimensionless Ordinates of Front-loaded Long-duration Design Storm.

ELAPSED TIME (Hr)	INCRM ORDINATE	SUM ORDINATE	ELAPSED TIME (Hr)	INRM ORDINATE	SUM ORDINATE	ELAPSED TIME (Hr)	INCRM ORDINATE	SUM ORDINATE
26.83	0.0055	0.9027	35.83	0.0000	1.0984	44.83	0.0000	1.0984
27.00	0.0055	0.9082	36.00	0.0000	1.0984	45.00	0.0000	1.0984
27.17	0.0054	0.9136	36.17	0.0000	1.0984	45.17	0.0000	1.0984
27.33	0.0054	0.9190	36.33	0.0000	1.0984	45.33	0.0000	1.0984
27.50	0.0054	0.9244	36.50	0.0000	1.0984	45.50	0.0000	1.0984
27.67	0.0053	0.9297	36.67	0.0000	1.0984	45.67	0.0000	1.0984
27.83	0.0053	0.9350	36.83	0.0000	1.0984	45.83	0.0000	1.0984
28.00	0.0053	0.9403	37.00	0.0000	1.0984	46.00	0.0000	1.0984
28.17	0.0053	0.9456	37.17	0.0000	1.0984	46.17	0.0000	1.0984
28.33	0.0052	0.9508	37.33	0.0000	1.0984	46.33	0.0000	1.0984
28.50	0.0052	0.9560	37.50	0.0000	1.0984	46.50	0.0000	1.0984
28.67	0.0052	0.9612	37.67	0.0000	1.0984	46.67	0.0000	1.0984
28.83	0.0052	0.9664	37.83	0.0000	1.0984	46.83	0.0000	1.0984
29.00	0.0052	0.9716	38.00	0.0000	1.0984	47.00	0.0000	1.0984
29.17	0.0051	0.9767	38.17	0.0000	1.0984	47.17	0.0000	1.0984
29.33	0.0051	0.9818	38.33	0.0000	1.0984	47.33	0.0000	1.0984
29.50	0.0051	0.9869	38.50	0.0000	1.0984	47.50	0.0000	1.0984
29.67	0.0050	0.9919	38.67	0.0000	1.0984	47.67	0.0001	1.0985
29.83	0.0050	0.9969	38.83	0.0000	1.0984	47.83	0.0002	1.0987
30.00	0.0050	1.0019	39.00	0.0000	1.0984	48.00	0.0003	1.0990
48.17	0.0004	1.0994	56.17	0.0026	1.2422			
48.33	0.0005	1.0999	56.33	0.0024	1.2446			
48.50	0.0006	1.1005	56.50	0.0023	1.2469			
48.67	0.0007	1.1012	56.67	0.0023	1.2492			
48.83	0.0007	1.1019	56.83	0.0022	1.2514			
49.00	0.0007	1.1026	57.00	0.0021	1.2535			
49.17	0.0007	1.1033	57.17	0.0019	1.2554			
49.33	0.0007	1.1040	57.33	0.0017	1.2571			
49.50	0.0007	1.1047	57.50	0.0016	1.2587			
49.67	0.0007	1.1054	57.67	0.0015	1.2602			
49.83	0.0007	1.1061	57.83	0.0015	1.2617			
50.00	0.0007	1.1068	58.00	0.0015	1.2632			
50.17	0.0007	1.1075	58.17	0.0015	1.2647			
50.33	0.0008	1.1083	58.33	0.0015	1.2662			
50.50	0.0009	1.1092	58.50	0.0015	1.2677			
50.67	0.0010	1.1102	58.67	0.0014	1.2691			
50.83	0.0011	1.1113	58.83	0.0014	1.2705			
51.00	0.0012	1.1125	59.00	0.0013	1.2718			

Table 3 (continued). Dimensionless Ordinates of Front-loaded Long-duration Design Storm.

ELAPSED TIME (Hr)	INCRM ORDINATE	SUM ORDINATE	ELAPSED TIME (Hr)	INRM ORDINATE	SUM ORDINATE	ELAPSED TIME (Hr)	INCRM ORDINATE	SUM ORDINATE
51.17	0.0013	1.1138	59.17	0.0013	1.2731			
51.33	0.0014	1.1152	59.33	0.0012	1.2743			
51.50	0.0014	1.1166	59.50	0.0012	1.2755			
51.67	0.0014	1.1180	59.67	0.0011	1.2766			
51.83	0.0014	1.1194	59.83	0.0010	1.2776			
52.00	0.0015	1.1209	60.00	0.0009	1.2785			
52.17	0.0016	1.1225	60.17	0.0009	1.2794			
52.33	0.0018	1.1243	60.33	0.0008	1.2802			
52.50	0.0020	1.1263	60.50	0.0008	1.2810			
52.67	0.0021	1.1284	60.67	0.0007	1.2817			
52.83	0.0023	1.1307	60.83	0.0007	1.2824			
53.00	0.0023	1.1330	61.00	0.0007	1.2831			
53.17	0.0024	1.1354	61.17	0.0007	1.2838			
53.33	0.0026	1.1380	61.33	0.0007	1.2845			
53.50	0.0028	1.1408	61.50	0.0007	1.2852			
53.67	0.0032	1.1440	61.67	0.0007	1.2859			
53.83	0.0039	1.1479	61.83	0.0007	1.2866			
54.00	0.0048	1.1527	62.00	0.0007	1.2873			
54.17	0.0056	1.1583	62.17	0.0007	1.2880			
54.33	0.0076	1.1659	62.33	0.0007	1.2887			
54.50	0.0096	1.1755	62.50	0.0007	1.2894			
54.67	0.0133	1.1888	62.67	0.0006	1.2900			
54.83	0.0133	1.2021	62.83	0.0005	1.2905			
55.00	0.0096	1.2117	63.00	0.0004	1.2909			
55.17	0.0076	1.2193	63.17	0.0003	1.2912			
55.33	0.0056	1.2249	63.33	0.0002	1.2914			
55.50	0.0048	1.2297	63.50	0.0001	1.2915			
55.67	0.0039	1.2336	63.67	0.0000	1.2915			
55.83	0.0032	1.2368	63.83	0.0000	1.2915			
56.00	0.0028	1.2396	64.00	0.0000	1.2915			

Table 4. Dimensionless Ordinates of Back-loaded Long-duration Design Storm.

ELAPSED TIME (Hr)	INCRM ORDINATE	SUM ORDINATE	ELAPSED TIME (Hr)	INCRM ORDINATE	SUM ORDINATE	ELAPSED TIME (Hr)	INCRM ORDINATE	SUM ORDINATE
0.00	0.0000	0.0000	8.17	0.0039	0.1352	16.17	0.0000	0.1931
0.17	0.0001	0.0001	8.33	0.0032	0.1384	16.33	0.0000	0.1931
0.33	0.0002	0.0003	8.50	0.0028	0.1412	16.50	0.0000	0.1931
0.50	0.0003	0.0006	8.67	0.0026	0.1438	16.67	0.0000	0.1931
0.67	0.0004	0.0010	8.83	0.0024	0.1462	16.83	0.0000	0.1931
0.83	0.0005	0.0015	9.00	0.0023	0.1485	17.00	0.0000	0.1931
1.00	0.0006	0.0021	9.17	0.0023	0.1508	17.17	0.0000	0.1931
1.17	0.0007	0.0028	9.33	0.0022	0.1530	17.33	0.0000	0.1931
1.33	0.0007	0.0035	9.50	0.0021	0.1551	17.50	0.0000	0.1931
1.50	0.0007	0.0042	9.67	0.0019	0.1570	17.67	0.0000	0.1931
1.67	0.0007	0.0049	9.83	0.0017	0.1587	17.83	0.0000	0.1931
1.83	0.0007	0.0056	10.00	0.0016	0.1603	18.00	0.0000	0.1931
2.00	0.0007	0.0063	10.17	0.0015	0.1618	18.17	0.0000	0.1931
2.17	0.0007	0.0070	10.33	0.0015	0.1633	18.33	0.0000	0.1931
2.33	0.0007	0.0077	10.50	0.0015	0.1648	18.50	0.0000	0.1931
2.50	0.0007	0.0084	10.67	0.0015	0.1663	18.67	0.0000	0.1931
2.67	0.0007	0.0091	10.83	0.0015	0.1678	18.83	0.0000	0.1931
2.83	0.0008	0.0099	11.00	0.0015	0.1693	19.00	0.0000	0.1931
3.00	0.0009	0.0108	11.17	0.0014	0.1707	19.17	0.0000	0.1931
3.17	0.0010	0.0118	11.33	0.0014	0.1721	19.33	0.0000	0.1931
3.33	0.0011	0.0129	11.50	0.0013	0.1734	19.50	0.0000	0.1931
3.50	0.0012	0.0141	11.67	0.0013	0.1747	19.67	0.0000	0.1931
3.67	0.0013	0.0154	11.83	0.0012	0.1759	19.83	0.0000	0.1931
3.83	0.0014	0.0168	12.00	0.0012	0.1771	20.00	0.0000	0.1931
4.00	0.0014	0.0182	12.17	0.0011	0.1782	20.17	0.0000	0.1931
4.17	0.0014	0.0196	12.33	0.0010	0.1792	20.33	0.0000	0.1931
4.33	0.0014	0.0210	12.50	0.0009	0.1801	20.50	0.0000	0.1931
4.50	0.0015	0.0225	12.67	0.0009	0.1810	20.67	0.0000	0.1931
4.67	0.0016	0.0241	12.83	0.0008	0.1818	20.83	0.0000	0.1931
4.83	0.0018	0.0259	13.00	0.0008	0.1826	21.00	0.0000	0.1931
5.00	0.0020	0.0279	13.17	0.0007	0.1833	21.17	0.0000	0.1931
5.17	0.0021	0.0300	13.33	0.0007	0.1840	21.33	0.0000	0.1931
5.33	0.0023	0.0323	13.50	0.0007	0.1847	21.50	0.0000	0.1931
5.50	0.0023	0.0346	13.67	0.0007	0.1854	21.67	0.0000	0.1931
5.67	0.0024	0.0370	13.83	0.0007	0.1861	21.83	0.0000	0.1931
5.83	0.0026	0.0396	14.00	0.0007	0.1868	22.00	0.0000	0.1931
6.00	0.0028	0.0424	14.17	0.0007	0.1875	22.17	0.0000	0.1931
6.17	0.0032	0.0456	14.33	0.0007	0.1882	22.33	0.0000	0.1931
6.33	0.0039	0.0495	14.50	0.0007	0.1889	22.50	0.0000	0.1931
6.50	0.0048	0.0543	14.67	0.0007	0.1896	22.67	0.0000	0.1931

Table 4 (continued). Dimensionless Ordinates of Back-loaded Long-duration Design Storm.

ELAPSED TIME (Hr)	INCRM ORDINATE	SUM ORDINATE	ELAPSED TIME (Hr)	INCRM ORDINATE	SUM ORDINATE	ELAPSED TIME (Hr)	INCRM ORDINATE	SUM ORDINATE
6.67	0.0056	0.0599	14.83	0.0007	0.1903	22.83	0.0000	0.1931
6.83	0.0076	0.0675	15.00	0.0007	0.1910	23.00	0.0000	0.1931
7.00	0.0096	0.0771	15.17	0.0006	0.1916	23.17	0.0000	0.1931
7.17	0.0133	0.0904	15.33	0.0005	0.1921	23.33	0.0000	0.1931
7.33	0.0133	0.1037	15.50	0.0004	0.1925	23.50	0.0000	0.1931
7.50	0.0096	0.1133	15.67	0.0003	0.1928	23.67	0.0000	0.1931
7.67	0.0076	0.1209	15.83	0.0002	0.1930	23.83	0.0000	0.1931
7.83	0.0056	0.1265	16.00	0.0001	0.1931	24.00	0.0000	0.1931
8.00	0.0048	0.1313						
24.17	0.0000	0.1931	32.17	0.0014	0.2137	40.17	0.0053	0.3402
24.33	0.0000	0.1931	32.33	0.0014	0.2151	40.33	0.0053	0.3455
24.50	0.0000	0.1931	32.50	0.0014	0.2165	40.50	0.0054	0.3509
24.67	0.0000	0.1931	32.67	0.0014	0.2179	40.67	0.0054	0.3563
24.83	0.0000	0.1931	32.83	0.0014	0.2193	40.83	0.0054	0.3617
25.00	0.0000	0.1931	33.00	0.0014	0.2207	41.00	0.0055	0.3672
25.17	0.0000	0.1931	33.17	0.0014	0.2221	41.17	0.0055	0.3727
25.33	0.0000	0.1931	33.33	0.0015	0.2236	41.33	0.0056	0.3783
25.50	0.0000	0.1931	33.50	0.0015	0.2251	41.50	0.0057	0.3840
25.67	0.0000	0.1931	33.67	0.0015	0.2266	41.67	0.0058	0.3898
25.83	0.0000	0.1931	33.83	0.0015	0.2281	41.83	0.0060	0.3958
26.00	0.0000	0.1931	34.00	0.0015	0.2296	42.00	0.0062	0.4020
26.17	0.0000	0.1931	34.17	0.0015	0.2311	42.17	0.0064	0.4084
26.33	0.0000	0.1931	34.33	0.0015	0.2326	42.33	0.0066	0.4150
26.50	0.0000	0.1931	34.50	0.0015	0.2341	42.50	0.0068	0.4218
26.67	0.0000	0.1931	34.67	0.0015	0.2356	42.67	0.0069	0.4287
26.83	0.0000	0.1931	34.83	0.0015	0.2371	42.83	0.0070	0.4357
27.00	0.0000	0.1931	35.00	0.0015	0.2386	43.00	0.0072	0.4429
27.17	0.0000	0.1931	35.17	0.0015	0.2401	43.17	0.0072	0.4501
27.33	0.0000	0.1931	35.33	0.0015	0.2416	43.33	0.0073	0.4574
27.50	0.0000	0.1931	35.50	0.0016	0.2432	43.50	0.0074	0.4648
27.67	0.0000	0.1931	35.67	0.0016	0.2448	43.67	0.0075	0.4723
27.83	0.0000	0.1931	35.83	0.0017	0.2465	43.83	0.0076	0.4799
28.00	0.0000	0.1931	36.00	0.0017	0.2482	44.00	0.0077	0.4876
28.17	0.0000	0.1931	36.17	0.0018	0.2500	44.17	0.0078	0.4954
28.33	0.0000	0.1931	36.33	0.0019	0.2519	44.33	0.0078	0.5032
28.50	0.0000	0.1931	36.50	0.0019	0.2538	44.50	0.0078	0.5110
28.67	0.0000	0.1931	36.67	0.0020	0.2558	44.67	0.0079	0.5189
28.83	0.0000	0.1931	36.83	0.0022	0.2580	44.83	0.0079	0.5268
29.00	0.0000	0.1931	37.00	0.0024	0.2604	45.00	0.0079	0.5347

Table 4 (continued). Dimensionless Ordinates of Back-loaded Long-duration Design Storm.

ELAPSED TIME (Hr)	INCRM ORDINATE	SUM ORDINATE	ELAPSED TIME (Hr)	INCRM ORDINATE	SUM ORDINATE	ELAPSED TIME (Hr)	INCRM ORDINATE	SUM ORDINATE
29.17	0.0001	0.1932	37.17	0.0026	0.2630	45.17	0.0081	0.5428
29.33	0.0003	0.1935	37.33	0.0028	0.2658	45.33	0.0082	0.5510
29.50	0.0005	0.1940	37.50	0.0030	0.2688	45.50	0.0082	0.5592
29.67	0.0007	0.1947	37.67	0.0032	0.2720	45.67	0.0093	0.5685
29.83	0.0009	0.1956	37.83	0.0034	0.2754	45.83	0.0099	0.5784
30.00	0.0010	0.1966	38.00	0.0036	0.2790	46.00	0.0102	0.5886
30.17	0.0011	0.1977	38.17	0.0038	0.2828	46.17	0.0104	0.5990
30.33	0.0012	0.1989	38.33	0.0040	0.2868	46.33	0.0107	0.6097
30.50	0.0013	0.2002	38.50	0.0042	0.2910	46.50	0.0114	0.6211
30.67	0.0013	0.2015	38.67	0.0045	0.2955	46.67	0.0118	0.6329
30.83	0.0013	0.2028	38.83	0.0047	0.3002	46.83	0.0142	0.6471
31.00	0.0013	0.2041	39.00	0.0048	0.3050	47.00	0.0220	0.6691
31.17	0.0013	0.2054	39.17	0.0049	0.3099	47.17	0.0290	0.6981
31.33	0.0013	0.2067	39.33	0.0049	0.3148	47.33	0.0160	0.7141
31.50	0.0014	0.2081	39.50	0.0049	0.3197	47.50	0.0127	0.7268
31.67	0.0014	0.2095	39.67	0.0050	0.3247	47.67	0.0116	0.7384
31.83	0.0014	0.2109	39.83	0.0051	0.3298	47.83	0.0110	0.7494
32.00	0.0014	0.2123	40.00	0.0051	0.3349	48.00	0.0106	0.7600
48.17	0.0102	0.7702	56.17	0.0054	1.1067			
48.33	0.0096	0.7798	56.33	0.0054	1.1121			
48.50	0.0082	0.7880	56.50	0.0054	1.1175			
48.67	0.0082	0.7962	56.67	0.0053	1.1228			
48.83	0.0082	0.8044	56.83	0.0053	1.1281			
49.00	0.0081	0.8125	57.00	0.0053	1.1334			
49.17	0.0080	0.8205	57.17	0.0053	1.1387			
49.33	0.0079	0.8284	57.33	0.0052	1.1439			
49.50	0.0079	0.8363	57.50	0.0052	1.1491			
49.67	0.0078	0.8441	57.67	0.0052	1.1543			
49.83	0.0078	0.8519	57.83	0.0052	1.1595			
50.00	0.0077	0.8596	58.00	0.0052	1.1647			
50.17	0.0077	0.8673	58.17	0.0051	1.1698			
50.33	0.0077	0.8750	58.33	0.0051	1.1749			
50.50	0.0077	0.8827	58.50	0.0051	1.1800			
50.67	0.0076	0.8903	58.67	0.0050	1.1850			
50.83	0.0075	0.8978	58.83	0.0050	1.1900			
51.00	0.0075	0.9053	59.00	0.0050	1.1950			
51.17	0.0074	0.9127	59.17	0.0050	1.2000			
51.33	0.0074	0.9201	59.33	0.0049	1.2049			
51.50	0.0073	0.9274	59.50	0.0049	1.2098			

Table 4 (continued). Dimensionless Ordinates of Back-loaded Long-duration Design Storm.

ELAPSED TIME (Hr)	INCRM ORDINATE	SUM ORDINATE	ELAPSED TIME (Hr)	INCRM ORDINATE	SUM ORDINATE	ELAPSED TIME (Hr)	INCRM ORDINATE	SUM ORDINATE
51.67	0.0073	0.9347	59.67	0.0049	1.2147			
51.83	0.0073	0.9420	59.83	0.0049	1.2196			
52.00	0.0072	0.9492	60.00	0.0048	1.2244			
52.17	0.0072	0.9564	60.17	0.0048	1.2292			
52.33	0.0072	0.9636	60.33	0.0048	1.2340			
52.50	0.0071	0.9707	60.50	0.0047	1.2387			
52.67	0.0071	0.9778	60.67	0.0046	1.2433			
52.83	0.0070	0.9848	60.83	0.0045	1.2478			
53.00	0.0070	0.9918	61.00	0.0044	1.2522			
53.17	0.0069	0.9987	61.17	0.0043	1.2565			
53.33	0.0068	1.0055	61.33	0.0042	1.2607			
53.50	0.0067	1.0122	61.50	0.0041	1.2648			
53.67	0.0067	1.0189	61.67	0.0039	1.2687			
53.83	0.0066	1.0255	61.83	0.0038	1.2725			
54.00	0.0065	1.0320	62.00	0.0037	1.2762			
54.17	0.0062	1.0382	62.17	0.0033	1.2795			
54.33	0.0062	1.0444	62.33	0.0029	1.2824			
54.50	0.0060	1.0504	62.50	0.0025	1.2849			
54.67	0.0059	1.0563	62.67	0.0021	1.2870			
54.83	0.0059	1.0622	62.83	0.0017	1.2887			
55.00	0.0058	1.0680	63.00	0.0013	1.2900			
55.17	0.0057	1.0737	63.17	0.0009	1.2909			
55.33	0.0056	1.0793	63.33	0.0005	1.2914			
55.50	0.0055	1.0848	63.50	0.0001	1.2915			
55.67	0.0055	1.0903	63.67	0.0000	1.2915			
55.83	0.0055	1.0958	63.83	0.0000	1.2915			
56.00	0.0055	1.1013	64.00	0.0000	1.2915			

Table 5. Dimensionless Ordinates of 24-hour Design Storm.

ELAPSED TIME (Hr)	INCRM ORDINATE	SUM ORDINATE	ELAPSED TIME (Hr)	INCRM ORDINATE	SUM ORDINATE	ELAPSED TIME (Hr)	INCRM ORDINATE	SUM ORDINATE
0.00	0.0000	0.0000	7.17	0.0080	0.2596	14.17	0.0072	0.6769
0.17	0.0036	0.0036	7.33	0.0082	0.2678	14.33	0.0072	0.6841
0.33	0.0038	0.0074	7.50	0.0084	0.2762	14.50	0.0072	0.6913
0.50	0.0040	0.0114	7.67	0.0088	0.2850	14.67	0.0071	0.6984
0.67	0.0042	0.0156	7.83	0.0093	0.2943	14.83	0.0071	0.7055
0.83	0.0045	0.0201	8.00	0.0099	0.3042	15.00	0.0070	0.7125
1.00	0.0047	0.0248	8.17	0.0102	0.3144	15.17	0.0070	0.7195
1.17	0.0048	0.0296	8.33	0.0104	0.3248	15.33	0.0069	0.7264
1.33	0.0049	0.0345	8.50	0.0107	0.3355	15.50	0.0068	0.7332
1.50	0.0049	0.0394	8.67	0.0114	0.3469	15.67	0.0067	0.7399
1.67	0.0049	0.0443	8.83	0.0127	0.3596	15.83	0.0066	0.7465
1.83	0.0050	0.0493	9.00	0.0142	0.3738	16.00	0.0065	0.7530
2.00	0.0051	0.0544	9.17	0.0220	0.3958	16.17	0.0064	0.7594
2.17	0.0051	0.0595	9.33	0.0290	0.4248	16.33	0.0063	0.7657
2.33	0.0053	0.0648	9.50	0.0160	0.4408	16.50	0.0062	0.7719
2.50	0.0053	0.0701	9.67	0.0127	0.4535	16.67	0.0060	0.7779
2.67	0.0054	0.0755	9.83	0.0116	0.4651	16.83	0.0059	0.7838
2.83	0.0054	0.0809	10.00	0.0110	0.4761	17.00	0.0059	0.7897
3.00	0.0054	0.0863	10.17	0.0106	0.4867	17.17	0.0058	0.7955
3.17	0.0055	0.0918	10.33	0.0102	0.4969	17.33	0.0057	0.8012
3.33	0.0055	0.0973	10.50	0.0096	0.5065	17.50	0.0056	0.8068
3.50	0.0056	0.1029	10.67	0.0089	0.5154	17.67	0.0055	0.8123
3.67	0.0057	0.1086	10.83	0.0085	0.5239	17.83	0.0055	0.8178
3.83	0.0058	0.1144	11.00	0.0083	0.5322	18.00	0.0055	0.8233
4.00	0.0060	0.1204	11.17	0.0082	0.5404	18.17	0.0055	0.8288
4.17	0.0062	0.1266	11.33	0.0081	0.5485	18.33	0.0054	0.8342
4.33	0.0064	0.1330	11.50	0.0080	0.5565	18.50	0.0054	0.8396
4.50	0.0066	0.1396	11.67	0.0079	0.5644	18.67	0.0054	0.8450
4.67	0.0068	0.1464	11.83	0.0078	0.5722	18.83	0.0053	0.8503
4.83	0.0069	0.1533	12.00	0.0078	0.5800	19.00	0.0053	0.8556
5.00	0.0070	0.1603	12.17	0.0077	0.5877	19.17	0.0053	0.8609
5.17	0.0072	0.1675	12.33	0.0077	0.5954	19.33	0.0053	0.8662
5.33	0.0072	0.1747	12.50	0.0076	0.6030	19.50	0.0052	0.8714
5.50	0.0073	0.1820	12.67	0.0076	0.6106	19.67	0.0052	0.8766
5.67	0.0074	0.1894	12.83	0.0075	0.6181	19.83	0.0052	0.8818
5.83	0.0075	0.1969	13.00	0.0075	0.6256	20.00	0.0052	0.8870
6.00	0.0076	0.2045	13.17	0.0074	0.6330	20.17	0.0052	0.8922
6.17	0.0077	0.2122	13.33	0.0074	0.6404	20.33	0.0051	0.8973
6.33	0.0078	0.2200	13.50	0.0074	0.6478	20.50	0.0051	0.9024
6.50	0.0078	0.2278	13.67	0.0073	0.6551	20.67	0.0051	0.9075

Table 5 (continued). Dimensionless Ordinates of 24-hour Design Storm.

ELAPSED TIME (Hr)	INCRM ORDINATE	SUM ORDINATE	ELAPSED TIME (Hr)	INCRM ORDINATE	SUM ORDINATE	ELAPSED TIME (Hr)	INCRM ORDINATE	SUM ORDINATE
6.67	0.0079	0.2357	13.83	0.0073	0.6624	20.83	0.0050	0.9125
6.83	0.0079	0.2436	14.00	0.0073	0.6697	21.00	0.0050	0.9175
7.00	0.0080	0.2516						
21.17	0.0050	0.9225						
21.33	0.0050	0.9275						
21.50	0.0049	0.9324						
21.67	0.0049	0.9373						
21.83	0.0049	0.9422						
22.00	0.0049	0.9471						
22.17	0.0048	0.9519						
22.33	0.0048	0.9567						
22.50	0.0048	0.9615						
22.67	0.0047	0.9662						
22.83	0.0046	0.9708						
23.00	0.0045	0.9753						
23.17	0.0044	0.9797						
23.33	0.0043	0.9840						
23.50	0.0042	0.9882						
23.67	0.0041	0.9923						
23.83	0.0039	0.9962						
24.00	0.0038	1.0000						

Attachment 2

Precipitation Magnitude-Frequency Estimates for SPU Rain Gauge Locations

Attachment 2 – Precipitation Magnitude-Frequency Estimates for SPU Rain Gauge Locations

This appendix contains adapted text and excerpted tables and figures from *Analysis of Precipitation-Frequency and Storm Characteristics for the City of Seattle* (MGS Engineering Consultants, Inc. for Seattle Public Utilities, January 2013). A majority of the analysis presented here is from rain gauge data ending in 2012. Tables 1, 3, and 4 were updated based on a study performed in 2020.

The results of homogeneity analyses indicate that at-site mean values for precipitation do not vary across the Seattle Metropolitan Area for durations of 3 hours and less. Accordingly, one set of intensity-duration-frequency (IDF) curves can be developed that are applicable to the Seattle Metropolitan Area. Table 1 and Figures 1 and 2 provide precipitation intensities and IDF curves representative of the Seattle Metropolitan Area for durations from 5 to 180 minutes.

Table 1. Intensity-Duration-Frequency Values for Durations from 5 Minutes Through 180 Minutes for Selected Recurrence Intervals for the Seattle Metropolitan Area.

Duration (minutes)	Duration (hours)	6-Month	2-Yr	5-Yr	10-Yr	20-Yr	25-Yr	50-Yr	100-Yr
5	0.0833	1.02	1.31	1.62	2.06	2.39	2.79	2.92	3.35
6	0.1000	0.97	1.23	1.52	1.93	2.23	2.60	2.72	3.10
8	0.1333	0.86	1.08	1.33	1.67	1.94	2.25	2.35	2.68
10	0.1667	0.76	0.96	1.17	1.48	1.70	1.98	2.07	2.36
12	0.2000	0.69	0.86	1.05	1.32	1.53	1.77	1.85	2.11
15	0.2500	0.60	0.75	0.92	1.15	1.33	1.54	1.61	1.83
20	0.3333	0.51	0.63	0.77	0.96	1.11	1.28	1.34	1.53
25	0.4167	0.45	0.56	0.67	0.84	0.96	1.11	1.16	1.32
30	0.5000	0.41	0.50	0.60	0.75	0.86	1.00	1.04	1.18
35	0.5833	0.37	0.46	0.55	0.69	0.79	0.91	0.95	1.07
40	0.6667	0.35	0.43	0.51	0.64	0.73	0.84	0.87	0.99
45	0.7500	0.33	0.40	0.48	0.60	0.68	0.78	0.82	0.92
50	0.8333	0.31	0.38	0.46	0.56	0.64	0.74	0.77	0.87
55	0.9167	0.30	0.36	0.43	0.53	0.61	0.70	0.73	0.82
60	1.0000	0.29	0.35	0.42	0.51	0.58	0.66	0.69	0.78
65	1.0833	0.28	0.34	0.40	0.49	0.56	0.63	0.66	0.74
70	1.1667	0.27	0.32	0.38	0.47	0.53	0.61	0.63	0.71
80	1.3333	0.25	0.30	0.36	0.44	0.50	0.57	0.59	0.66
90	1.5000	0.24	0.29	0.34	0.41	0.47	0.53	0.55	0.62
100	1.6667	0.23	0.27	0.32	0.39	0.44	0.50	0.52	0.58
120	2.0000	0.21	0.25	0.30	0.36	0.40	0.46	0.47	0.53
140	2.3333	0.20	0.24	0.28	0.33	0.37	0.42	0.44	0.49
160	2.6667	0.19	0.22	0.26	0.31	0.35	0.39	0.41	0.45
180	3.0000	0.18	0.21	0.25	0.29	0.33	0.37	0.38	0.42

Precipitation Intensities (in/hr)

Recurrence Interval (years)

Table 2. Two-hour Precipitation Magnitude-Frequency Values for Selected Recurrence Intervals for the Seattle Metropolitan Area.

Recurrence Interval	2-Hour Total (inches)
6-month	0.40
2-yr	0.58
5-yr	0.70
10-yr	0.78
20-yr	0.88
25-yr	0.92
50-yr	1.04
100-yr	1.14

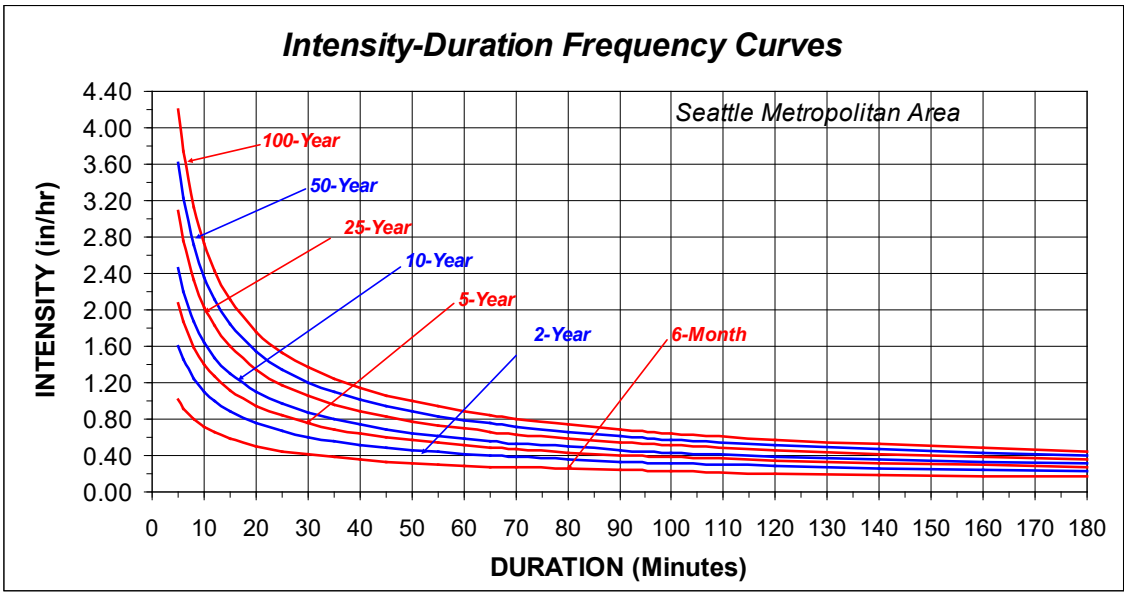

Figure 1. Intensity-Duration-Frequency Curves for the Seattle Metropolitan Area.

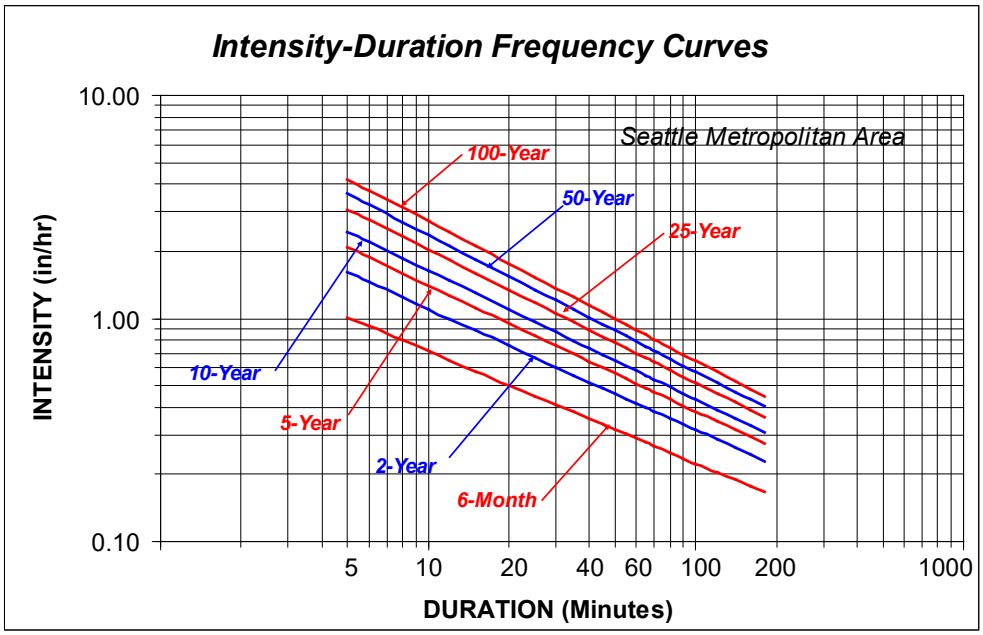

Figure 2. Intensity-Duration-Frequency Curves for the Seattle Metropolitan Area.

The following tables and figures contain estimates of precipitation-frequency values for durations of 6 hours, 12 hours, 24 hours, 48 hours, and 7 days for locations of SPU precipitation gauges (Table 2) in both tabular format and as magnitude-frequency curves. These precipitation values are based on estimates of the at-site mean values for the location of SPU gauges (Table 3) based on the spatial analysis of precipitation (gridded datasets) and the applicable regional growth curves obtained from the regional frequency analyses. Corrections have been applied to provide equivalent partial duration series estimates for frequently occurring events (5 times/year, 2 times/year, once/year, 2-year, and 5-year recurrence intervals).

Table 3. Listing of City of Seattle (SPU) Precipitation Gauges.

Station ID	Station Name	Latitude	Longitude	Year Start	Year End	Gauge Type
RG01	Haller Lake Shop	47.7211	122.3431	1965	2020	TB
RG02	Mathews Beach Pump Stn	47.6950	122.2731	1969	2020	TB
RG03	UW Hydraulics Lab	47.6481	122.3081	1965	2020	TB
RG04	Maple Leaf Reservoir	47.6900	122.3119	1965	2020	TB
RG05	Fauntleroy Ferry Dock	47.5231	122.3919	1968	2020	TB
RG07	Whitman Middle School	47.6961	122.3769	1965	2020	TB
RG08	Ballard Locks	47.6650	122.3969	1965	2020	TB
RG09	Woodland Park Zoo	47.6681	122.3539	1965	2020	TB
RG10	Rainier Ave Elementary	47.5000	122.2600	1968	2010	TB
RG11	Metro-KC Denny Regulating	47.6169	122.3550	1970	2020	TB
RG12	Catherine Blaine Jr	47.6419	122.3969	1965	2020	TB
RG14	West Seattle High School	47.5781	122.3819	1965	2020	TB
RG15	Metro-KC Diagonal Pump	47.5619	122.3400	1965	2020	TB
RG16	Metro-KC E Marginal Way	47.5350	122.3139	1970	2020	TB
RG17	West Seattle Engr Shop	47.5211	122.3450	1965	2020	TB
RG18	Hillman Engr Shop	47.5481	122.2750	1965	2020	TB
RG20	TT Minor Elementary	47.6119	122.3069	1975	2011	TB
RG25	Garfield Community Center	47.6076	-122.3020	2010	2020	TB
RG30	Rainier Beach Public Library	47.5214	-122.2700	2011	2020	TB
RG32	Beacon Telemetry Shack	47.5698	-122.3080	2016	2020	TB
RG33	Fire Station #38	47.6688	-122.2840	2016	2020	TB
RG34	Fire Station #39	47.7213	-122.2970	2016	2020	TB
RG35	Capitol Hill Library	47.6229	-122.3220	2016	2020	TB
RG36	High Point Library	47.5480	-122.3760	2016	2020	TB
45-7473	Seattle Tacoma Airport	47.4500	122.3000	1940	2020	HR

TB – Tipping Bucket

HR – NOAA Hourly Gauge

Table 4. Listing of Best Estimate At-site Mean Values for City of Seattle (SPU) Precipitation Gauges.

Station ID	Station Name	6 Hr	12 Hr	24 Hr	48 Hr	72 Hr	7 Day
RG01	Haller Lake Shop	1.020	1.495	2.000	2.465	2.985	4.290
RG02	Mathews Beach Pump Stn	1.030	1.525	2.105	2.595	3.085	4.470
RG03	UW Hydraulics Lab	1.055	1.535	2.075	2.570	3.060	4.330
RG04	Maple Leaf Reservoir	1.035	1.520	2.065	2.585	3.105	4.435
RG05	Fauntleroy Ferry Dock	1.070	1.560	2.115	2.675	3.105	4.260
RG07	Whitman Middle School	1.050	1.535	2.050	2.535	3.095	4.510
RG08	Ballard Locks	1.055	1.545	2.065	2.545	3.045	4.335
RG09	Woodland Park Zoo	1.020	1.480	1.980	2.465	2.935	4.190
RG10	Rainier Ave Elementary	1.100	1.595	2.250	2.825	3.345	4.630
RG11	Metro-KC Denny Regulating	1.025	1.500	2.020	2.520	2.955	4.100
RG12	Catherine Blaine Jr	1.045	1.530	2.045	2.550	3.080	4.435
RG14	West Seattle High School	1.065	1.570	2.110	2.665	3.205	4.495
RG15	Metro-KC Diagonal Pump	1.055	1.535	2.095	2.655	3.135	4.335
RG16	Metro-KC E Marginal Way	1.065	1.545	2.160	2.700	3.205	4.440
RG17	West Seattle Engr Shop	1.100	1.590	2.210	2.785	3.325	4.665
RG18	Hillman Engr Shop	1.080	1.560	2.165	2.735	3.235	4.510
RG20	TT Minor Elementary	1.080	1.595	2.150	2.720	3.170	4.440
RG25	Garfield Community Center	1.080	1.565	2.150	2.720	3.170	4.440
RG30	Rainier Beach Public Library	1.100	1.595	2.250	2.825	3.345	4.630
RG32	Beacon Telemetry Shack	1.070	1.555	2.150	2.700	3.195	4.465
RG33	Fire Station #38	1.045	1.525	2.090	2.600	3.100	4.430
RG34	Fire Station #39	1.025	1.510	2.045	2.525	3.030	4.390
RG35	Capitol Hill Library	1.055	1.540	2.100	2.625	3.125	4.415
RG36	High Point Library	1.070	1.560	2.120	2.670	3.165	4.400

Best Estimate At-Site Mean Values (inches)

Table 5. Precipitation-Magnitude-Frequency Estimates for of SPU Gauge 01.

Duration (hr)	0.5-Yr	1-Yr	2-Yr	5-Yr	10-Yr	25-Yr	50-Yr	100-Yr	500-Yr
6	0.75	0.89	1.03	1.23	1.37	1.58	1.74	1.91	2.31
12	1.05	1.26	1.48	1.78	1.99	2.32	2.56	2.81	3.40
24	1.39	1.70	2.01	2.44	2.75	3.22	3.58	3.94	4.83
48	1.67	2.05	2.45	2.98	3.37	3.96	4.41	4.86	5.97
72	2.05	2.50	2.95	3.56	3.99	4.63	5.11	5.59	6.72
168	2.92	3.55	4.18	4.98	5.53	6.32	6.89	7.44	8.67

Precipitation (in)

Recurrence Interval (years)

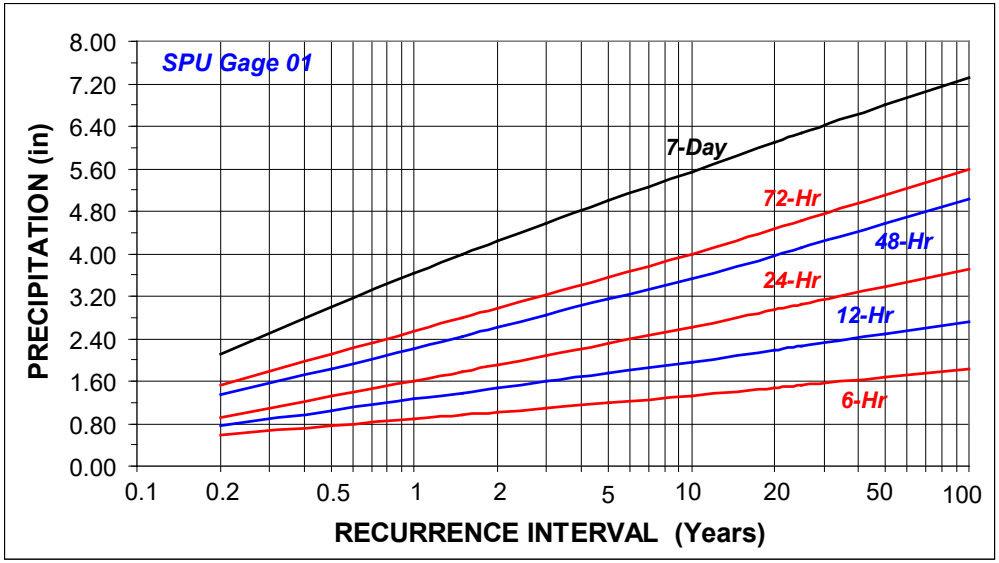

Figure 3. Precipitation-Magnitude-Frequency Estimates for of SPU Gauge 01.

Table 6. Precipitation-Magnitude-Frequency Estimates for SPU Gauge 02.

Duration (hr)	0.5-Yr	1-Yr	2-Yr	5-Yr	10-Yr	25-Yr	50-Yr	100-Yr	500-Yr
6	0.77	0.91	1.06	1.26	1.40	1.62	1.78	1.95	2.36
12	1.08	1.30	1.53	1.83	2.05	2.38	2.64	2.89	3.50
24	1.44	1.75	2.07	2.51	2.83	3.31	3.68	4.06	4.97
48	1.73	2.12	2.53	3.08	3.49	4.09	4.56	5.03	6.18
72	2.13	2.59	3.06	3.69	4.13	4.80	5.30	5.79	6.97
168	3.03	3.69	4.34	5.17	5.75	6.57	7.16	7.74	9.01

Precipitation (in)

Recurrence Interval (years)

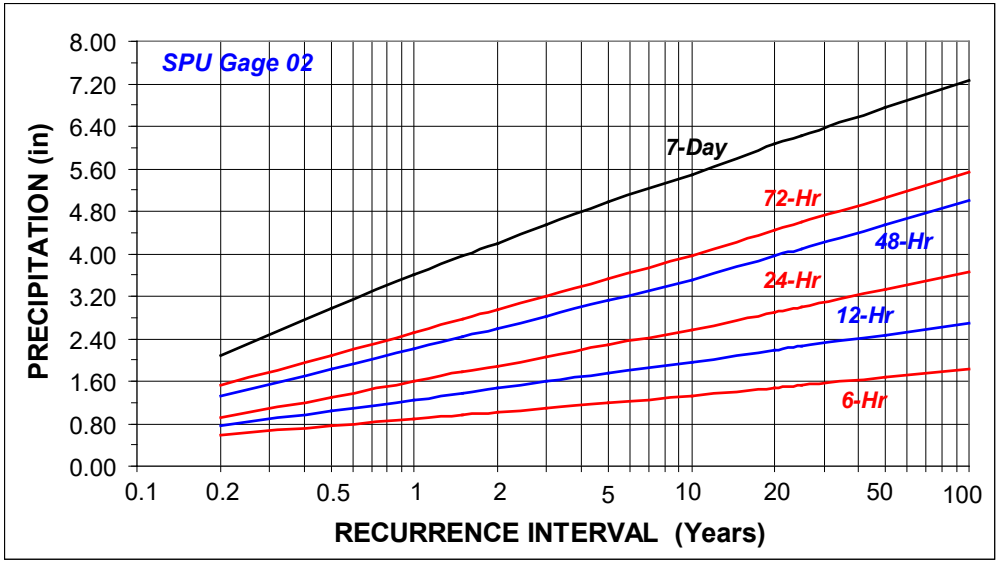

Figure 4. Precipitation-Magnitude-Frequency Estimates for SPU Gauge 02.

Table 7. Precipitation-Magnitude-Frequency Estimates for SPU Gauge 03.

Duration (hr)	0.5-Yr	1-Yr	2-Yr	5-Yr	10-Yr	25-Yr	50-Yr	100-Yr	500-Yr
6	0.77	0.91	1.06	1.26	1.41	1.62	1.79	1.96	2.37
12	1.09	1.31	1.53	1.84	2.06	2.39	2.65	2.90	3.52
24	1.44	1.75	2.08	2.52	2.84	3.33	3.70	4.08	4.99
48	1.74	2.14	2.55	3.10	3.51	4.12	4.59	5.06	6.22
72	2.14	2.60	3.08	3.71	4.16	4.83	5.33	5.83	7.01
168	3.05	3.71	4.37	5.21	5.79	6.61	7.21	7.78	9.07

Precipitation (in)

Recurrence Interval (years)

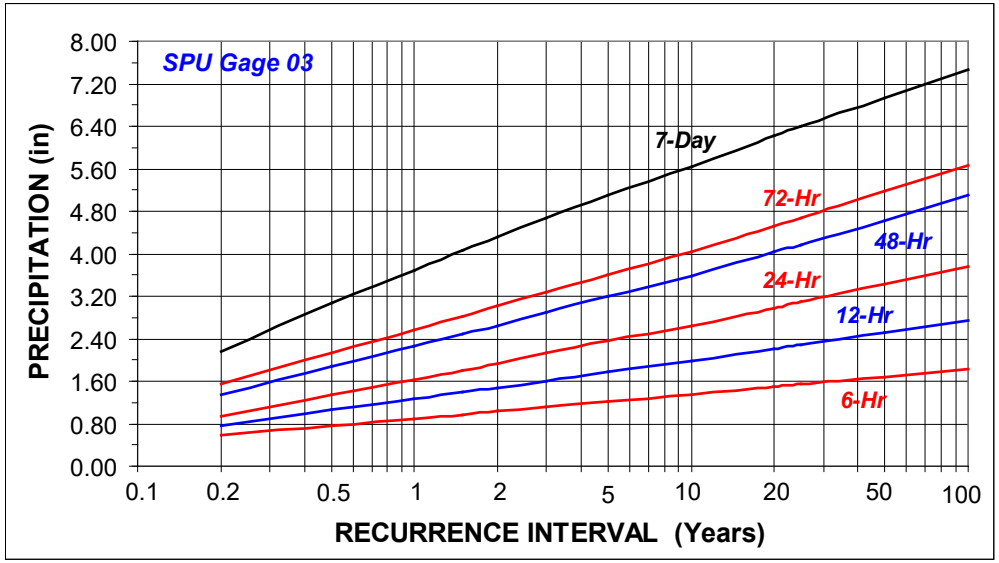

Figure 5. Precipitation-Magnitude-Frequency Estimates for SPU Gauge 03.

Table 8. Precipitation-Magnitude-Frequency Estimates for SPU Gauge 04.

Duration (hr)	0.5-Yr	1-Yr	2-Yr	5-Yr	10-Yr	25-Yr	50-Yr	100-Yr	500-Yr
6	0.77	0.91	1.06	1.26	1.40	1.62	1.78	1.95	2.36
12	1.08	1.30	1.53	1.83	2.05	2.38	2.64	2.89	3.50
24	1.44	1.75	2.07	2.51	2.83	3.31	3.68	4.06	4.97
48	1.73	2.12	2.53	3.08	3.49	4.09	4.56	5.03	6.18
72	2.13	2.59	3.06	3.69	4.13	4.80	5.30	5.79	6.97
168	3.03	3.69	4.34	5.17	5.75	6.57	7.16	7.74	9.01

Precipitation (in)

Recurrence Interval (years)

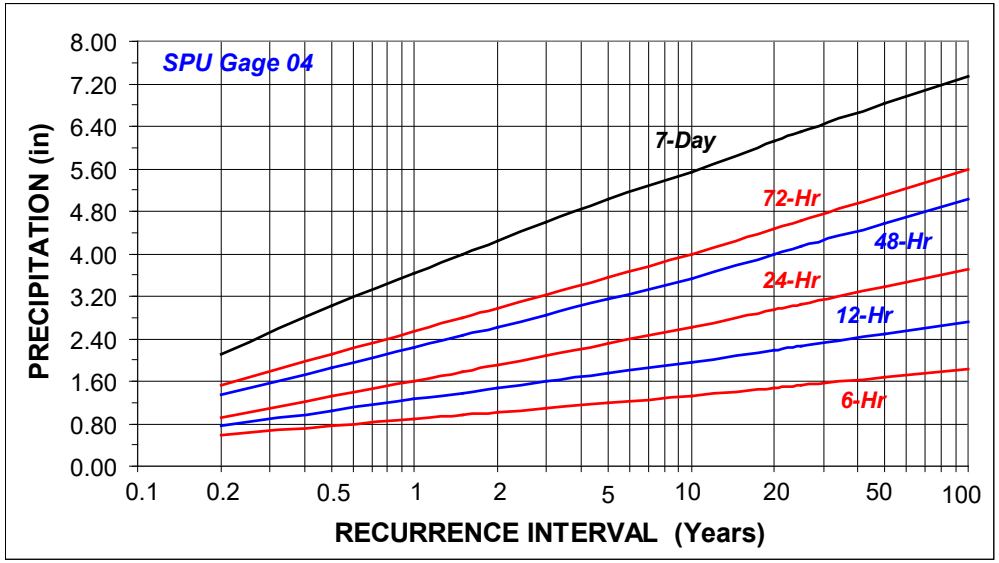

Figure 6. Precipitation-Magnitude-Frequency Estimates for SPU Gauge 04.

Table 9. Precipitation-Magnitude-Frequency Estimates for SPU Gauge 05.

Duration (hr)	0.5-Yr	1-Yr	2-Yr	5-Yr	10-Yr	25-Yr	50-Yr	100-Yr	500-Yr
6	0.80	0.94	1.09	1.30	1.45	1.67	1.85	2.02	2.44
12	1.13	1.36	1.59	1.91	2.14	2.48	2.75	3.01	3.65
24	1.50	1.82	2.16	2.62	2.95	3.45	3.84	4.23	5.18
48	1.82	2.23	2.66	3.24	3.66	4.30	4.79	5.29	6.50
72	2.24	2.72	3.22	3.88	4.35	5.05	5.58	6.10	7.33
168	3.20	3.90	4.59	5.47	6.08	6.94	7.57	8.17	9.52

Precipitation (in)

Recurrence Interval (years)

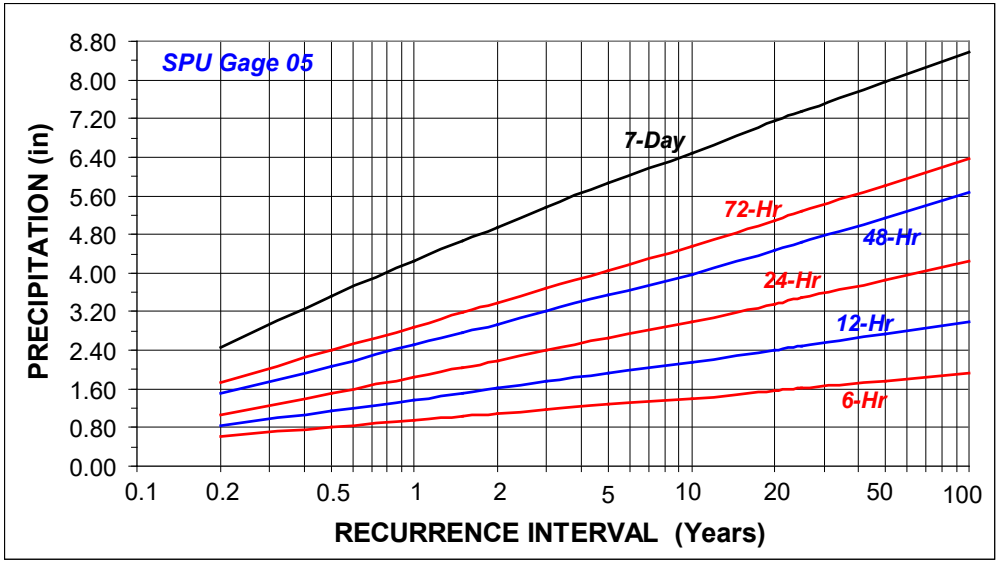

Figure 7. Precipitation-Magnitude-Frequency Estimates for SPU Gauge 05.

Table 10. Precipitation-Magnitude-Frequency Estimates for SPU Gauge 07.

Duration (hr)	0.5-Yr	1-Yr	2-Yr	5-Yr	10-Yr	25-Yr	50-Yr	100-Yr	500-Yr
6	0.77	0.91	1.06	1.26	1.40	1.62	1.78	1.95	2.36
12	1.08	1.30	1.53	1.83	2.05	2.38	2.64	2.89	3.50
24	1.44	1.75	2.07	2.51	2.83	3.31	3.68	4.06	4.97
48	1.73	2.12	2.53	3.08	3.49	4.09	4.56	5.03	6.18
72	2.13	2.59	3.06	3.69	4.13	4.80	5.30	5.79	6.97
168	3.03	3.69	4.34	5.17	5.75	6.57	7.16	7.74	9.01

Precipitation (in)

Recurrence Interval (years)

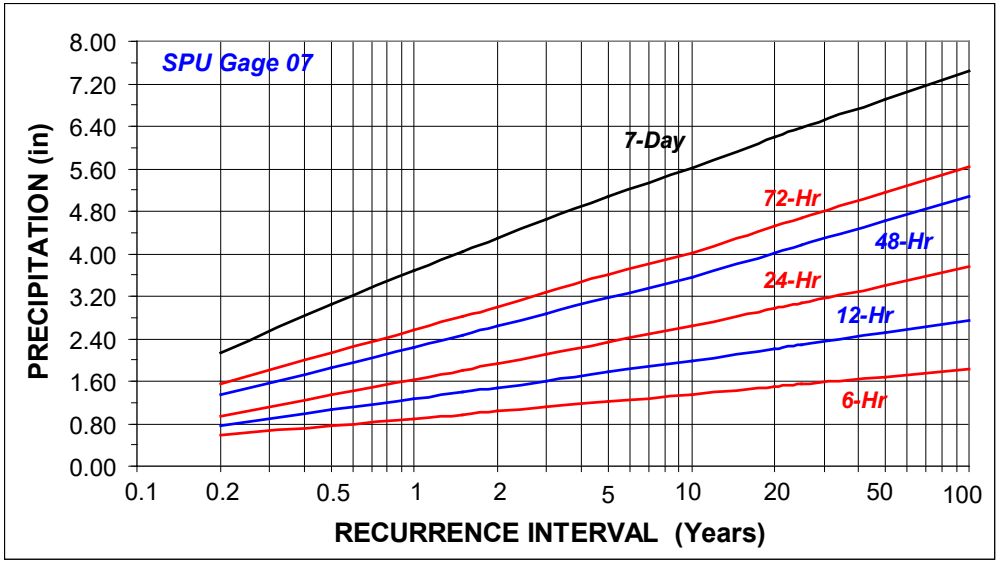

Figure 8. Precipitation-Magnitude-Frequency Estimates for SPU Gauge 07.

Table 11. Precipitation-Magnitude-Frequency Estimates for SPU Gauge 08.

Duration (hr)	0.5-Yr	1-Yr	2-Yr	5-Yr	10-Yr	25-Yr	50-Yr	100-Yr	500-Yr
6	0.78	0.92	1.07	1.27	1.41	1.63	1.80	1.97	2.38
12	1.09	1.31	1.54	1.85	2.07	2.41	2.66	2.92	3.53
24	1.45	1.76	2.09	2.53	2.86	3.34	3.72	4.10	5.01
48	1.75	2.15	2.56	3.12	3.53	4.14	4.61	5.09	6.25
72	2.15	2.62	3.09	3.73	4.18	4.85	5.36	5.86	7.05
168	3.07	3.74	4.40	5.24	5.82	6.65	7.25	7.83	9.12

Precipitation (in)

Recurrence Interval (years)

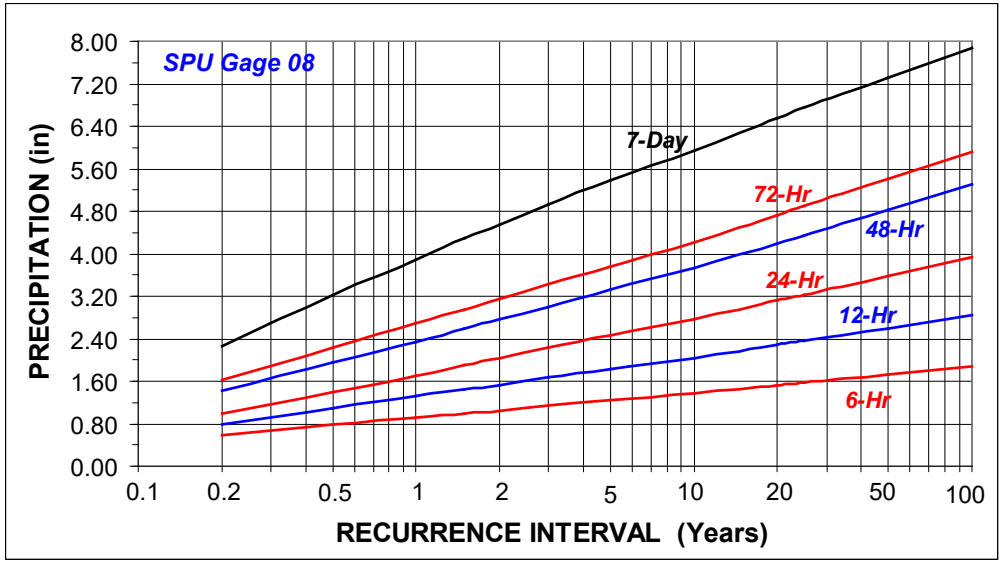

Figure 9. Precipitation-Magnitude-Frequency Estimates for SPU Gauge 08.

Table 12. Precipitation-Magnitude-Frequency Estimates for SPU Gauge 09.

Duration (hr)	0.5-Yr	1-Yr	2-Yr	5-Yr	10-Yr	25-Yr	50-Yr	100-Yr	500-Yr
6	0.77	0.91	1.06	1.26	1.41	1.62	1.79	1.96	2.37
12	1.09	1.31	1.53	1.84	2.06	2.39	2.65	2.90	3.52
24	1.44	1.75	2.08	2.52	2.84	3.33	3.70	4.08	4.99
48	1.74	2.14	2.55	3.10	3.51	4.12	4.59	5.06	6.22
72	2.14	2.60	3.08	3.71	4.16	4.83	5.33	5.83	7.01
168	3.05	3.71	4.37	5.21	5.79	6.61	7.21	7.78	9.07

Precipitation (in)

Recurrence Interval (years)

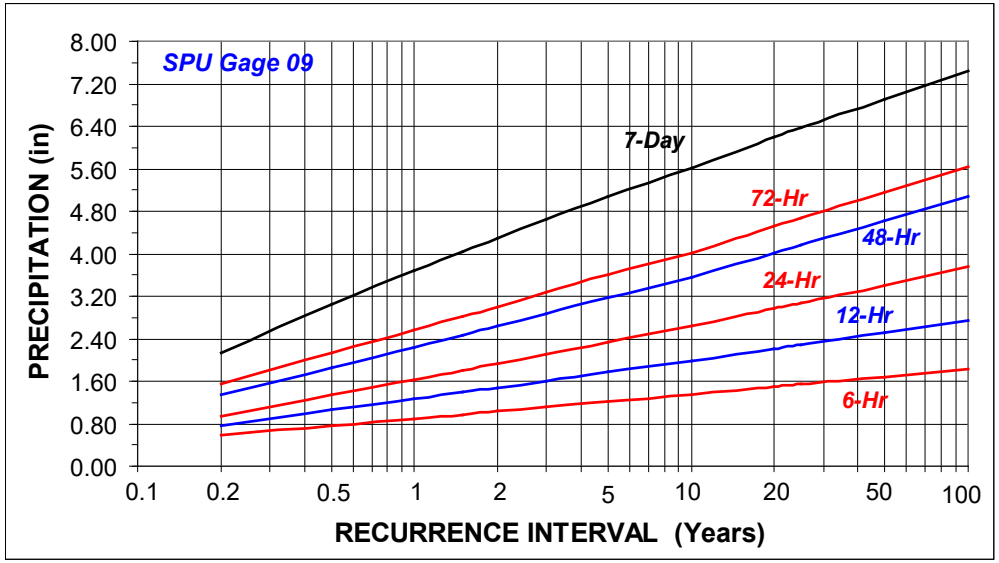

Figure 10. Precipitation-Magnitude-Frequency Estimates for SPU Gauge 09.

Table 13. Precipitation-Magnitude-Frequency Estimates for SPU Gauge 10.

Duration (hr)	0.5-Yr	1-Yr	2-Yr	5-Yr	10-Yr	25-Yr	50-Yr	100-Yr	500-Yr
6	0.81	0.96	1.12	1.33	1.48	1.71	1.89	2.07	2.50
12	1.16	1.39	1.63	1.96	2.20	2.55	2.82	3.09	3.74
24	1.54	1.87	2.22	2.69	3.04	3.55	3.95	4.36	5.33
48	1.88	2.30	2.75	3.35	3.78	4.44	4.95	5.46	6.71
72	2.31	2.81	3.33	4.01	4.50	5.22	5.76	6.30	7.58
168	3.32	4.04	4.75	5.66	6.29	7.19	7.84	8.46	9.86

Precipitation (in)

Recurrence Interval (years)

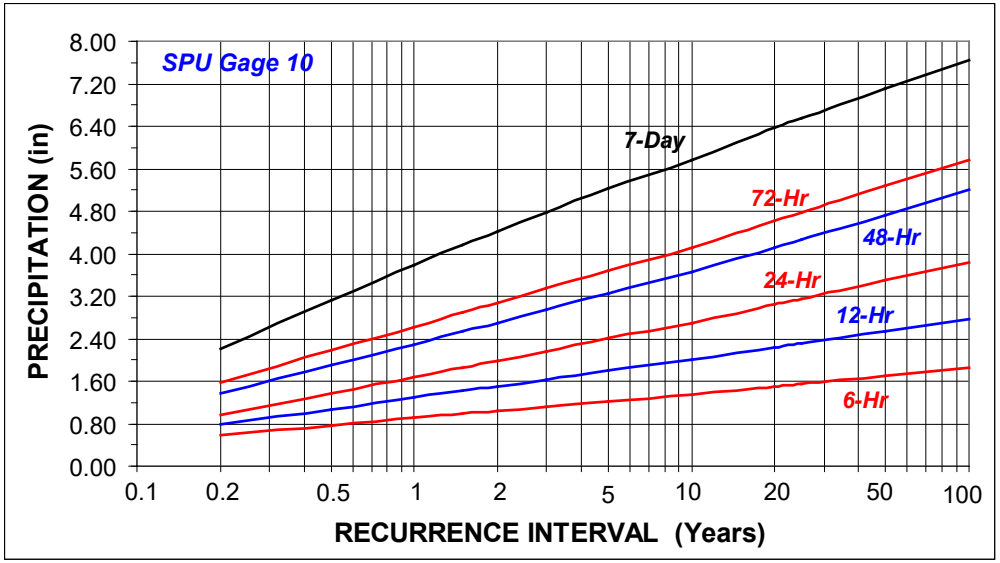

Figure 11. Precipitation-Magnitude-Frequency Estimates for SPU Gauge 10.

Table 14. Precipitation-Magnitude-Frequency Estimates for SPU Gauge 11.

Duration (hr)	0.5-Yr	1-Yr	2-Yr	5-Yr	10-Yr	25-Yr	50-Yr	100-Yr	500-Yr
6	0.78	0.92	1.07	1.27	1.42	1.64	1.80	1.98	2.39
12	1.10	1.32	1.55	1.86	2.08	2.42	2.67	2.93	3.55
24	1.46	1.77	2.10	2.55	2.87	3.36	3.73	4.12	5.04
48	1.76	2.16	2.57	3.14	3.55	4.16	4.64	5.12	6.29
72	2.16	2.63	3.11	3.75	4.21	4.88	5.39	5.90	7.09
168	3.09	3.76	4.42	5.27	5.86	6.70	7.30	7.88	9.18

Precipitation (in)

Recurrence Interval (years)

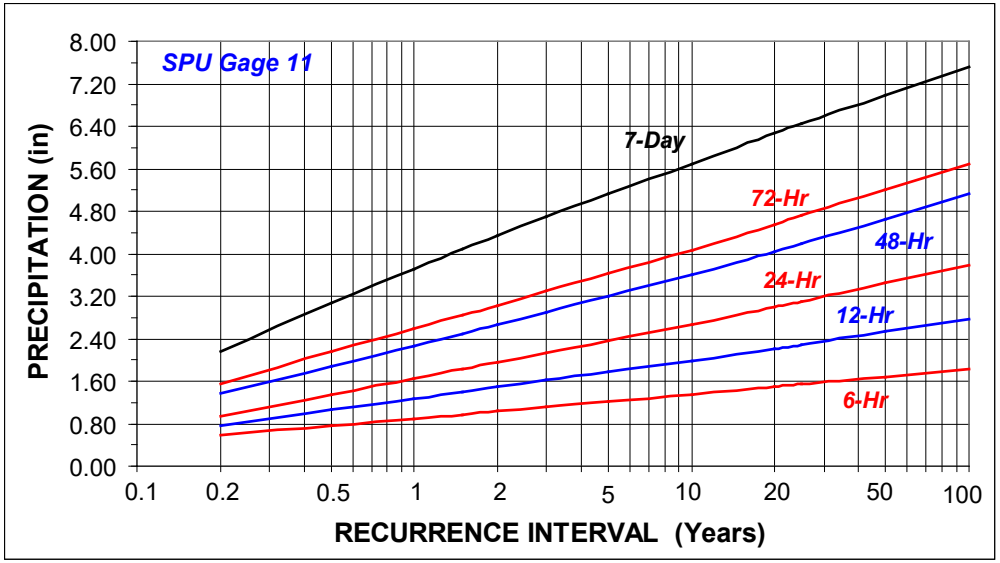

Figure 12. Precipitation-Magnitude-Frequency Estimates for SPU Gauge 11.

Table 15. Precipitation-Magnitude-Frequency Estimates for SPU Gauge 12.

Duration (hr)	0.5-Yr	1-Yr	2-Yr	5-Yr	10-Yr	25-Yr	50-Yr	100-Yr	500-Yr
6	0.78	0.92	1.07	1.27	1.41	1.63	1.80	1.97	2.38
12	1.09	1.31	1.54	1.85	2.07	2.41	2.66	2.92	3.53
24	1.45	1.76	2.09	2.53	2.86	3.34	3.72	4.10	5.01
48	1.75	2.15	2.56	3.12	3.53	4.14	4.61	5.09	6.25
72	2.15	2.62	3.09	3.73	4.18	4.85	5.36	5.86	7.05
168	3.07	3.74	4.40	5.24	5.82	6.65	7.25	7.83	9.12

Precipitation (in)

Recurrence Interval (years)

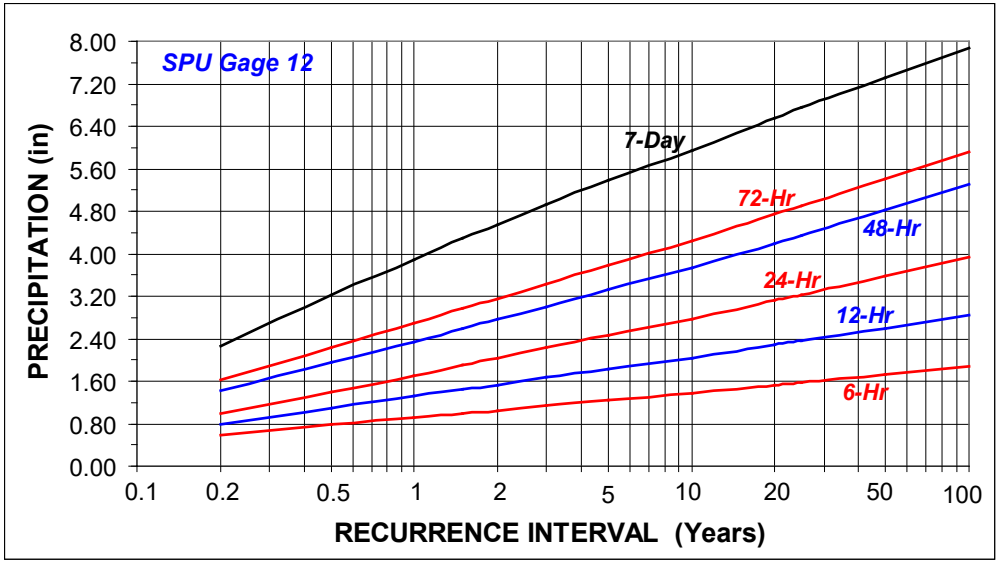

Figure 13. Precipitation-Magnitude-Frequency Estimates for SPU Gauge 12.

Table 16. Precipitation-Magnitude-Frequency Estimates for SPU Gauge 14.

Duration (hr)	0.5-Yr	1-Yr	2-Yr	5-Yr	10-Yr	25-Yr	50-Yr	100-Yr	500-Yr
6	0.79	0.93	1.09	1.29	1.44	1.66	1.83	2.01	2.43
12	1.12	1.34	1.58	1.89	2.12	2.46	2.72	2.99	3.61
24	1.49	1.81	2.14	2.60	2.93	3.43	3.81	4.20	5.14
48	1.80	2.21	2.63	3.21	3.62	4.26	4.74	5.23	6.43
72	2.21	2.69	3.18	3.84	4.30	4.99	5.51	6.03	7.25
168	3.17	3.85	4.53	5.40	6.00	6.86	7.48	8.08	9.41

Precipitation (in)

Recurrence Interval (years)

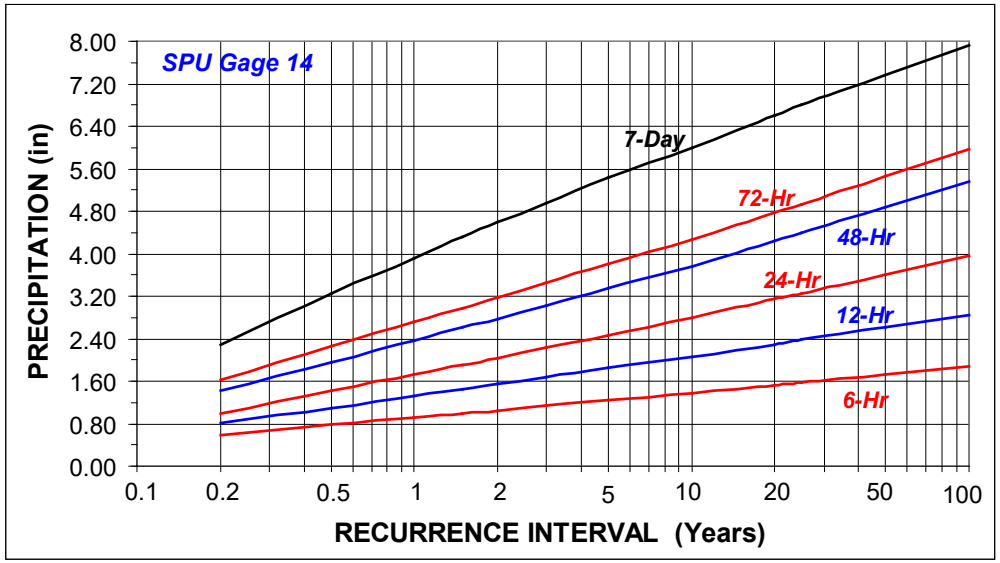

Figure 14. Precipitation-Magnitude-Frequency Estimates for SPU Gauge 14.

Table 17. Precipitation-Magnitude-Frequency Estimates for SPU Gauge 15.

Duration (hr)	0.5-Yr	1-Yr	2-Yr	5-Yr	10-Yr	25-Yr	50-Yr	100-Yr	500-Yr
6	0.78	0.92	1.07	1.28	1.42	1.64	1.81	1.98	2.40
12	1.10	1.32	1.56	1.87	2.09	2.43	2.69	2.95	3.56
24	1.46	1.78	2.11	2.56	2.88	3.38	3.75	4.14	5.06
48	1.77	2.17	2.59	3.15	3.57	4.19	4.66	5.15	6.32
72	2.18	2.65	3.13	3.77	4.23	4.91	5.42	5.93	7.13
168	3.11	3.78	4.45	5.30	5.90	6.74	7.34	7.93	9.24

Precipitation (in)

Recurrence Interval (years)

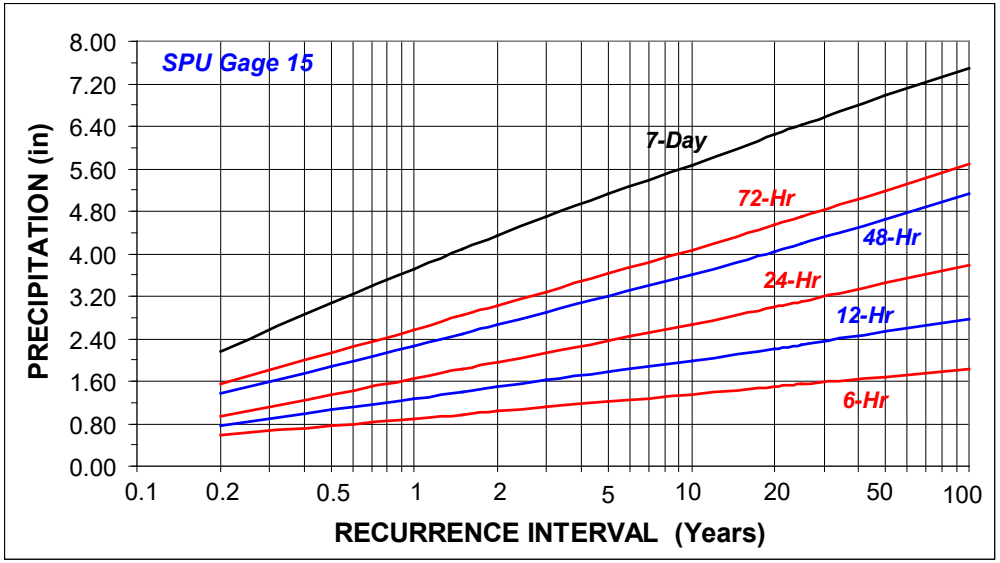

Figure 15. Precipitation-Magnitude-Frequency Estimates for SPU Gauge 15.

Table 18. Precipitation-Magnitude-Frequency Estimates for SPU Gauge 16.

Duration (hr)	0.5-Yr	1-Yr	2-Yr	5-Yr	10-Yr	25-Yr	50-Yr	100-Yr	500-Yr
6	0.79	0.93	1.08	1.29	1.43	1.65	1.82	2.00	2.42
12	1.11	1.34	1.57	1.88	2.11	2.45	2.71	2.97	3.60
24	1.48	1.80	2.13	2.59	2.91	3.41	3.79	4.18	5.12
48	1.79	2.20	2.62	3.19	3.60	4.23	4.72	5.21	6.39
72	2.20	2.68	3.17	3.82	4.28	4.97	5.48	6.00	7.21
168	3.15	3.83	4.51	5.37	5.97	6.82	7.43	8.03	9.35

Precipitation (in)

Recurrence Interval (years)

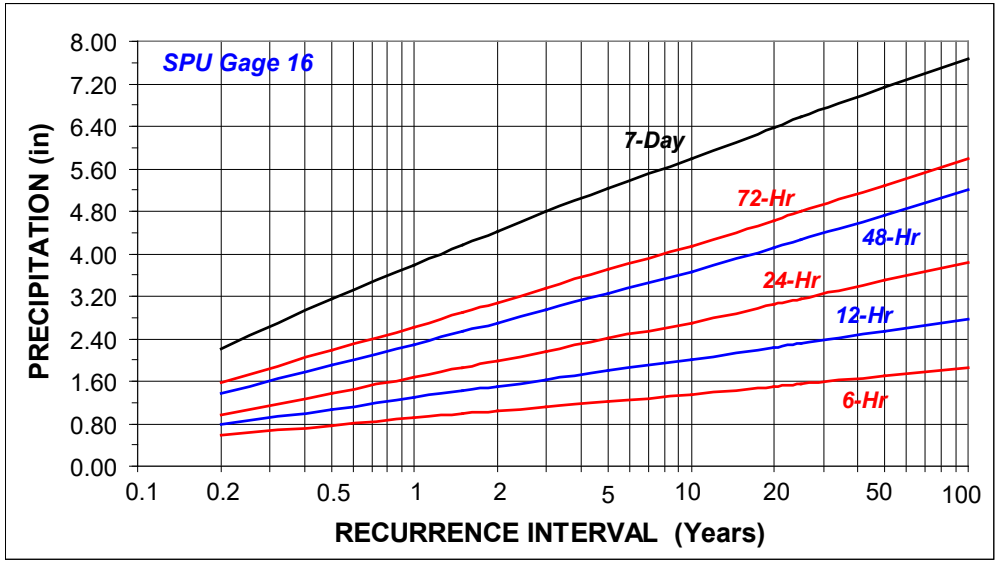

Figure 16. Precipitation-Magnitude-Frequency Estimates for SPU Gauge 16.

Table 19. Precipitation-Magnitude-Frequency Estimates for SPU Gauge 17.

Duration (hr)	0.5-Yr	1-Yr	2-Yr	5-Yr	10-Yr	25-Yr	50-Yr	100-Yr	500-Yr
6	0.81	0.96	1.12	1.33	1.48	1.71	1.89	2.07	2.50
12	1.16	1.39	1.63	1.96	2.20	2.55	2.82	3.09	3.74
24	1.54	1.87	2.22	2.69	3.04	3.55	3.95	4.36	5.33
48	1.88	2.30	2.75	3.35	3.78	4.44	4.95	5.46	6.71
72	2.31	2.81	3.33	4.01	4.50	5.22	5.76	6.30	7.58
168	3.32	4.04	4.75	5.66	6.29	7.19	7.84	8.46	9.86

Precipitation (in)

Recurrence Interval (years)

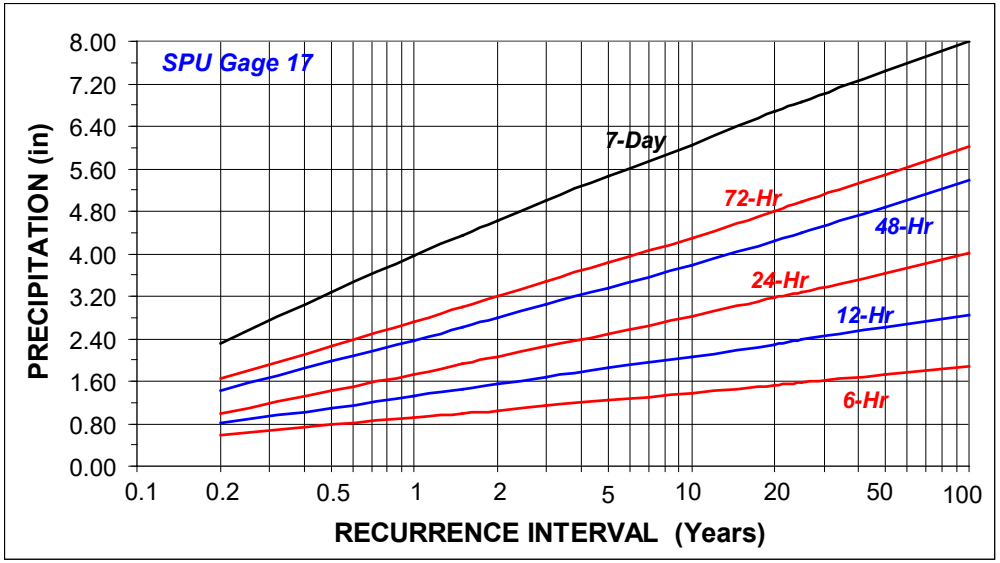

Figure 17. Precipitation-Magnitude-Frequency Estimates for SPU Gauge 17.

Table 20. Precipitation-Magnitude-Frequency Estimates for SPU Gauge 18.

Duration (hr)	0.5-Yr	1-Yr	2-Yr	5-Yr	10-Yr	25-Yr	50-Yr	100-Yr	500-Yr
6	0.79	0.93	1.08	1.28	1.43	1.65	1.82	1.99	2.41
12	1.11	1.33	1.56	1.87	2.10	2.44	2.70	2.96	3.58
24	1.47	1.79	2.12	2.57	2.90	3.39	3.77	4.16	5.09
48	1.78	2.18	2.60	3.17	3.59	4.21	4.69	5.18	6.36
72	2.19	2.66	3.15	3.79	4.26	4.94	5.45	5.96	7.17
168	3.13	3.81	4.48	5.34	5.93	6.78	7.39	7.98	9.29

Precipitation (in)

Recurrence Interval (years)

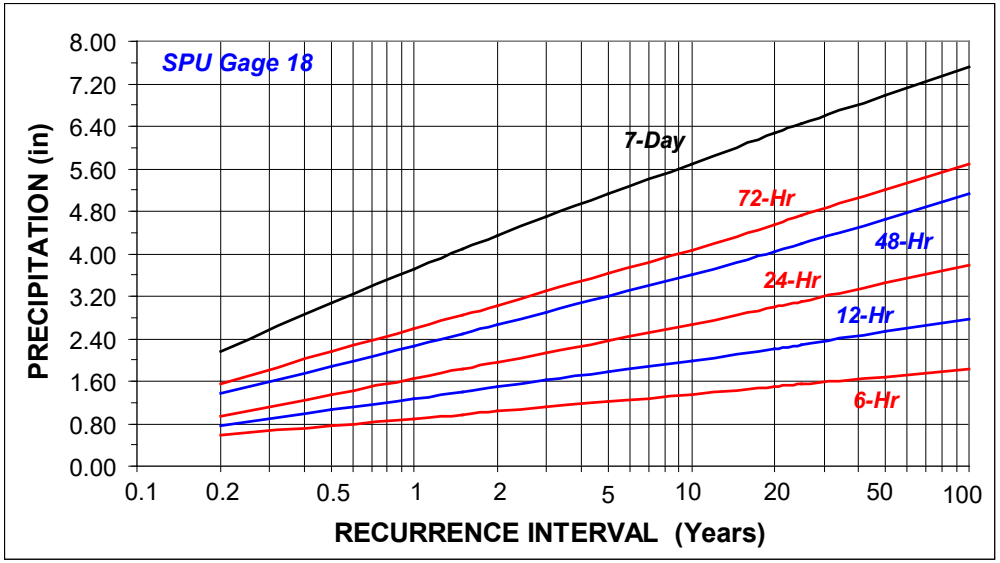

Figure 18. Precipitation-Magnitude-Frequency Estimates for SPU Gauge 18.

Table 21. Precipitation-Magnitude-Frequency Estimates for SPU Gauge 25.

Duration (hr)	0.5-Yr	1-Yr	2-Yr	5-Yr	10-Yr	25-Yr	50-Yr	100-Yr	500-Yr
6	0.79	0.93	1.08	1.28	1.43	1.65	1.82	1.99	2.41
12	1.11	1.33	1.56	1.87	2.10	2.44	2.70	2.96	3.58
24	1.47	1.79	2.12	2.57	2.90	3.39	3.77	4.16	5.09
48	1.78	2.18	2.60	3.17	3.59	4.21	4.69	5.18	6.36
72	2.19	2.66	3.15	3.79	4.26	4.94	5.45	5.96	7.17
168	3.13	3.81	4.48	5.34	5.93	6.78	7.39	7.98	9.29

Precipitation (in)

Recurrence Interval (years)

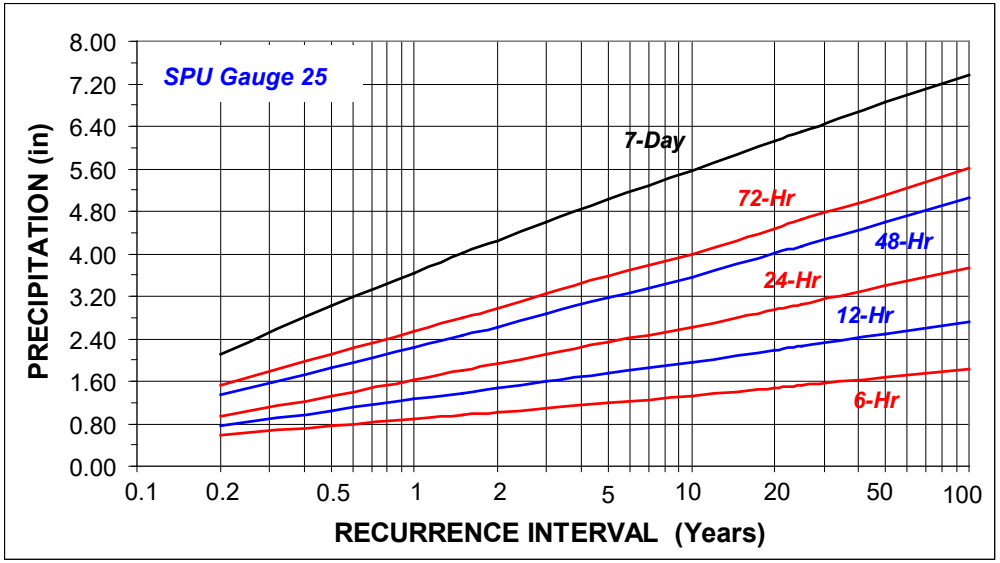

Figure 19. Precipitation-Magnitude-Frequency Estimates for SPU Gauge 25.

Table 22. Precipitation-Magnitude-Frequency Estimates for SeaTac.

Duration (hr)	0.5-Yr	1-Yr	2-Yr	5-Yr	10-Yr	25-Yr	50-Yr	100-Yr	500-Yr
6	0.82	0.97	1.13	1.34	1.50	1.73	1.91	2.09	2.52
12	1.17	1.41	1.65	1.98	2.22	2.58	2.85	3.13	3.79
24	1.56	1.90	2.25	2.73	3.08	3.60	4.01	4.42	5.41
48	1.91	2.34	2.78	3.39	3.84	4.50	5.02	5.54	6.80
72	2.35	2.86	3.38	4.07	4.57	5.30	5.85	6.40	7.70
168	3.37	4.10	4.83	5.76	6.40	7.31	7.97	8.61	10.02

Precipitation (in)

Recurrence Interval (years)

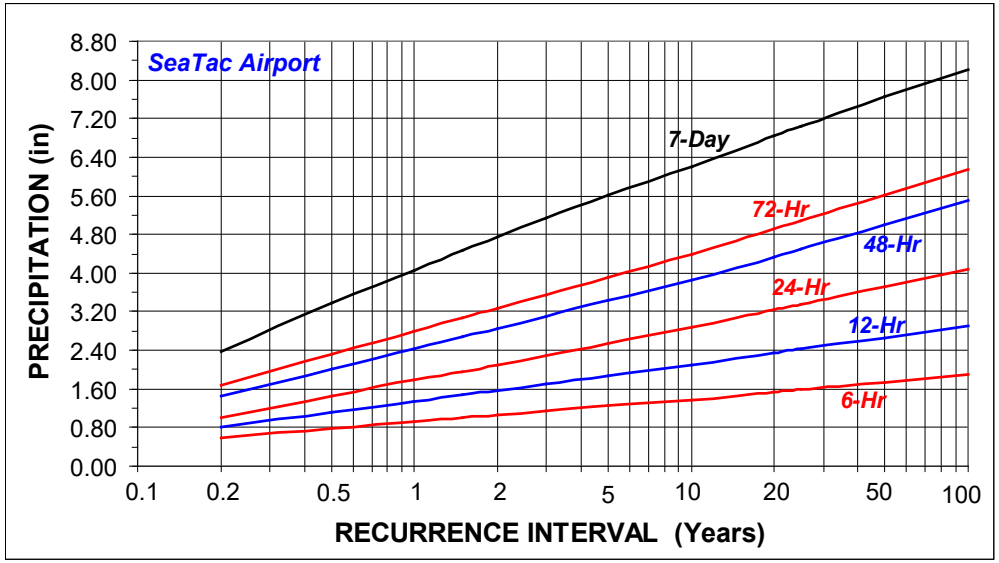

Figure 20. Precipitation-Magnitude-Frequency Estimates for SeaTac.

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APPENDIX G

Stormwater Control Operations and Maintenance Requirements

City of Seattle | Stormwater Manual

July 2026

City of Seattle

This appendix contains the maintenance requirements for the following typical stormwater BMPs and components:

No. 1 – Detention Ponds G-2
No. 2 – Infiltration BMPs G-5
No. 3 – Detention Pipes and Vaults G-10
No. 4 – Flow Control Structure & Control Device G-13
No. 5 – Catch Basins and Maintenance Holes G-18
No. 6 – Reserved G-22
No. 7 – Debris Barriers (e.g., Trash Racks) G-23
No. 8 – Energy Dissipaters G-24
No. 9 – Basic and Compost-Amended Biofiltration Swales G-26
No. 10 – Wet and Continuous Inflow Biofiltration Swales G-28
No. 11 – Filter Strips (Basic and CAVFS) G-30
No. 12 – Wet Ponds G-32
No. 13 – Wet Vaults G-36
No. 14 – Stormwater Treatment Wetlands G-39
No. 15 – Sand Filter Basins G-43
No. 16 – Sand Filter Vaults G-47
No. 17 – Proprietary Technology Filter Cartridge Systems (example: BayFilter, FloGard PerkFilter, StormFilter) G-50
No. 18 – API Oil/Water Separators G-53
No. 19 – Coalescing Plate Oil/Water Separators G-56
No. 20 – Catch Basin Filter Socks G-59
No. 21 – Proprietary Technology Filterra System G-60
No. 22 – Proprietary Technology Modular Wetland System G-62
No. 23 – Bioretention Facilities G-64
No. 24 – Cisterns G-71
No. 25 – Downspout, Sheet Flow, and Concentrated Dispersion Systems G-72
No. 26 – Permeable Pavement1 ..... G-76
No. 27 – Trees G-79
No. 28 – Vegetated Roof Systems G-80
No. 29 – Rain Gardens G-83

Refer to the *Stormwater Management Manual for Western Washington* (SWMMWW) (Ecology 2024) for maintenance requirements for the following BMP:

- Media filter drain (MFD)

All stormwater facilities, best management practices (BMPs), and drainage systems shall be kept in continuous working order consistent with their design and permitting. All stormwater facilities, BMPs, and drainage systems shall be kept accessible for maintenance and inspection at all times.

Any evidence of contaminants or pollution such as oil, gasoline, concrete slurries, or paint shall be immediately corrected. This includes removing the source of the contamination as well as any contaminants that have been collected or deposited into the facility or conveyance system.

Materials removed shall be disposed of according to applicable regulations. Refer to *Volume 4, Section 2.1.3. BMP 3: Dispose of Fluids and Wastes Properly*.

Training/written guidance is required for the proper operation and maintenance of many of the BMPs contained in this manual. Provide proper training and copies of the Operations and Maintenance Manuals to property owners, tenants, and responsible individuals.

No. 1 – Detention Ponds

Maintenance Component	Recommended Inspection Frequency[1]	Defect or Problem	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed
Facility – General Requirements	A	Trash and debris	Any trash and debris that exceeds 1 cubic foot per 1,000 square feet (this is about equal to the amount of trash it would take to fill up one standard size office garbage can).	Trash and debris cleared from site.
	M (March – October)	Noxious weeds	Any noxious or nuisance vegetation that may constitute a hazard to City personnel or the public.	Noxious and nuisance vegetation removed according to applicable regulations. No danger of noxious vegetation where City personnel or the public might normally be.
	A, E	Contaminants and pollution	Any evidence of contaminants or pollution such as oil, gasoline, concrete slurries, or paint.	Materials removed and disposed of according to applicable regulations. Source control BMPs implemented if appropriate. No contaminants present other than a surface oil film.
Top or Side Slopes of Dam, Berm, or Embankment	A	Rodent holes	Any evidence of rodent holes if facility is acting as a dam or berm, or any evidence of water piping through dam or berm via rodent holes.	Rodents removed or destroyed and dam or berm repaired.
	A	Beaver dams	Dam results in change or function of the facility.	Facility is returned to design function (coordinate trapping of beavers and removal of dams with appropriate permitting agencies).

No. 1 – Detention Ponds

Maintenance Component	Recommended Inspection Frequency[1]	Defect or Problem	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed
Top or Side Slopes of Dam, Berm, or Embankment (continued)	A	Tree growth	Tree growth threatens integrity of dams, berms, or slopes; does not allow maintenance access; or interferes with maintenance activity. If trees are not a threat to dam, berm, or embankment integrity or not interfering with access or maintenance, they do not need to be removed.	Trees do not hinder facility performance or maintenance activities.
	A	Erosion	Eroded damage over 2 inches deep where cause of damage is still present or where there is potential for continued erosion. Any erosion observed on a compacted slope.	Slopes stabilized using appropriate erosion control measures. If erosion is occurring on compacted slope, a licensed engineer should be consulted to resolve the source of erosion.
	A	Settlement	Any part of a dam, berm, or embankment that has settled 4 inches lower than the design elevation.	Top or side slope restored to design dimensions. If settlement is significant, a licensed engineer should be consulted to determine the cause of the settlement.
Storage Area	A	Sediment accumulation	Accumulated sediment that exceeds 10 percent of the designed pond depth.	Sediment cleaned out to designed pond shape and depth. Pond re-seeded if necessary to control erosion.
	A	Liner damaged (if applicable)	Liner is visible or pond does not hold water as designed.	Liner repaired or replaced.
Inlet/Outlet Pipe	A	Sediment accumulation	Sediment filling 1/3 or more of the pipe.	Inlet/outlet pipes clear of sediment.

No. 1 – Detention Ponds

Maintenance Component	Recommended Inspection Frequency[1]	Defect or Problem	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed
Inlet/Outlet Pipe (continued)	B, W, E	Trash and debris	Trash and debris accumulated in inlet/outlet pipes (includes floatables and non-floatables).	No trash or debris in pipes.
	A	Damaged	Cracks wider than ½ inch at the joint of the inlet/outlet pipes. Any evidence of soil entering at the joints of the inlet/outlet pipes.	No cracks more than ¼ inch wide at the joint of the inlet/outlet pipe.
Emergency Overflow/Spillway	A	Tree growth	Tree growth impedes flow or threatens stability of spillway.	Trees removed.
	A	Rock missing	Only one layer of rock exists above native soil in an area 5 square feet or larger or any exposure of native soil on the spillway.	Spillway restored to design standards.

[1] Inspection frequency:

A = Annually; B = Biannually; M = Monthly; E = Recommend that additional inspections be performed as appropriate after major events (e.g., >1 inch of precipitation in 24 hours or environmental incident that causes contaminant release); Q = Quarterly (four times per year); W = Recommend that at least one inspection occur during the wet season, preferably after trees have lost their leaves.

No. 2 – Infiltration BMPs

Maintenance Component	Recommended Inspection Frequency[1]	Defect or Problem	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed
Facility – General Requirements	A, W	Trash and debris	Any trash and debris that exceeds 1 cubic foot per 1,000 square feet (this is about equal to the amount of trash it would take to fill up one standard size office garbage can).	Trash and debris cleared from site.
	M (March – October)	Noxious weeds	Any noxious or nuisance vegetation that may constitute a hazard to City personnel or the public.	Noxious and nuisance vegetation removed according to applicable regulations. No danger of noxious vegetation where City personnel or the public might normally be.
	A, W, E	Contaminants and pollution	Any evidence of contaminants or pollution such as oil, gasoline, concrete slurries, or paint.	Materials removed and disposed of according to applicable regulations. Source control BMPs implemented if appropriate. No contaminants present other than a surface oil film.
	A	Grass/groundcover	Grass or groundcover exceeds 18 inches in height.	Grass or groundcover mowed to a height no greater than 6 inches.
Infiltration Pond, Top or Side Slopes of Dam, Berm, or Embankment	A	Rodent holes	Any evidence of rodent holes if facility is acting as a dam or berm, or any evidence of water piping through dam or berm via rodent holes.	Rodents removed or destroyed and dam or berm repaired.

No. 2 – Infiltration BMPs

Maintenance Component	Recommended Inspection Frequency[1]	Defect or Problem	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed
Infiltration Pond, Top or Side Slopes of Dam, Berm, or Embankment (continued)	A	Tree growth	Tree growth threatens integrity of dams, berms, or slopes; does not allow maintenance access; or interferes with maintenance activity. If trees are not a threat to dam, berm, or embankment integrity or not interfering with access or maintenance, they do not need to be removed.	Trees do not hinder facility performance or maintenance activities.
	A	Erosion	Eroded damage over 2 inches deep where cause of damage is still present or where there is potential for continued erosion. Any erosion observed on a compacted slope.	Slopes stabilized using appropriate erosion control measures. If erosion is occurring on compacted slope, a licensed engineer should be consulted to resolve the source of erosion.
	A	Settlement	Any part of a dam, berm, or embankment that has settled 4 inches lower than the design elevation.	Top or side slope restored to design dimensions. If settlement is significant, a licensed engineer should be consulted to determine the cause of the settlement.
Infiltration Pond, Tank, Vault, Trench, or Small Basin Storage Area	A	Sediment accumulation	If 2 inches or more of sediment is present or a percolation test indicates facility is working at or less than 90 percent of design.	Facility infiltrates as designed.
	A	Liner damaged (if applicable)	Liner is visible or pond does not hold water as designed.	Liner repaired or replaced.

No. 2 – Infiltration BMPs

Maintenance Component	Recommended Inspection Frequency[1]	Defect or Problem	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed
Infiltration Tank Structure	A	Plugged air vent	Any blockage of the vent.	Tank or vault freely vents.
	A	Tank bent out of shape	Any part of tank/pipe is bent out of shape more than 10 percent of its design shape.	Tank repaired or replaced to design.
	A	Gaps between sections, damaged joints, or cracks or tears in wall	A gap wider than ½ inch at the joint of any tank sections. Any evidence of soil particles entering the tank at a joint or through a wall.	No water or soil entering tank through joints or walls.
Infiltration Vault Structure	A	Damage to wall, frame, bottom, and/or top slab	Cracks wider than ½ inch. Any evidence of soil entering the structure through cracks. Qualified inspection personnel determines that the vault is not structurally sound.	Vault is sealed and structurally sound.
Inlet/Outlet Pipes	A	Sediment accumulation	Sediment filling 1/3 or more of the pipe.	Inlet/outlet pipes clear of sediment.
	B, W, E	Trash and debris	Trash and debris accumulated in inlet/outlet pipes (includes floatables and non-floatables).	No trash or debris in pipes.
	A	Damaged	Cracks wider than ½ inch at the joint of the inlet/outlet pipes. Any evidence of soil entering at the joints of the inlet/outlet pipes.	No cracks more than ¼inch wide at the joint of the inlet/outlet pipe.
Access Maintenance Hole	A	Cover/lid not in place	Cover/lid is missing or only partially in place. **Any open maintenance hole requires immediate maintenance.**	Maintenance hole access cover/lid in place and secure.

No. 2 – Infiltration BMPs

Maintenance Component	Recommended Inspection Frequency[1]	Defect or Problem	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed
Access Maintenance Hole (continued)	A	Locking mechanism not working	Mechanism cannot be opened by one maintenance person with proper tools. Bolts cannot be seated. Self-locking cover/lid does not work.	Mechanism opens with proper tools.
	A	Cover/lid difficult to remove	One maintenance person cannot remove cover/lid after applying 80 lbs of lift.	Cover/lid can be removed and reinstalled by one maintenance person.
	A	Ladder rungs unsafe	Missing rungs, misalignment, rust, or cracks.	Ladder meets design standards and allows maintenance person safe access.
Large Access Doors/Plate	A	Damaged or difficult to open	Large access doors or plates cannot be opened/removed using normal equipment.	Replace or repair access door so it can be opened as designed.
	A	Gaps, does not cover completely	Large access doors not flat and/or access opening not completely covered.	Doors close flat and cover access opening completely.
	A	Lifting rings missing, rusted	Lifting rings not capable of lifting weight of door or plate.	Lifting rings sufficient to lift or remove door or plate.
Infiltration Pond, Tank, Vault, Trench, or Small Basin Filter Bags	A	Plugged	Filter bag more than 1/2 full.	Replace filter bag or redesign system.
Infiltration Pond, Tank, Vault, Trench, or Small Basin Pre-settling Ponds and Vaults	A, W	Sediment accumulation	Six inches or more of sediment has accumulated.	Pre-settling occurs as designed.
Infiltration Pond, Rock Filter	A	Plugged	High water level on upstream side of filter remains for extended period of time or little or no water flows through filter during heavy rainstorms.	Rock filter replaced; evaluate need for filter and remove if not necessary.

No. 2 – Infiltration BMPs

Maintenance Component	Recommended Inspection Frequency[1]	Defect or Problem	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed
Infiltration Pond Emergency Overflow Spillway	A	Rock missing	Only one layer of rock exists above native soil in an area 5 square feet or larger, or any exposure of native soil at the top of outflow path of spillway. Rip-rap on inside slopes need not be replaced.	Spillway restored to design standards.
	A	Tree growth	Tree growth impedes flow or threatens stability of spillway.	Trees removed.
Drain Rock	A, W	Water ponding	If water enters the facility from the surface, inspect to see if water is ponding at the surface during storm events. If buried drain rock, observe drawdown through observation/ maintenance port or cleanout.	Clear piping through facility when ponding occurs. Replace rock material/sand reservoirs as necessary. Tilling of subgrade below reservoir may be necessary (for trenches) prior to backfill.

[1] Inspection frequency:

A = Annually; B = Biannually; M = Monthly; E = Recommend that additional inspections be performed as appropriate after major events (e.g., >1 inch of precipitation in 24 hours or environmental incident that causes contaminant release); Q = Quarterly (four times per year); W = Recommend that at least one inspection occur during the wet season, preferably after trees have lost their leaves.

No. 3 – Detention Pipes and Vaults

Maintenance Component	Recommended Inspection Frequency[1]	Defect or Problem	Conditions When Maintenance is Needed	Results Expected When Maintenance is Performed
Facility – General Requirements	A, E	Contaminants and pollution	Any evidence of contaminants or pollution such as oil, gasoline, concrete slurries, or paint.	Materials removed and disposed of according to applicable regulations. Source control BMPs implemented if appropriate. No contaminants present other than a surface oil film.
Pipe or Vault Storage Area	B, W, E	Trash and debris	Any trash and debris accumulated in vault or pipe (includes floatables and non-floatables).	No trash or debris in vault or pipe.
	A	Sediment accumulation	Accumulated sediment depth exceeds 10 percent of the diameter of the storage area for ½ the length of storage vault or any point depth exceeds 15 percent of diameter.	All sediment removed from storage area.
Pipe or Vault Structure	A	Plugged air vent	Any blockage of the vent.	Pipe or vault freely vents.
	A	Pipe bent out of shape	Any part of vault/pipe is bent out of shape more than 10 percent of its design shape.	Pipe or vault repaired or replaced to design.
	A	Gaps between sections, damaged joints, or cracks or tears in wall	A gap wider than ½ inch at the joint of any pipe or vault sections. Any evidence of soil particles entering the pipe or vault at a joint or through a wall.	No water or soil entering pipe or vault through joints or walls.

No. 3 – Detention Pipes and Vaults

Maintenance Component	Recommended Inspection Frequency[1]	Defect or Problem	Conditions When Maintenance is Needed	Results Expected When Maintenance is Performed
Vault Structure	A	Damage to wall, frame, bottom, and/or top slab	Cracks wider than ½ inch. Any evidence of soil entering the structure through cracks. Qualified inspection personnel determines that the vault is not structurally sound.	Vault sealed and structurally sound.
Inlet/Outlet Pipes	A	Sediment accumulation	Sediment filling 1/3 or more of the pipe	Inlet/outlet pipes clear of sediment
	B, W, E	Trash and debris	Trash and debris accumulated in inlet/outlet pipes (includes floatables and non-floatables).	No trash or debris in pipes.
	A	Damaged	Cracks wider than ½ inch at the joint of the inlet/outlet pipes. Any evidence of soil entering at the joints of the inlet/outlet pipes.	No cracks more than ¼-inch wide at the joint of the inlet/outlet pipe.
Access Maintenance Hole	A	Cover/lid not in place	Cover/lid is missing or only partially in place. Any open maintenance hole requires immediate maintenance.	Maintenance hole access cover/lid in place and secure.
	A	Locking mechanism not working	Mechanism cannot be opened by one maintenance person with proper tools. Bolts cannot be seated. Self-locking cover/lid does not work.	Mechanism opens with proper tools.
	A	Cover/lid difficult to remove	One maintenance person cannot remove cover/lid after applying 80 lbs of lift.	Cover/lid can be removed and reinstalled by one maintenance person.
	A	Cover/lid not locatable or accessible	Unable to identify/locate or access.	Access Maintenance hole must be at grade or readily accessible at all times.

No. 3 – Detention Pipes and Vaults

Maintenance Component	Recommended Inspection Frequency[1]	Defect or Problem	Conditions When Maintenance is Needed	Results Expected When Maintenance is Performed
Access Maintenance Hole (continued)	A	Ladder rungs unsafe	Missing rungs, misalignment, rust, or cracks.	Ladder meets design standards and allows maintenance person safe access.
Large Access Doors/Plate	A	Damaged or difficult to open	Large access doors or plates cannot be opened/removed using normal equipment.	Replace or repair access door so it can open as designed.
	A	Gaps, does not cover completely	Large access doors not flat and/or access opening not completely covered.	Doors close flat and cover access opening completely.
	A	Lifting rings missing, rusted	Lifting rings not capable of lifting weight of door or plate.	Lifting rings sufficient to lift or remove door or plate.

[1] Inspection frequency:

A = Annually; B = Biannually; M = Monthly; E = Recommend that additional inspections be performed as appropriate after major events (e.g., >1 inch of precipitation in 24 hours or environmental incident that causes contaminant release); Q = Quarterly (four times per year); W = Recommend that at least one inspection occur during the wet season, preferably after trees have lost their leaves.

No. 4 – Flow Control Structure & Control Device

The Flow Control Structure and Control Device shall conform with design criteria shown upon the approved plans or the design standards in place at the time of construction. This includes but is not limited to, orifice diameter(s), orifice elevation(s), and overflow elevation. Reference Standard Plans No. 270, 271, and 272.

Maintenance Component	Recommended Inspection Frequency[1]	Defect or Problem	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
Structure	A	Trash and debris	Trash or debris of more than ½ cubic foot that is located immediately in front of the structure opening or is blocking capacity of the structure by more than 10 percent.	No trash or debris blocking or potentially blocking entrance to structure.
			Trash or debris in the structure that exceeds 1/3 the depth from the bottom of basin to invert the lowest pipe into or out of the basin.	No trash or debris in the structure.
			Deposits of garbage exceeding 1 cubic foot in volume.	No condition present that would attract or support the breeding of insects or rodents.
	A	Sediment	Sediment exceeds 60 percent of the depth from the bottom of the structure to the invert of the lowest pipe into or out of the structure or the bottom of the control device section or is within 6 inches of the invert of the lowest pipe into or out of the structure or the bottom of the control device section.	Sump of structure contains no sediment.

No. 4 – Flow Control Structure & Control Device

Maintenance Component	Recommended Inspection Frequency[1]	Defect or Problem	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
Structure (continued)	A	Damage to frame and/or top slab	Corner of frame extends more than ¾ inch past curb face into the street (If applicable).	Frame is even with curb.
			Top slab has holes larger than 2 square inches or cracks wider than ¼ inch.	Top slab is free of holes and cracks.
			Frame not sitting flush on top slab, i.e., separation of more than ¾ inch of the frame from the top slab.	Frame is sitting flush on top slab.
	A	Cracks in walls or bottom	Cracks wider than ½ inch and longer than 3 feet. Any evidence of soil particles entering structure through cracks. Maintenance person judges that structure is unsound.	Structure is sealed and structurally sound.
			Cracks wider than ½ inch and longer than 1 foot at the joint of any inlet/outlet pipe. Any evidence of soil particles entering structure through cracks.	No cracks more than ¼inch wide at the joint of inlet/outlet pipe.
	A	Settlement/ misalignment	Structure has settled more than 1 inch or has rotated more than 2 inches out of alignment.	Basin replaced or repaired to design standards.
	A	Damaged pipe joints	Cracks wider than ½ inch at the joint of the inlet/outlet pipes. Any evidence of soil entering the structure at the joint of the inlet/outlet pipes.	No cracks more than ¼ inch wide at the joint of inlet/outlet pipes.

No. 4 – Flow Control Structure & Control Device

Maintenance Component	Recommended Inspection Frequency[1]	Defect or Problem	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
Structure (continued)	A, E	Contaminants and pollution	Any evidence of contaminants or pollution such as oil, gasoline, concrete slurries, or paint.	Materials removed and disposed of according to applicable regulations. Source control BMPs implemented if appropriate. No contaminants present other than a surface oil film.
	A	Ladder rungs missing or unsafe	Ladder is unsafe due to missing rungs, misalignment, rust, cracks, or sharp edges.	Ladder meets design standards and allows maintenance person safe access.
Control Device	A	Damaged or missing	Riser section is not securely attached to structure wall and outlet pipe structure should support at least 1,000 lbs of up or down pressure.	T section securely attached to wall and outlet pipe.
			Structure is not in upright position (allow up to 10 percent from plumb).	Structure is in correct position.
			Connections to outlet pipe are not watertight or show signs of deteriorated grout.	Connections to outlet pipe are watertight; structure repaired or replaced and works as designed.
			Any holes—other than designed holes—in the structure.	Structure has no holes other than designed holes.
Shear Gate (if applicable)	A	Damaged or missing	Cleanout gate is missing.	Replace cleanout gate.
			Cleanout gate is not watertight.	Gate is watertight and works as designed.
			Gate cannot be moved up and down by one maintenance person.	Gate moves up and down easily and is watertight.

No. 4 – Flow Control Structure & Control Device

Maintenance Component	Recommended Inspection Frequency[1]	Defect or Problem	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
Shear Gate (if applicable) (continued)	A	Damaged or missing	Chain/rod leading to gate is missing or damaged.	Chain is in place and works as designed.
Orifice Plate	A	Damaged or missing	Control device is not working properly due to missing, out of place, or bent orifice plate.	Plate is in place and works as designed.
	A	Obstructions	Any trash, debris, sediment, or vegetation blocking the plate.	Plate is free of all obstructions and works as designed.
Overflow Pipe	A	Obstructions	Any trash or debris blocking (or having the potential of blocking) the overflow pipe.	Pipe is free of all obstructions and works as designed.
	A	Deformed or damaged lip	Lip of overflow pipe is bent or deformed.	Overflow pipe does not allow overflow at an elevation lower than design.
Inlet/Outlet Pipe	A	Sediment accumulation	Sediment filling 1/3 or more of the pipe.	Inlet/outlet pipes clear of sediment.
	B, W, E	Trash and debris	Trash and debris accumulated in inlet/outlet pipes (includes floatables and non-floatables).	No trash or debris in pipes.
	A	Damaged	Cracks wider than ½ inch at the joint of the inlet/outlet pipes. Any evidence of soil entering at the joints of the inlet/outlet pipes.	No cracks more than ¼inch wide at the joint of the inlet/outlet pipe.
Metal Grates (if applicable)	A	Unsafe grate opening	Grate with opening wider than 7/8 inch.	Grate opening meets design standards.
	B, W, E	Trash and debris	Trash and debris that is blocking more than 20 percent of grate surface.	Grate free of trash and debris. Materials removed and disposed of according to applicable regulations.
	A	Damaged or missing	Grate missing or broken member(s) of the grate.	Grate is in place and meets design standards.

No. 4 – Flow Control Structure & Control Device

Maintenance Component	Recommended Inspection Frequency[1]	Defect or Problem	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
Maintenance Hole Cover/Lid	A	Cover/lid not in place	Cover/lid is missing or only partially in place. **Any open structure requires urgent maintenance.**	Cover/lid protects opening to structure.
	A	Cover/lid not locatable or accessible	Unable to identify/locate or access.	Maintenance hole cover/lid must be at grade or readily accessible at all times.
	A	Locking mechanism not working	Mechanism cannot be opened by one maintenance person with proper tools. Bolts cannot be seated. Self-locking cover/lid does not work.	Mechanism opens with proper tools.
	A	Cover/lid difficult to remove	One maintenance person cannot remove cover/lid after applying 80 lbs of lift.	Cover/lid can be removed and reinstalled by one maintenance person.

[1] Inspection frequency:

A = Annually; B = Biannually; M = Monthly; E = Recommend that additional inspections be performed as appropriate after major events (e.g., >1 inch of precipitation in 24 hours or environmental incident that causes contaminant release); Q = Quarterly (four times per year); W = Recommend that at least one inspection occur during the wet season, preferably after trees have lost their leaves.

No. 5 – Catch Basins and Maintenance Holes

Maintenance Component	Recommended Inspection Frequency[1]	Defect or Problem	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
Structure	A	Sediment	Sediment exceeds 60 percent of the depth from the bottom of the catch basin to the invert of the lowest pipe into or out of the catch basin or is within 6 inches of the invert of the lowest pipe into or out of the catch basin.	Sump of catch basin contains no sediment.
	B, W, E	Trash and debris	Trash or debris of more than ½ cubic foot that is located immediately in front of the catch basin opening or is blocking capacity of the catch basin by more than 10 percent.	No trash or debris blocking or potentially blocking entrance to the catch basin.
	A	Trash and debris (continued)	Trash or debris in the catch basin that exceeds 1/3 the depth from the bottom of basin to invert of the lowest pipe into or out of the basin.	No trash or debris in the catch basin.
	A	Trash and debris (continued)	Dead animals or vegetation that could generate odors that could cause complaints or dangerous gases (e.g., methane).	No dead animals or vegetation present within catch basin.
	A	Trash and debris (continued)	Deposits of garbage exceeding 1 cubic foot in volume.	No condition present that would attract or support the breeding of insects or rodents.

No. 5 – Catch Basins and Maintenance Holes

Maintenance Component	Recommended Inspection Frequency[1]	Defect or Problem	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
Structure (continued)	A	Damage to frame and/or top slab	Corner of frame extends more than ¾ inch past curb face into the street (if applicable).	Frame is even with curb.
			Top slab has holes larger than 2 square inches or cracks wider than ¼ inch.	Top slab is free of holes and cracks.
			Frame not sitting flush on top slab, i.e., separation of more than ¾ inch of the frame from the top slab.	Frame is sitting flush on top slab.
	A	Cracks in walls or bottom	Cracks wider than ½ inch and longer than 3 feet. Any evidence of soil particles entering catch basin through cracks. Maintenance person judges that catch basin is unsound.	Catch basin is sealed and structurally sound.
			Cracks wider than ½ inch and longer than 1 foot at the joint of any inlet/outlet pipe. Any evidence of soil particles entering catch basin through cracks.	No cracks more than ¼inch wide at the joint of inlet/outlet pipe.
	A	Settlement/ misalignment	Catch basin has settled more than 1 inch or has rotated more than 2 inches out of alignment.	Basin replaced or repaired to design standards.
	A	Damaged pipe joints	Cracks wider than ½ inch at the joint of the inlet/outlet pipes. Any evidence of soil entering the catch basin at the joint of the inlet/outlet pipes.	No cracks more than ¼inch wide at the joint of inlet/outlet pipes.

No. 5 – Catch Basins and Maintenance Holes

Maintenance Component	Recommended Inspection Frequency[1]	Defect or Problem	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
Structure (continued)	A, E	Contaminants and pollution	Any evidence of contaminants or pollution such as oil, gasoline, concrete slurries, or paint.	Materials removed and disposed of according to applicable regulations. Source control BMPs implemented if appropriate. No contaminants present other than a surface oil film.
Inlet/Outlet Pipe	A	Sediment accumulation	Sediment filling 1/3 or more of the pipe.	Inlet/outlet pipes clear of sediment.
	B, W, E	Trash and debris	Trash and debris accumulated in inlet/outlet pipes (includes floatables and non-floatables).	No trash or debris in pipes.
	A	Damaged	Cracks wider than ½ inch at the joint of the inlet/outlet pipes. Any evidence of soil entering at the joints of the inlet/outlet pipes.	No cracks more than ¼inch wide at the joint of the inlet/outlet pipe.
Catch Basin Outlet Trap (Reference Standard Plan No. 267)	A	Missing	When the required outlet trap is not installed upon the outlet pipe.	Outlet trap installed and prevents floatables from being discharged.
	A	Permanently installed	When the trap is grouted to the outlet pipe and is not removable to allow for maintenance and inspection.	Outlet trap removable for maintenance and inspection.
	A	Damaged	Cracks, broken welds, seams, or any other conditions that allow water to be discharged from other than the submerged portion of the trap.	Water will be discharged from the submerged portion of the trap.
Metal Grates (Catch Basins)	A	Unsafe grate opening	Grate with opening wider than 7/8 inch.	Grate opening meets design standards.
	B, W, E	Trash and debris	Trash and debris that is blocking more than 20 percent of grate surface.	Grate free of trash and debris. Materials removed and disposed of according to applicable regulations.

No. 5 – Catch Basins and Maintenance Holes

Maintenance Component	Recommended Inspection Frequency[1]	Defect or Problem	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
Metal Grates (Catch Basins) (continued)	A	Damaged or missing	Grate missing or broken member(s) of the grate. **Any open structure requires urgent maintenance.**	Grate is in place and meets design standards.
Maintenance Hole Cover/Lid	A	Cover/lid not in place	Cover/lid is missing or only partially in place. **Any open structure requires urgent maintenance.**	Cover/lid protects opening to structure.
	A	Cover/lid not locatable or accessible	Unable to identify/locate or access.	Maintenance hole cover/lid must be at grade or readily accessible at all times.
	A	Locking mechanism not working	Mechanism cannot be opened by one maintenance person with proper tools. Bolts cannot be seated. Self-locking cover/lid does not work.	Mechanism opens with proper tools.
	A	Cover/lid difficult to remove	One maintenance person cannot remove cover/lid after applying 80 lbs of lift.	Cover/lid can be removed and reinstalled by one maintenance person.

[1] Inspection frequency:

A = Annually; B = Biannually; M = Monthly; E = Recommend that additional inspections be performed as appropriate after major events (e.g., >1 inch of precipitation in 24 hours or environmental incident that causes contaminant release); Q = Quarterly (four times per year); W = Recommend that at least one inspection occur during the wet season, preferably after trees have lost their leaves.

No. 6 – Reserved

No. 7 – Debris Barriers (e.g., Trash Racks)

Maintenance Component	Recommended Inspection Frequency[1]	Defect or Problem	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
Facility – General Requirements	B, W, E	Trash and debris	Trash or debris plugging more than 20 percent of the area of the barrier.	Barrier clear to receive capacity flow.
	A	Sediment accumulation	Sediment accumulation of greater than 20 percent of the area of the barrier.	Barrier clear to receive capacity flow.
Structure	A	Cracked, broken, or loose	Structure that bars attach to is damaged. Pipe is loose or cracked. Concrete structure is cracked, broken, or loose.	Sound structure barrier.
Bars	A	Bar spacing	Bar spacing exceeds 6 inches.	Bars have at most 6-inch spacing.
	A	Damaged or missing bars	Bars bent out of shape more than 3 inches.	Bars in place with no bends more than ¾ inch.
			Bars missing or entire barrier missing	Bars in place according to design.
			Bars loose and rust is causing 50 percent deterioration to any part of barrier.	Repair or replace barrier to design standards.

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No. 8 – Energy Dissipaters

Maintenance Component	Recommended Inspection Frequency[1]	Defect or Problem	Conditions When Maintenance is Needed	Results Expected When Maintenance is Performed
Facility – General Requirements	B, W, E	Trash and debris	Trash and/or debris accumulation.	Dissipater clear of trash and/or debris.
	A, E	Contaminants and pollution	Any evidence of contaminants or pollution such as oil, gasoline, concrete slurries, or paint.	Materials removed and disposed of according to applicable regulations. Source control BMPs implemented if appropriate. No contaminants present other than a surface oil film.
Rock Pad	A	Missing or moved rock	One layer or less of rock exists above a native soil area 5 square feet or more. Any exposed native soil.	Rock pad prevents erosion.
Dispersion Trench	A	Pipe plugged with sediment	Accumulated sediment that exceeds 20 percent of the design depth.	Pipe cleaned/flushed so that it matches design.
	A	Not discharging water properly	Visual evidence of water discharging at concentrated points along trench (normal condition is a “sheet flow” of water along trench).	Water discharges from feature by sheet flow.
	A	Perforations plugged	Over 1/4 of perforations in pipe are plugged with debris or sediment.	Perforations freely discharge flow.
	A	Water flows out top of “distributor” catch basin	Water flows out of distributor catch basin during any storm less than the design storm.	No flow discharges from distributor catch basin.
	A	Receiving area over-saturated	Water in receiving area is causing or has potential of causing landslide problems.	No danger of landslides.
Gabions	A	Damaged mesh	Mesh of gabion broken, twisted, or deformed so structure is weakened or rock may fall out.	Mesh is intact with no rock missing.

No. 8 – Energy Dissipaters

Maintenance Component	Recommended Inspection Frequency[1]	Defect or Problem	Conditions When Maintenance is Needed	Results Expected When Maintenance is Performed
Gabions (continued)	A	Corrosion	Gabion mesh shows corrosion through more than ¼ of its gage.	All gabion mesh capable of containing rock and retaining designed form.
	A	Collapsed or deformed baskets	Gabion basket shape deformed due to any cause.	All gabion baskets intact, structure stands as designed.
	A	Missing rock	Any rock missing that could cause gabion to lose structural integrity.	No rock missing.
Maintenance Hole/Chamber	A	Worn or damaged post, baffles, or side of chamber.	Structure dissipating flow deteriorates to ½ of original size or any concentrated worn spot exceeding 1 square foot, which would make structure unsound.	Structure in no danger of failing.
	A	Damage to wall, frame, bottom, and/or top slab	Cracks wider than ½ inch. Any evidence of soil entering the structure through cracks. Maintenance inspection personnel determines that the structure is not structurally sound.	Maintenance hole/chamber sealed and structurally sound.
	A	Damaged pipe joints	Cracks wider than ½ inch at the joint of the inlet/outlet pipes. Any evidence of soil entering the structure at the joint of the inlet/outlet pipes.	No soil or water enters. No water discharges at the joint of inlet/outlet pipes.

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No. 9 – Basic and Compost-Amended Biofiltration Swales

Maintenance Component	Recommended Inspection Frequency[1]	Defect or Problem	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
Facility – General Requirements	M	Trash and debris	Trash and/or debris accumulation.	No trash or debris at the site.
	B, E	Contaminants and pollution	Any evidence of contaminants or pollution such as oil, gasoline, concrete slurries, or paint.	Materials removed and disposed of according to applicable regulations. Source control BMPs implemented if appropriate. No contaminants present other than a surface oil film.
Swale Section	B, E	Sediment accumulation	Sediment depth exceeds 2 inches in 10 percent of the swale treatment area.	No sediment deposits in treatment area of the biofiltration swale.
			Sediment inhibits grass growth over 10 percent of swale length.	Grass growth not inhibited by sediment.
			Sediment inhibits even spreading of flow.	Flows are spread evenly over entire swale width.
	B, E	Erosion/scouring	Eroded or scoured swale bottom due to channelization or high flows.	No eroded or scoured areas in biofiltration swale. Cause of erosion or scour addressed.
	M	Poor vegetation coverage	Grass is sparse or bare or eroded patches occur in more than 10 percent of the swale bottom.	Swale has no bare spots. Grass is thick and healthy.
	B	Grass too tall	Grass is excessively tall (greater than 10 inches) **and** impedes swale performance (i.e., flow control or water quality). Grass is thin Nuisance weeds and other vegetation have taken over.	Grass between 3 and 4 inches tall, thick and healthy. No clippings left in swale. No nuisance vegetation present.

No. 9 – Basic and Compost-Amended Biofiltration Swales

Maintenance Component	Recommended Inspection Frequency[1]	Defect or Problem	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
Swale Section (continued)	B	Excessive shade	Grass growth is poor because sunlight does not reach swale.	Healthy grass growth. or Swale converted to a wet biofiltration swale.
	B	Constant baseflow	Continuous flow through the swale, even when it has been dry for weeks or an eroded muddy channel has formed in the swale bottom.	Baseflow removed from swale by a low-flow pea-gravel drain or bypassed around the swale.
	B	Standing water	Water pools in the swale between storms or does not drain freely.	Swale drains freely and no standing water in swale between storms.
	B	Channelization	Flow concentrates and erodes channel through swale.	No flow channels in swale.
Flow Spreader	B	Concentrated flow	Flow from spreader not uniformly distributed across entire swale width.	Flows are spread evenly over entire swale width.
Inlet/Outlet Pipe	A	Sediment accumulation	Sediment filling 1/3 or more of the pipe.	Inlet/outlet pipes clear of sediment.
	B, W, E	Trash and debris	Trash and debris accumulated in inlet/outlet pipes (includes floatables and non-floatables).	No trash or debris in pipes.
	A	Damaged	Cracks wider than ½ inch at the joint of the inlet/outlet pipes. Any evidence of soil entering at the joints of the inlet/outlet pipes.	No cracks more than ¼inch wide at the joint of the inlet/outlet pipe.

[1] Inspection frequency:

A = Annually; B = Biannually; M = Monthly; E = Recommend that additional inspections be performed as appropriate after major events (e.g., >1 inch of precipitation in 24 hours or environmental incident that causes contaminant release); Q = Quarterly (four times per year); W = Recommend that at least one inspection occur during the wet season, preferably after trees have lost their leaves.

No. 10 – Wet and Continuous Inflow Biofiltration Swales

Maintenance Component	Recommended Inspection Frequency[1]	Defect or Problem	Condition When Maintenance is Needed	Results Expected When Maintenance Is Performed
Facility – General Requirements	M	Trash and debris	Any trash and/or debris accumulated at the site.	No trash or debris at the site.
	B, E	Contaminants and pollution	Any evidence of contaminants or pollution such as oil, gasoline, concrete slurries, or paint.	Materials removed and disposed of according to applicable regulations. Source control BMPs implemented if appropriate. No contaminants present other than a surface oil film.
Swale Section	B, E	Sediment accumulation	Sediment depth exceeds 2 inches in 10 percent of the swale treatment area.	No sediment deposits in treatment area.
	B, E	Erosion/scouring	Eroded or scoured swale bottom due to channelization or high flows.	No eroded or scoured areas in biofiltration swale. Cause of erosion or scour addressed.
	B	Water depth	Water not retained to a depth of about 4 inches during the wet season.	Water depth of 4 inches throughout swale for most of wet season.
	B	Vegetation ineffective	Vegetation sparse; does not provide adequate filtration. Vegetation crowded out by very dense clumps of cattail or nuisance vegetation.	Wetland vegetation fully covers bottom of swale. No cattails or nuisance vegetation present.
	B	Insufficient water	Wetland vegetation dies due to lack of water.	Wetland vegetation remains healthy (may require converting to grass-lined biofiltration swale).
Flow Spreader	B	Concentrated flow	Flow from spreader not uniformly distributed across entire swale width.	Flows are spread evenly over entire swale width.
Inlet/Outlet Pipe	A	Sediment accumulation	Sediment filling 1/3 or more of the pipe.	Inlet/outlet pipes clear of sediment.

No. 10 – Wet and Continuous Inflow Biofiltration Swales

Maintenance Component	Recommended Inspection Frequency[1]	Defect or Problem	Condition When Maintenance is Needed	Results Expected When Maintenance Is Performed
Inlet/Outlet Pipe (continued)	B, W, E	Trash and debris	Trash and debris accumulated in inlet/outlet pipes (includes floatables and non-floatables).	No trash or debris in pipes.
	A	Damaged	Cracks wider than ½ inch at the joint of the inlet/outlet pipes. Any evidence of soil entering at the joints of the inlet/outlet pipes.	No cracks more than ¼inch wide at the joint of the inlet/outlet pipe.

[1] Inspection frequency:

A = Annually; B = Biannually; M = Monthly; E = Recommend that additional inspections be performed as appropriate after major events (e.g., >1 inch of precipitation in 24 hours or environmental incident that causes contaminant release); Q = Quarterly (four times per year); W = Recommend that at least one inspection occur during the wet season, preferably after trees have lost their leaves.

No. 11 – Filter Strips (Basic and CAVFS)

Maintenance Component	Recommended Inspection Frequency[1]	Defect or Problem	Condition When Maintenance is Needed	Results Expected When Maintenance Is Performed
Facility – General Requirements	M	Trash and debris	Any trash and/or debris accumulated at the site.	No trash or debris at the site.
	B, E	Contaminants and pollution	Any evidence of contaminants or pollution such as oil, gasoline, concrete slurries, or paint.	Materials removed and disposed of according to applicable regulations. Source control BMPs implemented if appropriate. No contaminants present other than a surface oil film.
Grass Strip	B, E	Sediment accumulation	Sediment accumulation exceeds 2 inches depth.	No sediment deposits in treatment area.
	B, E	Erosion/scouring	Eroded or scoured areas due to channelization or high flows.	No eroded or scoured areas. Cause of erosion or scour addressed.
	B	Vegetation ineffective	Grass has died out. Grass has become excessively tall (greater than 10 inches). Nuisance vegetation is taking over.	Grass is healthy; between 3 and 4 inches tall. No nuisance vegetation present.
Flow Spreader	B	Concentrated flow	Flow from spreader not uniformly distributed across entire filter width.	Flows are spread evenly over entire filter width.
Inlet/Outlet Pipe	A	Sediment accumulation	Sediment filling 1/3 or more of the pipe.	Inlet/outlet pipes clear of sediment.
	B, W, E	Trash and debris	Trash and debris accumulated in inlet/outlet pipes (includes floatables and non-floatables).	No trash or debris in pipes.

No. 11 – Filter Strips (Basic and CAVFS)

Maintenance Component	Recommended Inspection Frequency[1]	Defect or Problem	Condition When Maintenance is Needed	Results Expected When Maintenance Is Performed
Inlet/Outlet Pipe (continued)	A	Damaged	Cracks wider than ½ inch at the joint of the inlet/outlet pipes. Any evidence of soil entering at the joints of the inlet/outlet pipes.	No cracks more than ¼inch wide at the joint of the inlet/outlet pipe.

[1] Inspection frequency:

A = Annually; B = Biannually; M = Monthly; E = Recommend that additional inspections be performed as appropriate after major events (e.g., >1 inch of precipitation in 24 hours or environmental incident that causes contaminant release); Q = Quarterly (four times per year); W = Recommend that at least one inspection occur during the wet season, preferably after trees have lost their leaves.

No. 12 – Wet Ponds

Maintenance Component	Recommended Inspection Frequency[1]	Defect or Problem	Condition When Maintenance is Needed	Results Expected When Maintenance Is Performed
Facility – General Requirements	A	Trash and debris	Any trash and/or debris accumulated at the site.	No trash or debris at the site.
	M (March – October)	Noxious weeds	Any noxious or nuisance vegetation that may constitute a hazard to City personnel or the public.	Noxious and nuisance vegetation removed according to applicable regulations. No danger of noxious vegetation where City personnel or the public might normally be.
	A, E	Contaminants and pollution	Any evidence of contaminants or pollution such as oil, gasoline, concrete slurries, or paint.	Materials removed and disposed of according to applicable regulations. Source control BMPs implemented if appropriate. No contaminants present other than a surface oil film.
	2X: June – October	Grass/groundcover	Grass or groundcover exceeds 18 inches in height.	Grass or groundcover mowed to a height no greater than 6 inches.
Side Slopes of Dam, Berm, Internal Berm, or Embankment	A	Rodent holes	Any evidence of rodent holes if facility is acting as a dam or berm. Any evidence of water piping through dam or berm via rodent holes.	Rodents removed or destroyed. Dam or berm repaired.

No. 12 – Wet Ponds

Maintenance Component	Recommended Inspection Frequency[1]	Defect or Problem	Condition When Maintenance is Needed	Results Expected When Maintenance Is Performed
Side Slopes of Dam, Berm, Internal Berm, or Embankment (continued)	A	Tree growth	Tree growth threatens integrity of dams, berms, or slopes, does not allow maintenance access, or interferes with maintenance activity. If trees are not a threat to dam, berm, or embankment integrity; are not interfering with access or maintenance; or leaves do not cause a plugging problem trees do not need to be removed.	Trees do not hinder facility performance or maintenance activities.
	A	Erosion	Eroded damage over 2 inches deep where cause of damage is still present or where there is potential for continued erosion. Any erosion observed on a compacted slope.	Slopes stabilized using appropriate erosion control measures. If erosion is occurring on compacted slope, a licensed engineer should be consulted to resolve source of erosion.
Top or Side Slopes of Dam, Berm, Internal Berm, or Embankment	A	Settlement	Any part of a dam, berm, or embankment that has settled 4 inches lower than the design elevation.	Top or side slope restored to design dimensions. If settlement is significant, a licensed engineer should be consulted to determine the cause of the settlement.
	A	Irregular surface on internal berm	Top of berm not uniform and level.	Top of berm graded to design elevation.
Pond Areas	A	Sediment accumulation (except first wet pool cell)	Accumulated sediment that exceeds 10 percent of the designed pond depth.	Sediment cleaned out to designed pond shape and depth.

No. 12 – Wet Ponds

Maintenance Component	Recommended Inspection Frequency[1]	Defect or Problem	Condition When Maintenance is Needed	Results Expected When Maintenance Is Performed
Pond Areas (continued)	A	Sediment accumulation (first wet pool cell)	Sediment accumulation in pond bottom that exceeds the depth of sediment storage (1 foot) plus 6 inches.	Sediment storage contains no sediment.
	A	Liner damaged (if applicable)	Liner is visible. Pond does not hold water as designed.	Liner repaired or replaced.
	A, W	Water level (first wet pool cell)	First cell empty; does not hold water.	Water retained in first cell for most of the year.
	M (March – October)	Algae mats (first wet pool cell)	Algae mats develop over more than 10 percent of the water surface.	Algae mats removed (usually in the late summer before fall rains).
Gravity Drain	A	Inoperable valve	Valve will not open and close.	Valve opens and closes normally.
	A	Valve will not seal	Valve does not seal completely.	Valve completely seals closed.
Emergency Overflow Spillway	A	Tree growth	Tree growth impedes flow or threatens stability of spillway.	Trees removed.
	A	Rock missing	Only one layer of rock exists above native soil in an area 5 square feet or larger. Any exposure of native soil at the top of outflow path of spillway. (Rip-rap on inside slopes need not be replaced.)	Spillway restored to design standards.
Inlet/Outlet Pipe	A	Sediment accumulation	Sediment filling 1/3 or more of the pipe.	Inlet/outlet pipes clear of sediment.
	B, W, E	Trash and debris	Trash and debris accumulated in inlet/outlet pipes (includes floatables and non-floatables).	No trash or debris in pipes.

No. 12 – Wet Ponds

Maintenance Component	Recommended Inspection Frequency[1]	Defect or Problem	Condition When Maintenance is Needed	Results Expected When Maintenance Is Performed
Inlet/Outlet Pipe (continued)	A	Damaged	Cracks wider than ½ inch at the joint of the inlet/outlet pipes. Any evidence of soil entering at the joints of the inlet/outlet pipes.	No cracks more than ¼inch wide at the joint of the inlet/outlet pipe.

[1] Inspection frequency:

A = Annually; B = Biannually; M = Monthly; E = Recommend that additional inspections be performed as appropriate after major events (e.g., >1 inch of precipitation in 24 hours or environmental incident that causes contaminant release); Q = Quarterly (four times per year); W = Recommend that at least one inspection occur during the wet season, preferably after trees have lost their leaves.

No. 13 – Wet Vaults

Maintenance Component	Recommended Inspection Frequency[1]	Defect or Problem	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
Facility – General Requirements	A	Trash and debris	Trash and debris accumulation.	Trash and debris removed from facility.
Treatment Area	A	Trash and debris	Any trash and debris accumulated in vault (includes floatables and non-floatables).	No trash or debris in vault.
	A	Sediment accumulation	Sediment accumulation in vault bottom exceeds the depth of the sediment zone plus 6 inches.	No sediment in vault.
	A, E	Contaminants and pollution	Any evidence of contaminants or pollution such as oil, gasoline, concrete slurries, or paint.	Materials removed and disposed of according to applicable regulations. Source control BMPs implemented if appropriate. No contaminants present other than a surface oil film.
Vault Structure	A	Damage to wall, frame, bottom, and/or top slab	Cracks wider than ½ inch. Any evidence of soil entering the structure through cracks. Vault does not retain water. Qualified inspection personnel determines that the vault is not structurally sound.	Vault sealed and structurally sound.
	A	Baffles damaged	Baffles corroding, cracking, warping, and/or showing signs of failure. Baffle cannot be removed.	Repair or replace baffles or walls to specifications.
	A	Ventilation	Ventilation area blocked or plugged.	No reduction of ventilation area exists.
Inlet/Outlet Pipe	A	Sediment accumulation	Sediment filling 1/3 or more of the pipe.	Inlet/outlet pipes clear of sediment.

No. 13 – Wet Vaults

Maintenance Component	Recommended Inspection Frequency[1]	Defect or Problem	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
Inlet/Outlet Pipe (continued)	B, W, E	Trash and debris	Trash and debris accumulated in inlet/outlet pipes (includes floatables and non-floatables).	No trash or debris in pipes.
	A	Damaged	Cracks wider than ½ inch at the joint of the inlet/outlet pipes. Any evidence of soil entering at the joints of the inlet/outlet pipes.	No cracks more than ¼inch wide at the joint of the inlet/outlet pipe.
Gravity Drain	A	Inoperable valve	Valve will not open and close.	Valve opens and closes normally.
	A	Valve will not seal	Valve does not seal completely.	Valve completely seals closed.
Access Maintenance Hole	A	Access cover/lid damaged or difficult to open	Access cover/lid cannot be easily opened by one person. Corrosion/deformation of cover/lid.	Access cover/lid can be opened by one person.
	A	Cover/lid not locatable or accessible	Unable to identify/locate or access.	Access Maintenance hole must be at grade or readily accessible at all times.
	A	Locking mechanism not working	Mechanism cannot be opened by one maintenance person with proper tools. Bolts cannot be seated. Self-locking cover/lid does not work.	Mechanism opens with proper tools.
	A	Cover/lid difficult to remove	One maintenance person cannot remove cover/lid after applying 80 lbs of lift.	Cover/lid can be removed and reinstalled by one maintenance person.
	A	Access doors/plate has gaps, does not cover completely	Large access doors not flat and/or access opening not completely covered.	Doors close flat and cover access opening completely.
	A	Lifting rings missing, rusted	Lifting rings not capable of lifting weight of door or plate.	Lifting rings sufficient to lift or remove door or plate.

No. 13 – Wet Vaults

Maintenance Component	Recommended Inspection Frequency[1]	Defect or Problem	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
Access Maintenance Hole (continued)	A	Ladder rungs unsafe	Missing rungs, misalignment, rust, or cracks.	Ladder meets design standards and allows maintenance person safe access.

[1] Inspection frequency:

A = Annually; B = Biannually; M = Monthly; E = Recommend that additional inspections be performed as appropriate after major events (e.g., >1 inch of precipitation in 24 hours or environmental incident that causes contaminant release); Q = Quarterly (four times per year); W = Recommend that at least one inspection occur during the wet season, preferably after trees have lost their leaves.

No. 14 – Stormwater Treatment Wetlands

Maintenance Component	Recommended Inspection Frequency[1]	Defect or Problem	Condition When Maintenance is Needed	Results Expected When Maintenance Is Performed
Facility – General Requirements	A	Trash and debris	Trash and debris accumulation.	Trash and debris removed from facility.
	M (March – October)	Noxious weeds	Any noxious or nuisance vegetation that may constitute a hazard to City personnel or the public.	Noxious and nuisance vegetation removed according to applicable regulations. No danger of noxious vegetation where City personnel or the public might normally be.
	A, E	Contaminants and pollution	Any evidence of contaminants or pollution such as oil, gasoline, concrete slurries, or paint.	Materials removed and disposed of according to applicable regulations. Source control BMPs implemented if appropriate. No contaminants present other than a surface oil film.
	2X: June – October	Grass/groundcover	Grass or groundcover exceeds 18 inches in height.	Grass or groundcover mowed to a height no greater than 6 inches.
Side Slopes of Dam, Berm, Internal Berm, or Embankment	A	Rodent holes	Any evidence of rodent holes if facility is acting as a dam or berm. Any evidence of water piping through dam or berm via rodent holes.	Rodents removed or destroyed. Dam or berm repaired.

No. 14 – Stormwater Treatment Wetlands

Maintenance Component	Recommended Inspection Frequency[1]	Defect or Problem	Condition When Maintenance is Needed	Results Expected When Maintenance Is Performed
Side Slopes of Dam, Berm, Internal Berm, or Embankment (continued)	A	Tree growth	Tree growth threatens integrity of dams, berms, or slopes; does not allow maintenance access; or interferes with maintenance activity. If trees are not a threat to dam, berm, or embankment integrity or not interfering with access or maintenance, they do not need to be removed.	Trees do not hinder facility performance or maintenance activities
	A	Erosion	Erosion damage over 2 inches deep where cause of damage is still present or where there is potential for continued erosion. Any erosion observed on a compacted slope.	Slopes stabilized using appropriate erosion control measures. If erosion is occurring on compacted slope, a licensed engineer should be consulted to resolve source of erosion.
Top or Side Slopes of Dam, Berm, Internal Berm, or Embankment	A	Settlement	Any part of a dam, berm, or embankment that has settled 4 inches lower than the design elevation.	Top or side slope restored to design dimensions. If settlement is significant, a licensed engineer should be consulted to determine the cause of the settlement.
	A	Irregular surface on internal berm	Top of berm not uniform and level.	Top of berm graded flat to design elevation.
Pond Areas	B	Sediment accumulation (first cell/forebay)	Sediment accumulations in pond bottom that exceeds the depth of sediment storage (1 foot) plus 6 inches.	Sediment storage contains no sediment.

No. 14 – Stormwater Treatment Wetlands

Maintenance Component	Recommended Inspection Frequency[1]	Defect or Problem	Condition When Maintenance is Needed	Results Expected When Maintenance Is Performed
Pond Areas (continued)	B	Sediment accumulation (wetland cell)	Accumulated sediment that exceeds 10 percent of the designed pond depth.	Sediment cleaned out to designed pond shape and depth.
	A	Liner damaged (if applicable)	Liner is visible or pond does not hold water as designed.	Liner repaired or replaced.
	A, W	Water level (first cell/forebay)	Cell does not hold 3 feet of water year-round.	3 feet of water retained year-round.
	A, W	Water level (wetland cell)	Cell does not retain water for at least 10 months of the year or wetland plants are not surviving.	Water retained at least 10 months of the year or wetland plants are surviving.
	M (March – October)	Algae mats (first cell/forebay)	Algae mats develop over more than 10 percent of the water.	Algae mats removed (usually in the late summer before fall rains).
	B	Vegetation	Vegetation dead, dying, or overgrown (cattails) or not meeting original planting specifications.	Plants in wetland cell surviving and not interfering with wetland function.
Gravity Drain	A	Inoperable valve	Valve will not open and close.	Valve opens and closes normally.
	A	Valve will not seal	Valve does not seal completely.	Valve completely seals closed.
Emergency Overflow Spillway	A	Tree growth	Tree growth impedes flow or threatens stability of spillway.	Trees removed.
	A	Rock missing	Only one layer of rock exists above native soil in an area 5 square feet or larger. Any exposure of native soil at the top of outflow path of spillway. (Rip-rap on inside slopes need not be replaced.)	Spillway restored to design standards.
Inlet/Outlet Pipe	A	Sediment accumulation	Sediment filling 1/3 or more of the pipe.	Inlet/outlet pipes clear of sediment.

No. 14 – Stormwater Treatment Wetlands

Maintenance Component	Recommended Inspection Frequency[1]	Defect or Problem	Condition When Maintenance is Needed	Results Expected When Maintenance Is Performed
Inlet/Outlet Pipe (continued)	B, W, E	Trash and debris	Trash and debris accumulated in inlet/outlet pipes (includes floatables and non-floatables).	No trash or debris in pipes.
	A	Damaged	Cracks wider than ½ inch at the joint of the inlet/outlet pipes. Any evidence of soil entering at the joints of the inlet/outlet pipes.	No cracks more than ¼inch wide at the joint of the inlet/outlet pipe.

[1] Inspection frequency:

A = Annually; B = Biannually; M = Monthly; E = Recommend that additional inspections be performed as appropriate after major events (e.g., >1 inch of precipitation in 24 hours or environmental incident that causes contaminant release); Q = Quarterly (four times per year); W = Recommend that at least one inspection occur during the wet season, preferably after trees have lost their leaves.

No. 15 – Sand Filter Basins

Maintenance Component	Recommended Inspection Frequency[1]	Defect or Problem	Condition When Maintenance is Needed	Results Expected When Maintenance Is Performed
Facility – General Requirements	A, E	Trash and debris	Trash and debris accumulation.	Trash and debris removed from facility.
	M (March – October)	Noxious weeds	Any noxious or nuisance vegetation that may constitute a hazard to City personnel or the public.	Noxious and nuisance vegetation removed according to applicable regulations. No danger of noxious vegetation where City personnel or the public might normally be.
	A, E	Contaminants and pollution	Any evidence of contaminants or pollution such as oil, gasoline, concrete slurries, or paint.	Materials removed and disposed of according to applicable regulations. Source control BMPs implemented if appropriate. No contaminants present other than a surface oil film.
	A	Grass/groundcover (not in the treatment area)	Grass or groundcover exceeds 18 inches in height.	Grass or groundcover mowed to a height no greater than 6 inches.
Pre-Treatment (if applicable)	A	Sediment accumulation	Sediment accumulations in pond bottom that exceeds the depth of sediment storage (1 foot) plus 6 inches.	Sediment storage contains no sediment.
	A	Liner damaged (if applicable)	Liner is visible. Pond does not hold water as designed.	Liner repaired or replaced.
	A, W	Water level	Cell empty; does not hold water.	Water retained in first cell for most of the year.
	M (March – October)	Algae mats	Algae mats develop over more than 10 percent of the water surface.	Algae mats removed.
Pond Area	B	Sediment accumulation	Sediment or crust depth exceeds ½ inch over 10 percent of surface area of sand filter.	No sediment or crust deposit on sand filter that would impede permeability of the filter section.

No. 15 – Sand Filter Basins

Maintenance Component	Recommended Inspection Frequency[1]	Defect or Problem	Condition When Maintenance is Needed	Results Expected When Maintenance Is Performed
Pond Area (continued)	2X: June – October	Grass (if applicable)	Grass becomes excessively tall (greater than 6 inches). Nuisance weeds and other vegetation start to take over. Thatch build up occurs.	Mow vegetation and/or remove nuisance vegetation.
Side Slopes of Pond	A	Rodent holes	Any evidence of rodent holes if facility is acting as a dam or berm. Any evidence of water piping through dam or berm via rodent holes.	Rodents removed or destroyed. Dam or berm repaired.
	A	Tree growth	Tree growth threatens integrity of dams, berms or slopes; does not allow maintenance access; or interferes with maintenance activity. If trees are not a threat to dam, berm, or embankment integrity or not interfering with access or maintenance, they do not need to be removed.	Trees do not hinder facility performance or maintenance activities.
	A	Erosion	Eroded damage over 2 inches deep where cause of damage is still present. Where there is potential for continued erosion. Any erosion observed on a compacted slope.	Slopes stabilized using appropriate erosion control measures. If erosion is occurring on compacted slope, a licensed engineer should be consulted to resolve source of erosion.

No. 15 – Sand Filter Basins

Maintenance Component	Recommended Inspection Frequency[1]	Defect or Problem	Condition When Maintenance is Needed	Results Expected When Maintenance Is Performed
Sand Filter Media	A, E	Plugging	Drawdown of water through the sand filter media, takes longer than 24 hours. Flow through the overflow pipes occurs frequently.	Sand filter media surface is aerated. Drawdown rate is normal.
	A	Prolonged flows	Sand is saturated for prolonged periods of time (several weeks) and does not dry out between storms due to continuous base flow or prolonged flows from detention facilities.	Excess flows bypassed or confined to small portion of filter media surface.
	A	Short circuiting	Flows become concentrated over one section of the sand filter rather than dispersed. Drawdown rate of pool exceeds 12 inches per hour.	Flow and percolation of water through the sand filter is uniform and dispersed across the entire filter area. Drawdown rate is normal.
	A	Media thickness	Sand thickness is less than 6 inches.	Rebuild sand thickness to a minimum of 6 inches and preferably to 18 inches.
Underdrains and Clean-Outs	A	Sediment/debris	Underdrains or clean-outs partially plugged or filled with sediment and/or debris. Junction box/cleanout wyes not watertight.	Underdrains and clean-outs free of sediment and debris and are watertight.
Inlet/Outlet Pipe	A	Sediment accumulation	Sediment filling 1/3 or more of the pipe.	Inlet/outlet pipes clear of sediment.
	B, W, E	Trash and debris	Trash and debris accumulated in inlet/outlet pipes (includes floatables and non-floatables).	No trash or debris in pipes.

No. 15 – Sand Filter Basins

Maintenance Component	Recommended Inspection Frequency[1]	Defect or Problem	Condition When Maintenance is Needed	Results Expected When Maintenance Is Performed
Inlet/Outlet Pipe (continued)	A	Damaged	Cracks wider than ½ inch at the joint of the inlet/outlet pipes. Any evidence of soil entering at the joints of the inlet/outlet pipes.	No cracks more than ¼inch wide at the joint of the inlet/outlet pipe.
Rock Pad	A	Missing or out of place	Only one layer of rock exists above native soil in an area 5 square feet or larger. Any exposure of native soil.	Rock pad restored to design standards.
Flow Spreader	A	Concentrated flow	Flow from spreader not uniformly distributed across sand filter.	Flows spread evenly over sand filter.

[1] Inspection frequency:

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No. 16 – Sand Filter Vaults

Maintenance Component	Recommended Inspection Frequency[1]	Defect or Problem	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
Facility – General Requirements	A, E	Trash and debris	Trash and debris accumulation.	Trash and debris removed from facility.
	M (March – October)	Noxious weeds	Any noxious or nuisance vegetation that may constitute a hazard to City personnel or the public.	Noxious and nuisance vegetation removed according to applicable regulations. No danger of noxious vegetation where City personnel or the public might normally be.
	A, E	Contaminants and pollution	Any evidence of contaminants or pollution such as oil, gasoline, concrete slurries, or paint.	Materials removed and disposed of according to applicable regulations. Source control BMPs implemented if appropriate. No contaminants present other than a surface oil film.
	A	Grass/groundcover	Grass or groundcover exceeds 18 inches in height.	Grass or groundcover mowed to a height no greater than 6 inches.
Pre-Treatment Chamber	A	Sediment accumulation	Sediment accumulation exceeds the depth of the sediment zone plus 6 inches.	Sediment storage contains no sediment.
Sand Filter Media	A	Sediment accumulation	Sediment depth exceeds ½ inch on sand filter media.	Sand filter freely drains at normal rate.
	A	Trash and debris	Trash and debris accumulated in vault (floatables and non-floatables)	No trash or debris in vault.
	A, E	Plugging	Drawdown of water through the sand filter media, takes longer than 24 hours. Flow through the overflow pipes occurs frequently.	Sand filter media drawdown rate is normal.

No. 16 – Sand Filter Vaults

Maintenance Component	Recommended Inspection Frequency[1]	Defect or Problem	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
Sand Filter Media (continued)	A	Short circuiting	Seepage or flow occurs along the vault walls and corners. Sand eroding near inflow area. Cleanout wyes are not watertight.	Sand filter media section re-laid and compacted along perimeter of vault to form a semi-seal. Erosion protection added to dissipate force of incoming flow and curtail erosion.
Vault Structure	A	Damage to walls, frame, bottom, and/or top slab.	Cracks wider than ½ inch. Any evidence of soil entering the structure through cracks. Qualified inspection personnel determines that the vault is not structurally sound.	Vault replaced or repaired to provide complete sealing of the structure.
	A	Ventilation	Ventilation area blocked or plugged	No reduction of ventilation area exists.
Underdrains and Cleanouts	A	Sediment/debris	Underdrains or clean-outs partially plugged, filled with sediment and/or debris, or not watertight.	Underdrains and clean-outs free of sediment and debris and sealed.
Inlet/Outlet Pipe	A	Sediment accumulation	Sediment filling 1/3 or more of the pipe.	Inlet/outlet pipes clear of sediment.
	B, W, E	Trash and debris	Trash and debris accumulated in inlet/outlet pipes (includes floatables and non-floatables).	No trash or debris in pipes.
	A	Damaged	Cracks wider than ½ inch at the joint of the inlet/outlet pipes. Any evidence of soil entering at the joints of the inlet/outlet pipes.	No cracks more than ¼inch wide at the joint of the inlet/outlet pipe.
Access Maintenance Hole	A	Cover/lid not in place	Cover/lid is missing or only partially in place. **Any open maintenance hole requires immediate maintenance.**	Maintenance hole access cover/lid in place and secure.

No. 16 – Sand Filter Vaults

Maintenance Component	Recommended Inspection Frequency[1]	Defect or Problem	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
Access Maintenance Hole (continued)	A	Locking mechanism not working	Mechanism cannot be opened by one maintenance person with proper tools. Bolts cannot be seated. Self-locking cover/lid does not work.	Mechanism opens with proper tools.
	A	Cover/lid difficult to remove	One maintenance person cannot remove cover/lid after applying 80 lbs of lift.	Cover/lid can be removed and reinstalled by one maintenance person.
	A	Cover/lid not locatable or accessible	Unable to identify/locate or access.	Access Maintenance hole must be at grade or readily accessible at all times.
Large Access Doors/Plate	A	Damaged or difficult to open	Large access doors or plates cannot be opened/removed using normal equipment.	Replace or repair access door so it can open as designed.
	A	Gaps, does not cover completely	Large access doors not flat and/or access opening not completely covered.	Doors close flat and cover access opening completely.
	A	Lifting rings missing, rusted	Lifting rings not capable of lifting weight of door or plate.	Lifting rings sufficient to lift or remove door or plate.

[1] Inspection frequency:

A = Annually; B = Biannually; M = Monthly; E = Recommend that additional inspections be performed as appropriate after major events (e.g., >1 inch of precipitation in 24 hours or environmental incident that causes contaminant release); Q = Quarterly (four times per year); W = Recommend that at least one inspection occur during the wet season, preferably after trees have lost their leaves.

No. 17 – Proprietary Technology Filter Cartridge Systems (example: BayFilter, FloGard PerkFilter, StormFilter)

*In addition to the specific maintenance criteria provided below, all manufacturers' requirements shall be followed.

Maintenance Component	Recommended Inspection Frequency[1,2]	Defect or Problem	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
Facility – General Requirements	A, E	Trash and debris	Any trash or debris or organic material that impairs the function of the facility.	Trash and debris removed from facility. Flow receives treatment instead of bypassing.
	A, E	Contaminants and pollution	Any evidence of contaminants or pollution such as oil, gasoline, concrete slurries, or paint.	Materials removed and disposed of according to applicable regulations. Source control BMPs implemented if appropriate. No contaminants present other than a surface oil film.
	A	Life cycle	Once per year.	Facility is re-inspected and any needed maintenance performed.
Vault Treatment Area	Varies – Refer to Manufacturer's requirements.	Sediment on vault floor	Varies – Refer to Manufacturer's requirements.	Vault is free of sediment.
	Varies – Refer to Manufacturer's requirements.	Sediment on top of cartridges	Varies – Refer to Manufacturer's requirements.	Vault is free of sediment.
	Varies – Refer to Manufacturer's requirements.	Multiple scum lines above top of cartridges	Thick or multiple scum lines above top of cartridges.	Cause of plugging corrected and canisters replaced if necessary.
Vault Structure	A	Damage to wall, frame, bottom, and/or top slab.	Cracks wider than ½ inch. Any evidence of soil particles entering the structure through the cracks. Qualified inspection personnel determines the vault is not structurally sound.	Vault replaced or repaired to design specifications.
	A	Baffles damaged	Baffles corroding, cracking, warping, and/or showing signs of failure.	Repair or replace baffles to specification.

No. 17 – Proprietary Technology Filter Cartridge Systems (example: BayFilter, FloGard PerkFilter, StormFilter)

*In addition to the specific maintenance criteria provided below, all manufacturers' requirements shall be followed.

Maintenance Component	Recommended Inspection Frequency[1,2]	Defect or Problem	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
Filter Media	A, E	Standing water in vault	Varies – Refer to Manufacturer's requirements.	No standing water in vault 24 hours after a rain event.
	A	Short circuiting	Flows do not properly enter filter cartridges.	Flows go through filter media.
Underdrains and Clean-outs	A	Sediment/debris	Underdrains or clean-outs partially plugged or filled with sediment and/or debris.	Underdrains and clean-outs free of sediment and debris.
Inlet/Outlet Pipe	A	Sediment accumulation	Sediment filling 1/3 or more of the pipe.	Inlet/outlet pipes clear of sediment.
	B, W, E	Trash and debris	Trash and debris accumulated in inlet/outlet pipes (includes floatables and non-floatables).	No trash or debris in pipes.
	A	Damaged	Cracks wider than ½ inch at the joint of the inlet/outlet pipes. Any evidence of soil entering at the joints of the inlet/outlet pipes.	Cracks repaired, and no evidence of soil entering.
Access Maintenance Hole	A	Cover/lid not in place	Cover/lid is missing or only partially in place. **Any open maintenance hole requires immediate maintenance.**	Maintenance hole access cover/lid in place and secure.
	A	Cover/lid not locatable or accessible	Unable to identify/locate or access.	Access Maintenance hole must be at grade or readily accessible at all times.
	A	Locking mechanism not working	Mechanism cannot be opened by one maintenance person with proper tools. Bolts cannot be seated. Self-locking cover/lid does not work.	Mechanism opens with proper tools.

No. 17 – Proprietary Technology Filter Cartridge Systems (example: BayFilter, FloGard PerkFilter, StormFilter)

*In addition to the specific maintenance criteria provided below, all manufacturers' requirements shall be followed.

Maintenance Component	Recommended Inspection Frequency[1,2]	Defect or Problem	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
Access Maintenance Hole (continued)	A	Cover/lid difficult to remove	One maintenance person cannot remove cover/lid after applying 80 lbs of lift.	Cover/lid can be removed and reinstalled by one maintenance person.
	A	Cover/lid rocking or noisy	Lid rocking when driven over.	Cover/lid not rocking.
	A	Ladder rungs unsafe	Missing rungs, misalignment, rust, or cracks.	Ladder meets design standards and allows maintenance person safe access.
Large Access Doors/Plate	A	Difficult to open	Large access doors or plates cannot be opened/removed using normal equipment.	Replace or repair access door so it can open as designed.
	A	Damaged	Hatch doors show major dents and stress.	Replace to support surface loading and uses.
	A	Gaps, does not cover completely	Large access doors not flat and/or access opening not completely covered.	Doors close flat and cover access opening completely.
	A	Lifting rings missing, rusted	Lifting rings not capable of lifting weight of door or plate.	Lifting rings sufficient to lift or remove door or plate.

1 Inspection frequency:

A = Annually; B = Biannually; M = Monthly; E = Recommend that additional inspections be performed as appropriate after major events (e.g., >1 inch of precipitation in 24 hours or environmental incident that causes contaminant release); Q = Quarterly (four times per year); W = Recommend that at least one inspection occur during the wet season, preferably after trees have lost their leaves.

2 Inspection frequencies provided are recommendations only. Proprietary technologies shall be inspected on a frequency as recommended by the manufacturer.

No. 18 – API Oil/Water Separators

Maintenance Component	Recommended Inspection Frequency[1]	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
Facility – General Requirements	A, E	Trash and debris	Any trash or debris that impairs the function of the facility.	Trash and debris removed from facility.
	A, E	Contaminants and pollution	Floating oil in excess of 1 inch in first chamber, any oil in other chambers, or other contaminants of any type in any chamber.	No contaminants present other than a surface oil film.
Vault Treatment Area	A, E	Sediment accumulation	Sediment accumulation exceeds 6 inches in the vault.	No sediment in the vault.
	A, E	Discharge water not clear	Inspection of discharge water shows obvious signs of poor water quality— effluent discharge from vault shows thick visible sheen.	Effluent discharge is clear.
	A, E	Trash or debris accumulation	Any trash and debris accumulation in vault (floatables and non-floatables).	Vault is clear of trash and debris.
	A, E	Oil accumulation	Oil accumulations that exceed 1 inch at the surface of the water in the oil/water separator chamber.	No visible oil depth on water.
	A	Damage to wall, frame, bottom, and/or top slab	Cracks wider than ½ inch. Any evidence of soil particles entering the structure through the cracks. Maintenance/inspection personnel determines that the vault is not structurally sound.	Vault replaced or repaired to design specifications.
	A	Baffles damaged	Baffles corroding, cracking, warping, and/or showing signs of failure.	Repair or replace baffles to specifications.
Gravity Drain	A	Inoperable valve	Valve will not open and close.	Valve opens and closes normally.

No. 18 – API Oil/Water Separators

Maintenance Component	Recommended Inspection Frequency[1]	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
Gravity Drain (continued)	A	Valve will not seal	Valve does not seal completely.	Valve completely seals closed.
Inlet/Outlet Pipe	A	Sediment accumulation	Sediment filling 1/3 or more of the pipe.	Inlet/outlet pipes clear of sediment.
	B, W, E	Trash and debris	Trash and debris accumulated in inlet/outlet pipes (includes floatables and non-floatables).	No trash or debris in pipes.
	A	Damaged	Cracks, broken welds, seams, or any other conditions that allow water to be discharged from other than the submerged portion of the tee.	Water will be discharged from the submerged portion of the tee.
	A	Missing	When the required inlet or outlet tee is not installed.	Tees installed.
	A	Permanently installed	When the tee is grouted to the inlet or outlet pipe and is not removable to allow for maintenance and inspection.	Tee removable for maintenance and inspection.
Access Maintenance Hole	A	Cover/lid not in place	Cover/lid is missing or only partially in place. **Any open maintenance hole requires immediate maintenance.**	Maintenance hole access cover/lid in place and secure.
	A	Cover/lid not locatable or accessible	Unable to identify/locate or access.	Access maintenance hole must be at grade or readily accessible at all times.
	A	Locking mechanism not working	Mechanism cannot be opened by one maintenance person with proper tools. Bolts cannot be seated. Self-locking cover/lid does not work.	Mechanism opens with proper tools.
	A	Cover/lid difficult to remove	One maintenance person cannot remove cover/lid after applying 80 lbs of lift.	Cover/lid can be removed and reinstalled by one maintenance person.

No. 18 – API Oil/Water Separators

Maintenance Component	Recommended Inspection Frequency[1]	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
Access Maintenance Hole (continued)	A	Ladder rungs unsafe	Missing rungs, misalignment, rust, or cracks.	Ladder meets design standards and allows maintenance person safe access.
Large Access Doors/Plate	A	Damaged or difficult to open	Large access doors or plates cannot be opened/removed using normal equipment.	Replace or repair access door so it can open as designed.
	A	Gaps, does not cover completely	Large access doors not flat and/or access opening not completely covered.	Doors close flat and cover access opening completely.
	A	Lifting rings missing, rusted	Lifting rings not capable of lifting weight of door or cover/lid.	Lifting rings sufficient to lift or remove cover/lid.

[1] Inspection frequency:

A = Annually; B = Biannually; M = Monthly; E = Recommend that additional inspections be performed as appropriate after major events (e.g., >1 inch of precipitation in 24 hours or environmental incident that causes contaminant release); Q = Quarterly (four times per year); W = Recommend that at least one inspection occur during the wet season, preferably after trees have lost their leaves.

No. 19 – Coalescing Plate Oil/Water Separators

Maintenance Component	Recommended Inspection Frequency[1]	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
Facility – General Requirements	A, E	Trash and debris	Any trash or debris that impairs the function of the facility.	Trash and debris removed from facility.
	A, E	Contaminants and pollution	Floating oil in excess of 1 inch in first chamber, any oil in other chambers, or other contaminants of any type in any chamber.	No contaminants present other than a surface oil film.
Vault Treatment Area	A, E	Sediment accumulation in the forebay	Sediment accumulation of 6 inches or greater in the forebay.	No sediment in the forebay.
	A, E	Discharge water not clear	Inspection of discharge water shows obvious signs of poor water quality – effluent discharge from vault shows thick visible sheen.	Repair function of plates so effluent is clear.
	A, E	Trash or debris accumulation	Trash and debris accumulation in vault (floatables and non-floatables).	Trash and debris removed from vault.
	A, E	Oil accumulation	Oil accumulation that exceeds 1 inch at the water surface in the coalescing plate chamber.	No visible oil depth on water and coalescing plates clear of oil.
Coalescing Plates	A	Damaged	Plate media broken, deformed, cracked, and/or showing signs of failure.	Replace that portion of media pack or entire plate pack depending on severity of failure.
	A, E	Sediment accumulation	Any sediment accumulation that interferes with the operation of the coalescing plates.	No sediment accumulation interfering with the coalescing plates.

No. 19 – Coalescing Plate Oil/Water Separators

Maintenance Component	Recommended Inspection Frequency[1]	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
Vault Structure	A	Damage to wall, frame, bottom, and/or top slab	Cracks wider than ½ inch. Any evidence of soil particles entering the structure through the cracks. Maintenance inspection personnel determines that the vault is not structurally sound.	Vault replaced or repaired to design specifications.
	A	Baffles damaged	Baffles corroding, cracking, warping, and/or showing signs of failure.	Repair or replace baffles to specifications.
Ventilation Pipes	A	Plugged	Any obstruction to the ventilation pipes.	Ventilation pipes are clear.
Shutoff Valve	A	Damaged or inoperable	Shutoff valve cannot be opened or closed.	Shutoff valve operates normally.
Inlet/Outlet Pipe	A	Sediment accumulation	Sediment filling 1/3 or more of the pipe.	Inlet/outlet pipes clear of sediment.
	B, W, E	Trash and debris	Trash and debris accumulated in inlet/outlet pipes (includes floatables and non-floatables).	No trash or debris in pipes.
	A	Damaged	Cracks, broken welds, seams, or any other conditions that allow water to be discharged from other than the submerged portion of the tee.	Water will be discharged from the submerged portion of the tee.
	A	Missing	When the required inlet or outlet tee is not installed.	Tees installed.
	A	Permanently installed	When the tee is grouted to the inlet or outlet pipe and is not removable to allow for maintenance and inspection.	Tee removable for maintenance and inspection.

No. 19 – Coalescing Plate Oil/Water Separators

Maintenance Component	Recommended Inspection Frequency[1]	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
Access Maintenance Hole	A	Cover/lid not in place	Cover/lid is missing or only partially in place. **Any open maintenance hole requires immediate maintenance.**	Maintenance hole access cover/lid in place and secure.
	A	Locking mechanism not working	Mechanism cannot be opened by one maintenance person with proper tools. Bolts cannot be seated. Self-locking cover/lid does not work.	Mechanism opens with proper tools.
	A	Cover/lid difficult to remove	One maintenance person cannot remove cover/lid after applying 80 lbs of lift.	Cover/lid can be removed and reinstalled by one maintenance person.
	A	Ladder rungs unsafe	Missing rungs, misalignment, rust, or cracks.	Ladder meets design standards and allows maintenance person safe access.
Large Access Doors/Plate	A	Damaged or difficult to open	Large access doors or plates cannot be opened/removed using normal equipment.	Replace or repair access door so it can open as designed.
	A	Gaps, does not cover completely	Large access doors not flat and/or access opening not completely covered.	Doors close flat and cover access opening completely.
	A	Lifting rings missing, rusted	Lifting rings not capable of lifting weight of door or plate.	Lifting rings sufficient to lift or remove door or plate.

[1] Inspection frequency:

A = Annually; B = Biannually; M = Monthly; E = Recommend that additional inspections be performed as appropriate after major events (e.g., >1 inch of precipitation in 24 hours or environmental incident that causes contaminant release); Q = Quarterly (four times per year); W = Recommend that at least one inspection occur during the wet season, preferably after trees have lost their leaves.

No. 20 – Catch Basin Filter Socks

Maintenance Component	Recommended Inspection Frequency[1,2]	Defect or Problem	Conditions When Maintenance is Needed	Results Expected When Maintenance is Performed
Media Insert[2]	M	Visible oil	Visible oil sheen passing through media.	Media insert replaced.
	M	Insert does not fit catch basin properly	Flow gets into catch basin without going through media.	All flow goes through media.
	M	Filter media plugged	Filter media plugged.	Flow through filter media is normal.
	M	Oil absorbent media saturated	Media is oil saturated.	Oil-absorbent media replaced.
	M	Water saturated	Catch basin insert is saturated with water, which no longer has the capacity to absorb.	Insert replaced.
	M	Service life exceeded	Regular interval replacement due to typical average life of product.	Media replaced at manufacturer's recommended interval.

[1] Inspection frequency:

A = Annually; B = Biannually; M = Monthly; E = Recommend that additional inspections be performed as appropriate after major events (e.g., >1 inch of precipitation in 24 hours or environmental incident that causes contaminant release); Q = Quarterly (four times per year); W = Recommend that at least one inspection occur during the wet season, preferably after trees have lost their leaves.

[2] Inspection frequencies provided are recommendations only. Catch basin filter socks shall be inspected on a frequency as recommended by the manufacturer.

No. 21 – Proprietary Technology Filterra System

*In addition to the specific maintenance criteria provided below, all manufacturers' requirements shall be followed.

Maintenance Component	Recommended Inspection Frequency[1,2]	Defect or Problem	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
Facility – General Requirements	A	Life cycle	Once per year, except mulch and trash removal twice per year.	Facility is re-inspected and any needed maintenance performed.
	B, E	Contaminants and pollution	Any evidence of contaminants or pollution such as oil, gasoline, concrete slurries, or paint.	Materials removed and disposed of according to applicable regulations. Source control BMPs implemented if appropriate. No contaminants present other than a surface oil film.
Inlet	B, E	Excessive sediment or trash accumulation	Accumulated sediments or trash impair free flow of water into system.	Inlet should be free of obstructions allowing free distributed flow of water into system.
Mulch Cover	B, E	Trash and floatable debris accumulation	Excessive trash and/or debris accumulation.	Minimal trash or other debris on mulch cover. Mulch cover raked level.
	B, E	"Ponding" of water on mulch cover	"Ponding" in unit could be indicative of clogging due to excessive fine sediment accumulation or spill of petroleum oils.	Stormwater should drain freely and evenly through mulch cover.
Proprietary Filter Media/ Vegetation Substrate	B, E	"Ponding" of water on mulch cover after mulch cover has been maintained	Excessive fine sediment passes the mulch cover and clogs the filter media/vegetative substrate.	Stormwater should drain freely and evenly through mulch cover. Replace substrate and vegetation when needed.
Vegetation	B, E	Plants not growing or in poor condition	Soil/mulch too wet. Evidence of spill. Incorrect plant selection. Pest infestation. Vandalism to plants.	Plants should be healthy and pest free.
	B, E	Plants not growing or in poor condition	Media/mulch too dry.	Irrigation is required.

No. 21 – Proprietary Technology Filterra System

*In addition to the specific maintenance criteria provided below, all manufacturers' requirements shall be followed.

Maintenance Component	Recommended Inspection Frequency[1,2]	Defect or Problem	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
Vegetation (continued)	B, E	Plants absent	Plants absent.	Appropriate plants are present.
	B, E	Excessive plant growth	Excessive plant growth inhibits facility function or becomes a hazard for pedestrian and vehicular circulation and safety.	Pruning and/or thinning vegetation maintains proper plant density. Appropriate plants are present.
Structure, if used	B	Structure has visible cracks	Cracks wider than ½ inch. Evidence of soil particles entering the structure through the cracks.	Structure is sealed and structurally sound.

1 Inspection frequency:

A = Annually; B = Biannually; M = Monthly; E = Recommend that additional inspections be performed as appropriate after major events (e.g., >1 inch of precipitation in 24 hours or environmental incident that causes contaminant release); Q = Quarterly (four times per year); W = Recommend that at least one inspection occur during the wet season, preferably after trees have lost their leaves.

2 Inspection frequencies provided are recommendations only. Proprietary technologies shall be inspected on a frequency as recommended by the manufacturer.

No. 22 – Proprietary Technology Modular Wetland System

*In addition to the specific maintenance criteria provided below, all manufacturers' requirements shall be followed.

Maintenance Component	Recommended Inspection Frequency[1,2]	Defect or Problem	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
Facility – General Requirements	B	Trash and debris	Any trash or debris that impairs the function of the facility.	Trash and debris removed from facility.
	B	Contaminants and pollution	Any evidence of contaminants or pollution such as oil, gasoline, concrete slurries, or paint.	Materials removed and disposed of according to applicable regulations. Source control BMPs implemented if appropriate. No contaminants present other than a surface oil film.
	B	Odor	Septic or foul odor coming from inside the system.	Odors are eliminated.
	B	Standing water	Standing water observed after a prolonged dry period.	No standing water.
Inlet/Outlet Pipe	B	Excessive sediment or trash accumulation	Accumulated sediments or trash impair free flow of water into system.	Inlet should be free of obstructions allowing free distributed flow of water into system.
	B	Pipe damage or blockage	Pipe damaged or otherwise not functioning properly.	Pipe is repaired, allowing free flow of water into system
Pre-Treatment Chamber	B	Sediment accumulation	Sediment accumulation in the pre-treatment chamber.	Sediment removed from the pre-treatment chamber.
	B	Access cover damage or difficulty opening	Access cover (manhole cover/grate) is damaged or cannot be opened using normal lifting pressure.	Access cover is repaired and can be opened using normal lifting pressure.
	B	Obstruction or clogging of screening device	Contaminants and pollutants collected by screen are obstructing flow of water into the system.	All pollutants removed and disposed of according to applicable regulations. Screen is free of obstructions and allows free flow of water into system.

No. 22 – Proprietary Technology Modular Wetland System

*In addition to the specific maintenance criteria provided below, all manufacturers' requirements shall be followed.

Maintenance Component	Recommended Inspection Frequency[1,2]	Defect or Problem	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
Pre-Treatment Chamber (continued)	B	Accumulated pollutants or debris in separation chamber	Accumulated pollutants or debris impedes function of unit.	All pollutants removed and disposed of according to applicable regulations.
Filter Media	A	Life cycle	Regular interval replacement due to typical average life of product or clogging.	Old filter media is removed and new filter media is installed.
Structure	A	Unit shows signs of structural deterioration	Visible cracks wider than ½ inch. Evidence of soil particles entering the structure through the cracks. Damage to frame.	Structure is sealed and structurally sound.
Access Cover	A	Hard to open	Cannot be easily opened.	Access lid is repaired or replaced.
	A	Buried	Buried.	Access lid functions as designed (refer to record drawings for design intent).
	A	Missing cover	Cover missing.	Cover replaced.
Vegetation	B	Plants not growing or in poor condition	Soil/mulch too wet. Evidence of spill. Incorrect plant selection. Pest infestation. Vandalism to plants.	Plants should be healthy and pest free.
	B	Excessive plant growth	Excessive plant growth inhibits facility function or becomes a hazard for pedestrian and vehicular circulation and safety.	Pruning and/or thinning vegetation maintains proper plant density. Appropriate plants are present.

[1] Inspection frequency:

A = Annually; B = Biannually; M = Monthly; E = Recommend that additional inspections be performed as appropriate after major events (e.g., >1 inch of precipitation in 24 hours or environmental incident that causes contaminant release); Q = Quarterly (four times per year); W = Recommend that at least one inspection occur during the wet season, preferably after trees have lost their leaves.

[2] Inspection frequencies provided are recommendations only. Proprietary technologies shall be inspected on a frequency as recommended by the manufacturer.

No. 23 – Bioretention Facilities

Maintenance Component	Recommended Inspection Frequency[1]	Defect or Problem	Conditions When Maintenance is Needed	Results Expected When Maintenance is Performed
Facility – General Requirements	B, E	Pests: Insects/rodents	Pest of concern is present and impacting facility function.	Pests removed or destroyed and facility returned to original functionality. Do not use pesticides or *Bacillus thuringiensis israelensis* (*Bti*).
	A, E	Trash	Trash and debris present.	No trash and debris present.
	B, E	Contaminants and pollution	Any evidence of contaminants or pollution such as oil, gasoline, concrete slurries, or paint.	Materials removed and disposed of according to applicable regulations. Source control BMPs implemented if appropriate. No contaminants present other than a surface oil film.
Earthen Side Slopes and Berms	B, E	Erosion	Erosion (gullies/rills) greater than 2 inches deep around inlets, outlet, and alongside slopes.	Cause of erosion is eliminated. Damaged area is stabilized (regrade, rock, vegetation, erosion control blanket). For deep channels or cuts (over 3 inches in ponding depth), temporary erosion control measures are in place until permanent repairs can be made.
	B, E	Erosion	Erosion of sides causes slope to become a hazard.	The hazard is eliminated and slopes are stabilized.
	A, E	Settlement	Settlement greater than 3 inches (relative to undisturbed sections of berm).	The design height is restored with additional mulch.

No. 23 – Bioretention Facilities

Maintenance Component	Recommended Inspection Frequency[1]	Defect or Problem	Conditions When Maintenance is Needed	Results Expected When Maintenance is Performed
Earthen Side Slopes and Berms (continued)	A, E	Berm leakage	Downstream face of berm wet, seeps or leaks evident.	Holes are plugged and berm is compacted (may require consultation with licensed engineer, particularly for larger berms).
			Any evidence of rodent holes or water piping in berm.	Rodents (refer to "Pests: Insects/rodents") removed or destroyed. Berm repaired/compacted.
Concrete Sidewalls	A	Cracks	Rot, cracks, or failure of concrete sidewalls.	Concrete is repaired or replaced.
Rockery Sidewalls	A	Instable rockery	Rockery side walls are insecure.	Rockery sidewalls are stable (may require consultation with licensed engineer, particularly for walls 4 feet or greater in height).
Facility Bottom Area	B	Sediment accumulation	Accumulated sediment to extent that infiltration rate is reduced (refer to “Bioretention Soil”) or surface storage capacity significantly impacted.	Sediment cleaned out to restore facility shape and depth. Damaged vegetation is replaced and mulched. Source of sediment identified and controlled (if feasible).
	B	Leaf accumulation	Accumulated leaves in facility.	No leaves clogging outlet structure or impeding water flow.
Check Dams and Weirs	A, E	Sediment, vegetation, or debris accumulation	Sediment, vegetation, or debris accumulated at or blocking (or having the potential to block) check dam, flow control weir, or orifice.	Blockage is cleared.

No. 23 – Bioretention Facilities

Maintenance Component	Recommended Inspection Frequency[1]	Defect or Problem	Conditions When Maintenance is Needed	Results Expected When Maintenance is Performed
Check Dams and Weirs (continued)	A, E	Erosion	Erosion and/or undercutting present.	No eroded or undercut areas in bioretention facility. Cause of erosion or undercutting addressed. Check dam or weir is repaired.
	A	Unlevel top of weir	Grade board or top of weir damaged or not level.	Weir restored to level position.
Bioretention Soil	As needed	Ponded water	Water remains in the basin 48 hours or longer after the end of a storm.	Cause of ponded water is identified and addressed: 1) Leaf litter/debris is removed. 2) Underdrain is clear. 3) Other water inputs (e.g., groundwater, illicit connections) investigated. 4) Contributing area verified and facility size is evaluated. If items #1–4 do not solve the problem, imported bioretention soil is replaced and replanted.
	As needed	Protection of soil	Maintenance will occur requiring entrance into the facility footprint.	Maintenance is performed without compacting bioretention soil media.
Splash Block Inlet	B	Water not properly directed to facility	Water is not being directed properly to the facility and away from the inlet structure.	Blocks are reconfigured to direct water to facility and away from structure.
Curb Cut Inlet/Outlet	A, E	Accumulated debris	Accumulated leaves, sediment, debris, or vegetation at curb cuts.	Blockage is cleared. Source of the blockage is identified and action is taken to prevent future blockages.

No. 23 – Bioretention Facilities

Maintenance Component	Recommended Inspection Frequency[1]	Defect or Problem	Conditions When Maintenance is Needed	Results Expected When Maintenance is Performed
Inlet/Outlet Pipe	A	Damaged pipe	Pipe is damaged.	Pipe is repaired/replaced. No cracks more than ¼inch wide at the joint of inlet/outlet pipes exist.
	A	Clogged pipe	Pipe is clogged	Pipe is clear.
	A, E	Accumulated debris	Accumulated leaves, sediment, debris, or vegetation at inlet or outlet pipe.	Pipe is clear of debris. Source of the blockage is identified and action is taken to prevent future blockages.
	A, E	Blocked access	Maintain access for inspections.	Vegetation is cleared within 1 foot of inlets and outlets. Access pathways are maintained.
	B	Erosion	Water disrupts soil media.	No eroded or scoured areas in bioretention facility. Cause of erosion or scour addressed. Pipes or splash blocks are reconfigured or repaired. A cover of rock or cobbles or other erosion protection measure maintained (e.g., matting) to protect the ground where concentrated water enters or exits the facility (e.g., a pipe, curb cut, or swale).
Overflow	A, E	Blocked overflow	Capacity reduced by sediment or debris.	No sediment or debris in overflow.

No. 23 – Bioretention Facilities

Maintenance Component	Recommended Inspection Frequency[1]	Defect or Problem	Conditions When Maintenance is Needed	Results Expected When Maintenance is Performed
Underdrain Pipe	A	Blocked underdrain	Plant roots, sediment, or debris reducing capacity of underdrain. Prolonged surface ponding (refer to "Bioretention Soil").	Underdrains and orifice are free of sediment and debris.
Facility Bottom Area and Upland Slope Vegetation	M	Lack of vegetation	Vegetation survival rate falls below 75 percent within first 2 years of establishment (unless project O&M manual or record drawing stipulates more or less than 75 percent survival rate).	Plants are healthy and pest free. Cause of poor vegetation growth addressed. Bioretention facility is replanted as necessary to attain 75 percent survival rate or greater. Plant selection is appropriate for site growing conditions.
Trees and Shrubs	A	Causing problems for operation of facility	Large trees and shrubs interfere with operation of the facility or access for maintenance	Trees and shrubs do not hinder facility performance or maintenance activities
	A	Dead trees or shrubs	Standing dead vegetation is present.	Trees and shrubs do not hinder facility performance or maintenance activities. Dead vegetation is removed. Cause of dead vegetation is addressed. Specific plants with high mortality rate are replaced with more appropriate species.

No. 23 – Bioretention Facilities

Maintenance Component	Recommended Inspection Frequency[1]	Defect or Problem	Conditions When Maintenance is Needed	Results Expected When Maintenance is Performed
Trees and Shrubs Adjacent to Vehicle Travel Areas (or areas where visibility needs to be maintained)	A	Safety issues	Vegetation causes some visibility (line of sight) or driver safety issues.	Appropriate height for sight clearance is maintained. Regular pruning maintains visual sight lines for safety or clearance along a walk or drive. Tree or shrub is removed or transplanted if presenting a continual safety hazard.
Emergent Vegetation	M	Conveyance blocked	Vegetation compromises conveyance.	Sedges and rushes are clear of dead foliage.
Noxious Weeds	M (March – October)	Presence of noxious weeds	Any noxious or nuisance vegetation that may constitute a hazard to City personnel or the public.	Noxious and nuisance vegetation removed according to applicable regulations. No danger of noxious vegetation where City personnel or the public might normally be.
Excessive Vegetation	M	Adjacent facilities compromised	Low-lying vegetation growing beyond facility edge onto sidewalks, paths, or street edge poses pedestrian safety hazard or may clog adjacent permeable pavement surfaces due to associated leaf litter, mulch, and soil.	Vegetation does not impede function of adjacent facilities or pose as safety hazard. Groundcovers and shrubs trimmed at facility edge. Excessive leaf litter is removed.

No. 23 – Bioretention Facilities

Maintenance Component	Recommended Inspection Frequency[1]	Defect or Problem	Conditions When Maintenance is Needed	Results Expected When Maintenance is Performed
Excessive Vegetation (continued)	M	Causes facility to not function properly	Excessive vegetation density inhibits stormwater flow beyond design ponding or becomes a hazard for pedestrian and vehicular circulation and safety.	Pruning and/or thinning vegetation maintains proper plant density and aesthetics. Plants that are weak, broken, or not true to form are removed or replaced in-kind. Appropriate plants are present.
Mulch	A	Lack of mulch	Bare spots (without mulch cover) are present or mulch depth less than 2 inches.	Facility has a minimum 3inch layer of an appropriate type of mulch. Mulch is kept away from woody stems.
Plant Watering	Weekly or as required (May – September)	Plant establishment	Plant establishment period (1–3 years).	Plants are watered as necessary during periods of no rain to ensure plant establishment.
Summer Watering (after establishment)	Weekly or as required (May – September)	Drought period	Established vegetation (after 3 years).	Plants are watered as necessary during drought conditions. Trees are watered up to 5 years after planting.

[1] Inspection frequency:

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No. 24 – Cisterns

Maintenance Component	Recommended Inspection Frequency[1]	Defect or Problem	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed
Roof	B	Debris accumulation in cistern	Debris has accumulated.	No debris in cistern.
Gutter	B	Debris accumulation in cistern	Debris has accumulated.	No debris in cistern or gutter.
Screens at the Top of Downspout and Cistern Inlet	A	Debris accumulation in cistern	Screen has deteriorated or is missing.	Screen is in place and functions as designed.
	Monthly (October – April), E	Debris accumulation in cistern	Preventative maintenance.	No debris in cistern or accumulated on screen.
Overflow Pipe	B	Damaged	Pipe is cracked, joints and fittings not sealed.	Overflow pipe is watertight and does not leak.
	B	Discharge is sporadic, cistern overtops	Debris has accumulated blocking flow.	Overflow pipe can convey overflow to point of discharge.
Cistern	A	Accumulated debris and/or sediment	More than 6 inches of accumulation in bottom of cistern.	Accumulation of debris and/or sediment removed.
Low Flow Orifice (detention cistern)	M (October – April), E	Cistern overflows are too frequent	Debris or other obstruction of orifice.	Orifice is clear.
Delivery and Distribution System (harvesting)	Varies	None – ongoing maintenance activity	Ongoing maintenance (e.g., replacing and/or cleaning filters, removing sediment and other pollutants from storage systems).	Manufacturer's, installer's, or designer's instructions for O&M are followed.
Access and Safety	Ongoing	None – ongoing maintenance activity	Access to cistern required for maintenance or cleaning.	Any cistern opening that could allow the entry of people is marked: "DANGER—CONFINED SPACE".
Pests	B	Mosquito infestation	Standing water remains for more than 3 days following storms.	All inlets, overflows, and other openings are protected with mosquito screens. No mosquito infestation present.

[1] Inspection frequency:

A = Annually; B = Biannually; M = Monthly; E = Recommend that additional inspections be performed as appropriate after major events (e.g., >1 inch of precipitation in 24 hours or environmental incident that causes contaminant release); Q = Quarterly (four times per year); W = Recommend that at least one inspection occur during the wet season, preferably after trees have lost their leaves.

No. 25 – Downspout, Sheet Flow, and Concentrated Dispersion Systems

Maintenance Component	Recommended Inspection Frequency[1]	Defect or Problem	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed
Splash Block	B	Water directed toward building	Water is being directed toward building structure.	Blocks direct water away from building structure.
	B	Water causing erosion	Water disrupts soil media.	Blocks are reconfigured/repaired and media is restored.
Transition Zone	B, E	Erosion	Adjacent soil erosion; uneven surface creating concentrated flow discharge; or less than 2 foot of width.	No eroded or scoured areas. Cause of erosion or scour is addressed.
Dispersion Trench	B	Concentrated flow	Visual evidence of water discharging at concentrated points along trench (normal condition is a "sheet flow" from edge of trench; intent is to prevent erosion damage).	No debris on trench surface. Notched grade board or other distributor type is aligned to prevent erosion. Trench is rebuilt to standards, if necessary.
Surface of Trench	A, E	Accumulated debris	Accumulated trash, debris, or sediment on drain rock surface impedes sheet flow from facility.	Trash or debris is removed/disposed in accordance with local solid waste requirements.
	A, E	Vegetation impeding flow	Vegetation/moss present on drain rock surface impedes sheet flow from facility.	Freely draining drain rock surface.
Pipe(s) to Trench	A	Accumulated debris in drains	Accumulation of trash, debris, or sediment in roof drains, gutters, driveway drains, area drains, etc.	No trash or debris in roof drains, gutters, driveway drains, or area drains.
	A	Accumulated debris in inlet pipe	Pipe from sump to trench or drywell has accumulated sediment or is plugged.	No sediment or debris in inlet/outlet pipe screen or inlet/outlet pipe.

No. 25 – Downspout, Sheet Flow, and Concentrated Dispersion Systems

Maintenance Component	Recommended Inspection Frequency[1]	Defect or Problem	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed
Pipe(s) to Trench (continued)	A	Damaged pipes	Cracked, collapsed, broken, or misaligned drain pipes.	No cracks more than ¼inch wide at the joint of the inlet/outlet pipe.
Rock Pad (concentrated flow dispersion)	A	Inadequate rock cover	Only one layer of rock exists above native soil in an area 6 square feet or larger, or any exposure of native soil.	Rock pad is repaired/replaced to meet design standards.
	A	Erosion	Soil erosion in or adjacent to rock pad.	Rock pad is repaired/replaced to meet design standards.
Dispersal Area (general)	A	Erosion	Erosion (gullies/rills) greater than 2 inches deep in dispersal area.	No eroded or scoured areas. Cause of erosion or scour is addressed.
	A	Accumulated sediment	Accumulated sediment or debris to extent that blocks or channelizes flow path.	No excess sediment or debris in dispersal area. Sediment source is addressed (if feasible).
Ponded Water	As needed	Ponded water	Standing surface water in dispersion area remains for more than 3 days after the end of a storm event.	System freely drains. Standing water in dispersion area does not persist for more than 3 days after a storm event. Cause of the standing water (e.g., grade depressions, compacted soil) addressed.
Vegetation	M	Plant survival	Dispersal area vegetation in establishment period (1–2 years, or additional 3rd year) during extreme dry weather).	Vegetation healthy and watered weekly during periods of no rain to ensure plant establishment.

No. 25 – Downspout, Sheet Flow, and Concentrated Dispersion Systems

Maintenance Component	Recommended Inspection Frequency[1]	Defect or Problem	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed
Vegetation (continued)	M	Lack of vegetation allowing erosion	Poor vegetation cover such that erosion is occurring.	Vegetation healthy and watered. No eroded or scoured areas present. Cause of erosion or scour addressed. Plant species appropriate for the soil and moisture conditions.
	M	Vegetation blocking flow	Vegetation inhibits dispersed flow along flow path.	Vegetation is trimmed, weeded, or replanted to restore dispersed flow path.
	M (March – October)	Presence of noxious weeds	Any noxious or nuisance vegetation that may constitute a hazard to City personnel or the public.	Noxious and nuisance vegetation removed according to applicable regulations. No danger of noxious vegetation where City personnel or the public might normally be.
Sump	A	Accumulated sediment	Accumulated sediment in the sump exceeds 30 percent of storage volume.	No sediment in sump or inlet/outlet pipes.
Access Lid	A	Hard to open	Cannot be easily opened.	Access lid is repaired or replaced.
	A	Buried	Buried.	Access lid functions as designed (refer to record drawings for design intent).
	A	Missing cover	Cover missing.	Cover replaced.

No. 25 – Downspout, Sheet Flow, and Concentrated Dispersion Systems

Maintenance Component	Recommended Inspection Frequency[1]	Defect or Problem	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed
Pest Control	B	Mosquito infestation	Standing surface water in dispersion area remains for more than 3 days after the end of a storm.	System freely drains. Standing water in dispersion area does not persist for more than 3 days after a storm event. Cause of the standing water (e.g., grade depressions, compacted soil) addressed.
Rodents	As required	Presence of rodents	Rodent holes or mounds disturb dispersion flow paths.	Rodents removed or destroyed. Holes filled. Flow path revegetated.

[1] Inspection frequency:

A = Annually; B = Biannually; M = Monthly; E = Recommend that additional inspections be performed as appropriate after major events (e.g., >1 inch of precipitation in 24 hours or environmental incident that causes contaminant release); Q = Quarterly (four times per year); W = Recommend that at least one inspection occur during the wet season, preferably after trees have lost their leaves.

No. 26 – Permeable Pavement[1]

Maintenance Component	Recommended Inspection Frequency[2]	Defect or Problem	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed
Facility – General Requirements	A	Unstable adjacent area	Runoff from adjacent pervious areas deposits soil, mulch, or sediment on paving.	No deposited soil or other materials on permeable pavement or other adjacent surfacing. All exposed soils that may erode to pavement surface mulched and/or planted.
	A	Wearing course covered by adjacent vegetation	Vegetation growing beyond facility edge onto sidewalks, paths, and street edge.	Vegetation does not impede function of adjacent facilities or pose as safety hazard. Groundcovers and shrubs trimmed to avoid overreaching the sidewalks, paths, and street edge.
	A, E	Contaminants and pollution	Any evidence of contaminants or pollution such as oil, gasoline, concrete slurries, or paint.	Materials removed and disposed of according to applicable regulations. Source control BMPs implemented if appropriate. No contaminants present other than a surface oil film.
Pavement Wearing Course (all types)	A	Accumulated sediment on surface	Sediment present at the surface of the pavement.	Sediment at surface does not inhibit infiltration.
	A	Surface clogged by moss	Moss growth inhibits infiltration or poses slip safety hazard.	Moss growth on surface does not inhibit infiltration or present a slip safety hazard.
	A	Surface is clogged	Ponding on surface or water flows off the permeable pavement surface during a rain event (does not infiltrate).	System drains freely. No standing water on surface between storms.
	A	Settlement	When deviation from original grade impedes function.	Original grade re-established.

No. 26 – Permeable Pavement[1]

Maintenance Component	Recommended Inspection Frequency[2]	Defect or Problem	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed
Permeable Asphalt or Cement Concrete	A	Cracks	Major cracks or trip hazards and concrete spalling and raveling.	Potholes or small cracks filled with patching mixes. Large cracks and settlement addressed by cutting and replacing the pavement section.
Permeable Paver or Open-Celled Paving Grid	A	Paver block missing or damaged	Paver block missing or damaged.	Individual damaged paver blocks removed and replaced or repaired per manufacturer's recommendations.
	A	Loss of aggregate material between paver blocks	Loss of aggregate material between paver blocks.	Aggregate replaced per manufacturer's recommendations.
Open-Celled Paving Grid	A	Paving grid missing or damaged	Three or more adjacent rings in paving grid missing or damaged.	Grid segment replaced or repaired per manufacturer's recommendations.
	A	Loss of aggregate material in paving grid	Loss of aggregate material in paving grid.	Aggregate gravel level maintained at the same level as the plastic rings or no more than ¼ inch above the top of rings.
	A	Lack of grass coverage	Poor grass coverage in paving grid.	Growing medium restored. Facility reseeded or planted. Aerated without damaging grid material. Vegetated area amended as needed.
	A	Weeds present	Weeds present	Weeds are removed if infiltration is hindered. Noxious weeds are removed.
Inlet/Outlet Pipe	A	Pipe is damaged	Pipe is damaged.	Pipe is repaired/replaced.

No. 26 – Permeable Pavement[1]

Maintenance Component	Recommended Inspection Frequency[2]	Defect or Problem	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed
Inlet/Outlet Pipe (continued)	A	Pipe is clogged	Pipe is clogged.	Roots or debris are removed.
	A, E	Erosion	Native soil exposed or other signs of erosion damage present.	No eroded or scoured areas. Cause of erosion or scour is addressed.
Underdrain Pipe	B	Blocked underdrain	Plant roots, sediment, or debris reducing capacity of underdrain (may cause prolonged drawdown period).	Underdrains and orifice free of sediment and debris.

1 Fog seal, chip seal, and other impervious overlays are not permitted on top of permeable pavement.

2 Inspection frequency:

A = Annually; B = Biannually; M = Monthly; E = Recommend that additional inspections be performed as appropriate after major events (e.g., >1 inch of precipitation in 24 hours or environmental incident that causes contaminant release); Q = Quarterly (four times per year); W = Recommend that at least one inspection occur during the wet season, preferably after trees have lost their leaves.

No. 27 – Trees

Maintenance Component	Recommended Inspection Frequency	Defect or Problem	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed
Tree	As needed	Tree needs pruning to maintain health or otherwise required	Depends on tree species / location.	Prune trees per industry standards (ANSI A300 standards) to preserve health and longevity of trees and avoid damage.
	As needed	Roots damaged by structures weighing down or blocking water and nutrients reaching roots	Structures or vehicles encroach on the tree's drip line (root zone).	Tree free of structures or vehicles over the root zone.
Newly Planted Tree within first 5 years	As needed	Dead or declining	Dead, damaged, or declining in first 5 years.	Tree replaced per planting plan or acceptable substitute.
Retained Tree or Newly Planted Tree after 5 years	As needed	Dead or declining	Dead, damaged, or declining, indicated by no leaves on a tree in summer.	Tree evaluated and treated by a certified arborist if Tier 1, 2, or 3 tree per SMC 25.11 Tree Protection. If tree continues to decline or die it must be replaced with an acceptable substitute.
Retained and Newly Planted Tree	Annual	Poor soil moisture and absorption	No mulch or sparse mulch (less than 2 inches thick).	Mulch annually with a 2- to 4-inch thick layer of arborist wood chips in a donut shape around the tree spaced at a hand's-width from the tree base to improve soil moisture and rainfall absorption.
	As needed	Weeds around tree and damage to tree bark and base	Weeds around base of the tree.	Mulch annually, per box above. Tree protected from string trimmers and mowers.
Newly Planted Tree	Annual	Lack of water during growing season	Appears wilted in summer, may have some dead leaves. Preventative requirement to water new plants weekly throughout growing season.	Tree provided with supplemental irrigation of 15-20 gallons of water twice a week for at least 5 growing seasons after planting.

No. 28 – Vegetated Roof Systems

Maintenance Component	Recommended Inspection Frequency[1]	Defect or Problem	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed
Facility – General Requirements	A	Improper access and safety for maintenance	Insufficient egress/ingress routes and fall protection.	Egress and ingress routes maintained to design standards and fire codes. Fall protection is appropriate.
	A	Border zone not defined	Vegetation is encroaching into border zone aggregate.	No weeds and undesirable vegetation present. Desirable vegetation transplanted.
	A	Flashing, gravel stops, utilities, or other structures on roof	Flashing, utilities, or other structures on roof are deteriorating (can serve as source of metal pollution in vegetated roof runoff).	Potential pollutant sources replaced or eliminated.
	B	Mosquitoes	Standing water remains for more than 3 days after the end of a storm.	System freely drains. Standing water on roof does not persist for more than 3 days after a storm event.
	As required	Nuisance animals	Nuisance animals causing erosion, damaging plants, or depositing large volumes of feces.	Measures in place to deter nuisance species.
Growth Medium	A	Water is not infiltrating properly	Water does not permeate growth media (runs off soil surface) or crusting is observed.	Stormwater infiltrates freely through growth media.
	A	Insufficient growth medium	Growth medium thickness is less than design thickness (due to erosion and plant uptake).	Growth medium is present at design thickness.
	A	Erosion	Growth media erosion/scour is visible (e.g., gullies).	No eroded or scoured areas. Cause of erosion or scour addressed.

No. 28 – Vegetated Roof Systems

Maintenance Component	Recommended Inspection Frequency[1]	Defect or Problem	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed
Roof Drain	B, E	Not draining	Sediment, vegetation, or debris reducing capacity of inlet structure.	Inlet clear. Cause of blockage addressed.
	A	Pipe is clogged	Pipe is clogged.	Debris, roots, or other obstruction removed and pipe is free draining.
Vegetation	B	Plant coverage	Vegetative coverage falls below 80 percent (unless design specifications stipulate less than 80 percent coverage).	Bare areas planted with vegetation. Erosion control measures installed until percent coverage goal attained.
			Summer watering – extensive vegetated roof system.	Vegetation watered weekly during periods of no rain during vegetation establishment period (1–2 years).
			Summer watering – extensive vegetated roof system (continued).	Vegetation watered during drought conditions or more often if necessary to maintain plant cover during post-establishment period (after 2 years).
			Summer watering – intensive vegetated roof system.	Vegetation watered deeply, but infrequently, and the top 6 to 12 inches of the root zone is moist during vegetation establishment period (1–2 years).
			Summer watering – intensive vegetated roof system (continued).	Vegetation watered during drought conditions or more often if necessary to maintain plant cover during post-establishment period (after 2 years).

No. 28 – Vegetated Roof Systems

Maintenance Component	Recommended Inspection Frequency[1]	Defect or Problem	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed
Vegetation (continued)	B	Plant coverage (continued)	Extensive roof with low density sedum population.	Sedums are mulch mowed.
	A	Poor plant establishment and possible nutrient deficiency in growth medium	Fertilization– extensive vegetated roof system.	Organic debris replenished. Annual soil test conducted to assess need for fertilizer. Minimal amounts of slow-release fertilizer applied.
			Fertilization– intensive vegetated roof system.	Annual soil test conducted to assess need for fertilizer. Minimal amounts of slow-release fertilizer applied.
			Dead vegetation is present.	Dead plant material recycled on the roof or removed and replaced (see manufacturer's recommendations).
	Q	Weeds	Weeds are present.	Weeds removed (manual methods preferred). IPM protocols followed.
	M (March – October)	Noxious weeds	Any noxious or nuisance vegetation that may constitute a hazard to City personnel or the public.	Noxious and nuisance vegetation removed according to applicable regulations. No danger of noxious vegetation where City personnel or the public might normally be.
Irrigation System (if any)	Based on manufacturer's instructions	Not applicable	Irrigation system is not working or routine maintenance needed.	Manufacturer's/installer's instructions are followed for operation and maintenance.

[1] Inspection frequency:

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No. 29 – Rain Gardens

Maintenance Component	Recommended Inspection Frequency[1]	Defect or Problem	Conditions When Maintenance is Needed	Results Expected When Maintenance is Performed
Facility – General Requirements	B, E	Mosquitoes	Standing water remains for more than 3 days after the end of a storm.	Rain garden drains freely. Standing water in rain garden does not persist for more than 3 days after a storm event. Cause of the standing water addressed (see "Ponded water").
	A, E	Trash	Trash and debris present.	No trash or debris present.
Earthen Side Slopes and Berms	B, E	Erosion	Persistent soil erosion on slopes.	No eroded or scoured areas. Cause of erosion or scour addressed.
Rockery Sidewalls	A	Unstable rockery	Rockery side walls are insecure.	Stable rockery sidewalls (may require consultation with licensed engineer, particularly for walls 4 feet or greater in height).
Rain Garden Bottom Area	B	Sediment accumulation	Visible sediment deposition in the rain garden that reduces drawdown time of water in the rain garden.	No sediment accumulation in rain garden. Source of sediment addressed.
	B	Debris accumulation	Accumulated leaves in facility.	No leaves clogging outlet structure or impeding water flow.
Mulch	A	Lack of mulch	Bare spots (without mulch cover) are present or mulch depth less than 2 inches.	Facility has a minimum 2 to 3inch layer of an appropriate type of mulch. Mulch kept away from woody stems.

No. 29 – Rain Gardens

Maintenance Component	Recommended Inspection Frequency[1]	Defect or Problem	Conditions When Maintenance is Needed	Results Expected When Maintenance is Performed
Splash Block Inlet	B	Water not properly directed to rain garden	Water is being directed toward building structure.	Blocks are reconfigured to direct water to rain garden and away from structure.
Pipe Inlet/Outlet	B	Erosion	Rock or cobble removed or missing and concentrated flows contacting soil.	No eroded or scoured areas. Cause of erosion or scour addressed. Cover of rock or cobbles protects the ground where concentrated water flows into the rain garden.
	A	Accumulated debris	Accumulated leaves, sediment, debris, or vegetation at curb cuts, inlet, or outlet pipe.	Blockage cleared.
	A	Damaged pipe	Pipe is damaged.	Pipe repaired/replaced.
	A	Clogged pipe	Pipe is clogged.	Pipe clear of roots and debris.
	A	Blocked access	Maintain access for inspections.	Vegetation cleared or transplanted within 1 foot of inlets and outlets.
Ponded Water	As needed	Ponded water	Excessive ponding water: Ponded water remains in the rain garden more than 48 hours after the end of a storm.	Rain garden drains freely. Standing water in rain garden does not persist for more than 48 hours after a storm event. Leaf litter/debris/sediment removed.
Overflow	A, E	Blocked overflow	Capacity reduced by sediment or debris.	No sediment or debris in overflow.
Vegetation	A	Blocked site distances and sidewalks	Vegetation inhibits sight distances and sidewalks.	Sidewalks and sight distances along roadways and sidewalks are kept clear.

No. 29 – Rain Gardens

Maintenance Component	Recommended Inspection Frequency[1]	Defect or Problem	Conditions When Maintenance is Needed	Results Expected When Maintenance is Performed
Vegetation (continued)	A	Blocked pipes	Vegetation is crowding inlets and outlets.	Inlets and outlets in rain garden clear of vegetation.
	M	Unhealthy vegetation	Yellowing: possible Nitrogen (N) deficiency. Poor growth: possible Phosphorous (P) deficiency. Poor flowering, spotting or curled leaves, or weak roots or stems: possible Potassium (K) deficiency.	Plants are healthy and appropriate for site conditions.
	M	Weeds	Presence of weeds.	Weeds removed (manual methods preferred) and mulch applied.
Summer Watering (years 1–3)	Weekly or as required (May – September)	Plant establishment	Tree, shrubs, and groundcovers in first 3 years of establishment period.	Plants are watered during plant establishment period (years 1–3).
Summer Watering (after establishment)	As needed	Drought conditions	Vegetation requires supplemental water.	Plants are watered during drought conditions or more often if necessary during post-establishment period (after 2 years).

[1] Inspection frequency:

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APPENDIX H

Financial Feasibility Documentation for Vegetated Roofs and Rainwater Harvesting

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Vegetated roofs and rainwater harvesting may not be financially feasible in all project situations. If the applicant determines that including a vegetated roof or rainwater harvesting to meet the on-site stormwater management requirement is not economically feasible using reasonable consideration of financial costs, even when engineering design limitations and physical limitations of the site would allow greater use of these best management practices (BMPs), then the applicant shall provide the following additional submittal documentation:

1. A narrative description and rationale with substantial evidence sufficient to explain and justify the applicant's conclusion that installation of a vegetated roof or rainwater harvesting is economically infeasible.
2. A detailed cost estimate of constructing the project as proposed (i.e., including the level of on-site stormwater management that is considered cost feasible for the project). The detailed cost estimate must include the following:
    - Breakdown of project costs into subtotals for demolition, site preparation, building construction, site paving, landscaping, and utilities, as applicable.
    - Itemization of the proposed stormwater control measures.
    - If a vegetated roof or rainwater harvesting would be feasible but for cost considerations, documentation of the difference in unit and total cost between the conventional surface and rainwater harvesting and/or alternative surface approach (e.g., the difference in cost between a standard roof and associated stormwater control BMPs compared to a vegetated roof and associated stormwater control BMPs).
3. A detailed cost estimate of constructing the project with additional stormwater control BMPs beyond what the applicant considers a feasible cost (i.e., beyond the proposed design itemized in item 2 above). That is, provide the additional cost the project would incur if the project were to use a vegetated roof or rainwater harvesting to meet the on-site stormwater management requirements.
4. Building/project valuation construction cost as determined by the Seattle Department of Construction and Inspection (SDCI).
5. If applicable, Street Improvement Plan or Utility Plan construction cost as determined by the Seattle Department of Transportation (SDOT) or capital improvement project cost as determined by applicable City department.
6. If the project does not achieve the on-site stormwater management requirements and the project application is not signed and stamped by a professional engineer, a signed statement by the applicant certifying that the project design implements the on-site stormwater management requirements is required.

Alternatively, the applicant may establish financial infeasibility of rainwater harvesting based on one of the following simplified criteria:

- The non-pollution-generating roof area is less than 20,000 square feet.
- The ratio of roof area to average daily rainwater demand is less than 10,000 square feet/gallons per minute (gpm) (refer to *Volume 3, Section 5.5.1.6* for rainwater demand calculations).

APPENDIX I

Landscape Management Plans and Integrated Pest Management Plans

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I-1. Landscape Management Plans

A landscape management plan (LMP) is a plan for defining the layout and long-term maintenance of landscaping features to minimize the use of pesticides (including herbicides and fungicides) and fertilizers and reduce the discharge of suspended solids and other pollutants. Use of an LMP that has been approved by the City of Seattle (City) is allowed as an alternative to the requirement to formally treat (with a water quality treatment BMP) the runoff from pollution-generating pervious surfaces (PGPS) that are subject to water quality treatment. LMPs have the potential to significantly reduce the pollutant load washing off managed green spaces. The requirements for obtaining City approval of an LMP are summarized in this section.

LMPs must address the basic principles provided in *Volume 1, Section 2.4.8*, tailoring them to fit the specific site. Every LMP will not necessarily be able to apply each of the listed recommendations related to the basic principles. In addition, landscapes are managed for different purposes, some more formal than others. Some recommendations may not be appropriate for very formal sites; therefore, they will not be adopted, in favor of other management practices that better fit the intended uses of the site. In the end, the extent to which an LMP is successful depends on the ability of the applied practices to retain soil, fertilizers, and pesticides on the site and away from receiving waters throughout the entire year.

If an LMP is proposed, it must be submitted with the engineering plans for the proposed project. The following documentation is required for the evaluation of an LMP submittal:

- Site vicinity map showing topography.
- Site plan, including topography, areas with saturated soils (if applicable), and high water tables (if applicable).
- Narrative describing how the basic principles in *Volume 1, Section 2.4.8* will be achieved.
- Plant list (with both common and scientific names) that includes the following:
    - Drought-tolerant plants, disease-resistant varieties, species for attracting beneficial insects (if any), and native plants.
    - Proposed spacing for shrubs and groundcovers.
    - Grass mix or mixes planned for turf areas, including their sun/shade tolerance, disease susceptibility, drought tolerance, and tolerance of wet soil conditions.
- Landscape plan indicating placement of landscape features, lawn areas, trees, and planting groups (e.g., forbs, herbs, and groundcovers) on the site.
- Signage plan including proposed locations of signs and content of signs.
    - Signage must be located to identify which areas are included in the LMP.
    - Signage must indicate how a copy of the approved LMP can be obtained.
    - Inclusion of the following information in the signage is also encouraged: basic educational information about the LMP for maintenance workers and the public.

- Information on soil preparation and fertility requirements.
- Information on the design of the irrigation method (e.g., installed sprinkler system, drip irrigation system, or manual watering).
- Landscape maintenance plan, including the following:
    - Physical care methods, such as thatch removal or aeration, and mowing height and frequency.
    - Type of fertilizer (including percentages of nitrogen, phosphorus, and potassium [N-P-K]) and fertilization schedule or criteria.
- Integrated Pest Management (IPM) plan (refer to *Section I1-*), including the following:
    - Type of chemicals to be used for common pests such as crane fly larvae and the criteria or schedule for application.
    - Any biocontrol methods to be used.
- Information about the storage of pesticides or other chemicals, and the measures that will be used to dispose of them, including the following:
    - How the chemicals will be stored on the site between applications to prevent contact with stormwater or spills into the drainage system (if applicable).
    - How excess quantities of fertilizers or chemicals will be handled for individual applications.
- Implementation plan, including the following:
    - The responsible party for ensuring that the LMP is implemented.
    - How the applicant will ensure that grounds crews have the training and/or resources required to implement the LMP and make adjustments based on advances in landscape care practices and products.
    - A fertilizer and pesticide application log, including rate of application, area treated, and disposal or storage of residue.

I-2. Integrated Pest Management Plans

An IPM plan is a natural, long-term, ecologically based systems approach to controlling pest populations. IPM uses techniques either to reduce pest populations or maintain them at levels below those causing economic injury, or to so manipulate the populations that they are prevented from causing injury.

The goals of IPM are the encouragement of optimal selective pesticide use (away from prophylactic, broad-spectrum use) and the maximization of natural controls to minimize environmental side effects by creating and maintaining healthy landscapes:

- **Design for a healthy landscape**. A landscape should be designed to maximize the intended uses of the land and minimize potential pest problems. Design considers such plant health factors as site usage, soils, topography, hydrology and drainage, proximity to sensitive or critical areas and existing vegetation as well as known pest sensitivity. Take drainage pathways into consideration when considering landscape management and the potential need for pest control.
- **Awareness of potential pest problems**. Certain plants have known pest problems. Likewise, certain cultural conditions or landscape situations can encourage the infestation of pests.
- **Maintenance for maximum landscape health**. A well-designed and maintained landscape dramatically reduces the need for pest control. Appropriate selection of plants, pruning, proper irrigation, applications of mulch and fertilizer, appropriate mowing techniques, and other practices all promote landscapes that resist pest pressures and support natural predators.
- **Minimize disturbance of naturally occurring biological controls**. Pests have natural predators and controls operating on them at all times. Disruption of these systems due to poor maintenance practices can result in the development of new pest problems.

The following step-by-step comprehensive IPM plan process is provided as a guide.

Step 1: Correctly Identify the Pest and Understand Its Life Cycle

Identify the pest (e.g., weed, insect, or disease). Learn more about the pest. Observe it and pay attention to any damage that may be occurring. Learn about the life cycle. Many pests are a problem only during certain seasons or can be treated effectively only during certain phases of the life cycle. Repeat this step if more than one pest is identified.

Step 2: Establish Tolerance/Action Thresholds

Every landscape has a population of some pest (insect, weed, or disease), which is good because it supports a population of beneficial species that keep pest numbers in check. Beneficial organisms may compete with, eat, or parasitize disease or pest organisms. Decide on the level of infestation that must be exceeded before treatment needs to be considered. Pest populations under this threshold should be monitored but do not need treatment. For instance, European crane flies usually do not cause serious damage to a lawn unless there are between 25 and 40 larvae per square foot feeding on the turf in February (in normal weather years). Also, most people consider a lawn healthy and well maintained even with up to

20 percent weed cover; therefore, treatment, other than continuing good maintenance practices, is generally unnecessary.

Step 3: Monitor Regularly to Detect Pest Problems

Regular monitoring is a key practice for anticipating and preventing major pest outbreaks. It begins with a visual evaluation of the lawn or landscape condition. Take a few minutes before mowing to walk around and look for problems. Keep a notebook, record when and where a problem occurs, then monitor for it at about the same time in future years. Specific monitoring techniques can be used in the appropriate season for some potential problem pests, such as the European crane fly.

Step 4: Modify Maintenance Program to Promote Plant Health and Discourage Pests

A healthy landscape is resistant to most pest problems. Lawn aeration and overseeding along with proper mowing height, fertilization, and irrigation will help the grass out-compete weeds. Correcting drainage problems and letting soil dry out between watering in the summer may reduce the number of surviving crane-fly larvae. Gradually replace pest-prone plants.

Step 5: If Pests Exceed the Tolerance Thresholds, Use Cultural, Physical, Mechanical, or Biological Controls Prior to Implementing Chemical Controls

When a pest outbreak occurs (or monitoring indicates that one is imminent), implement cultural, physical, mechanical, or biological controls. If these types of controls prove insufficient, then consider chemical control options that are the least toxic or have the least non-target impact.

Here are two examples of an IPM approach for damaged lawns:

- **Red thread disease** is most likely under low-nitrogen fertility conditions and most severe during slow growth conditions. Mow the lawn and bag the clippings to remove diseased blades. Fertilize lightly to help the grass recover, then begin grasscycling (e.g., leaving grass clippings on a mowed lawn) and change to fall fertilization with a slow release or natural organic fertilizer to provide an even supply of nutrients. Chemical fungicides are not recommended because red thread cannot kill the lawn.
- **Crane fly damage** is most prevalent on lawns that stay wet in the winter and are irrigated in the summer. Correct the winter drainage and/or allow the soil to dry between irrigation cycles; larvae are susceptible to drying out so these changes can reduce their numbers. It may also be possible to reduce the number of crane fly larvae by using a power dethatcher on a cool, cloudy day when they are feeding close to the surface. Current studies are investigating the use of beneficial nematodes that parasitize the crane fly larvae; this type of treatment may eventually be a reasonable alternative.

Only after trying suitable non-chemical control methods or determining that the pest outbreak is causing too much serious damage should chemical controls be considered. Determine the available products and choose the one that is the least toxic and has the least non-target impact.

Step 6: Evaluate and Record Effectiveness of Control and Modify Maintenance or Plant Choices to Support Recovery and Prevent Recurrence

Keep records. Note when, where, and what symptoms occurred, or when monitoring revealed a potential pest problem. Note what controls were applied and when, and the effectiveness of the control. Monitor the following year for the same problems. Review your landscape maintenance and cultural practices to see if they can be modified to prevent or reduce the severity of the problem.

A comprehensive IPM program should also include the proper use of pesticides as a last resort and vegetation/fertilizer management to eliminate or minimize the contamination of stormwater.

I-3. References

Refer to the Seattle Public Utilities IPM web page for additional resources for developing an LMP or IPM plan: www.seattle.gov/utilities/protecting-our-environment/sustainability-tips/landscaping/for-professionals/integrated-pest-management.

APPENDIX J

Plant and Tree Lists for Stormwater BMPs

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INTRODUCTION

The following plant lists were developed as a guide for bioretention (infiltrating and non-infiltrating), soil cell bioretention (infiltrating and non-infiltrating), biofiltration swales, sand filters, and wet ponds. For information regarding planting for other BMPs, refer to *Volume 3, Chapter 5*. More stringent requirements have been developed for BMPs sited in the right-of-way and can be found in the Seattle Right-of-Way Improvements Manual.

The following design principles should be considered during plant selection:

- Select plants to minimize irrigation and maintenance needs. Coordinate planting design, whenever possible, with maintenance staff.
- Where appropriate, use regionally native species.
- Design a planting plan with a goal of achieving a minimum of 80 percent evergreen groundcover. Evergreen groundcover helps trap sediment and protects soil and infiltration rates during the wet season.
- Consider biodiversity of species, including a minimum of three to five species for planting plans for small BMPs, and increasing species diversity where possible. Species and genetic diversity increase resilience and the ability of a BMP to adapt during varying site conditions.
- Incorporate pollinator, bird, and wildlife species into planting plans where possible. Maximize various seasonal habitat function. For example, flowering plants should bloom three of the four seasons. Planting plans for BMPs adjacent to natural areas should include native trees, shrubs, and groundcover that provide habitat value and support.

Refer to *Volume 3, Section 5.2* for minimum tree requirements for stormwater management. Approved tree species for parcels are listed in the *Green Factor tree list* posted on SDCI's website. Approved tree species for the right-of-way are listed in the SDOT Approved Street Tree List posted on SDOT's website. Trees used for On-site Stormwater Management or Flow Control Management may be selected from the trees in Table J.8 through J.18 if they meet the mature height and canopy requirements in Volume 3, Section 5.2 – Tree Retention and Planting.

For vegetated roof systems, refer to the *Green Factor plant list* posted on SDCI's website. Refer to *Volume 3, Section 5.6.1* for minimum vegetation requirements for stormwater management.

The plant lists for the following applications are included in this *Appendix*.

- J-1. Plant Lists for Bioretention and Soil Cell Bioretention (Tables J.1 through J.17)
- J-2. Plant Lists for Biofiltration Swales (Tables J.18 through J. 20)
- J-3. Plant Lists for Sand Filters (Table J.21)
- J-4. Plant Lists for Wet Ponds (Table J.22)

The Seattle Right-of-Way Improvements Manual establishes height limits for non-street tree plantings in rights-of-way. Maximum plant height within 30 feet of a stop sign is 24 inches. Elsewhere in the right-of-way, plantings are allowed to be 30 inches with the exception of accent shrubs as directed. Refer to Streets Illustrated, Section 3.3 for clearance guidance.

J-1. Plants and Trees for Bioretention and Soil Cell Bioretention (Bioretention BMPs)

Plants and trees used for bioretention BMPs (infiltrating bioretention, non-infiltrating bioretention, soil cell bioretention) shall be selected from the Tables J.1 through J.17. Select the trees based on the location the tree will be placed in, or near, the bioretention BMP. The following bioretention planting zone codes apply to Tables J.1 through J.17. The planting zones are also shown in Figure J.1:

- Zone 1: designation for plants that are used in the bottoms of bioretention BMPs.
- Zone 2: designation for plants that are used in the lower slopes/wetted/ponded area of bioretention BMPs.
- Zone 3: species appropriate for planting at the tops and upper slopes of bioretention BMPs that are used as a border and as accents along the sidewalk, including vertical and accent plants and trees.
- Zone 4: low, durable plants (under 24 inches) that are used in sight clearance areas or as accents at the edge of the BMP.
- Zone 5: designation for steppable plants used in the crossing zones and access areas along the curb — these plants may need to tolerate foot traffic, depending on their location.

The following operations and maintenance/special needs code (O&M code) apply to Tables J.1 through J.7:

- A = Cut back perennials to 3 inches above ground in fall (October/November).
- B = Leave foliage and seedheads for winter interest and cut back if foliage collapses. Cut back in spring (mid-January to mid-March) before new growth emerges.
- C = Hand-rake in spring (mid-January to mid-March) before new growth emerges. Cut back to ground or thin every 2 to 3 years as needed.
- DS = Deadhead perennials in spring/summer to encourage reblooming and for neater appearance. Deadheading not required for function.
- DF = Deadhead perennials in fall for neater appearance and to prevent resowing. Deadheading not required for function.
- E = Cut back or prune over sidewalk or clear zones. Remove deadwood anytime fall to spring.
- F = May need replacing every 5+/ years. (Replacement not required if vegetation coverage meets requirements.)
- G = May need dividing every few years. Reasons for division include dieback in center and to increase coverage.

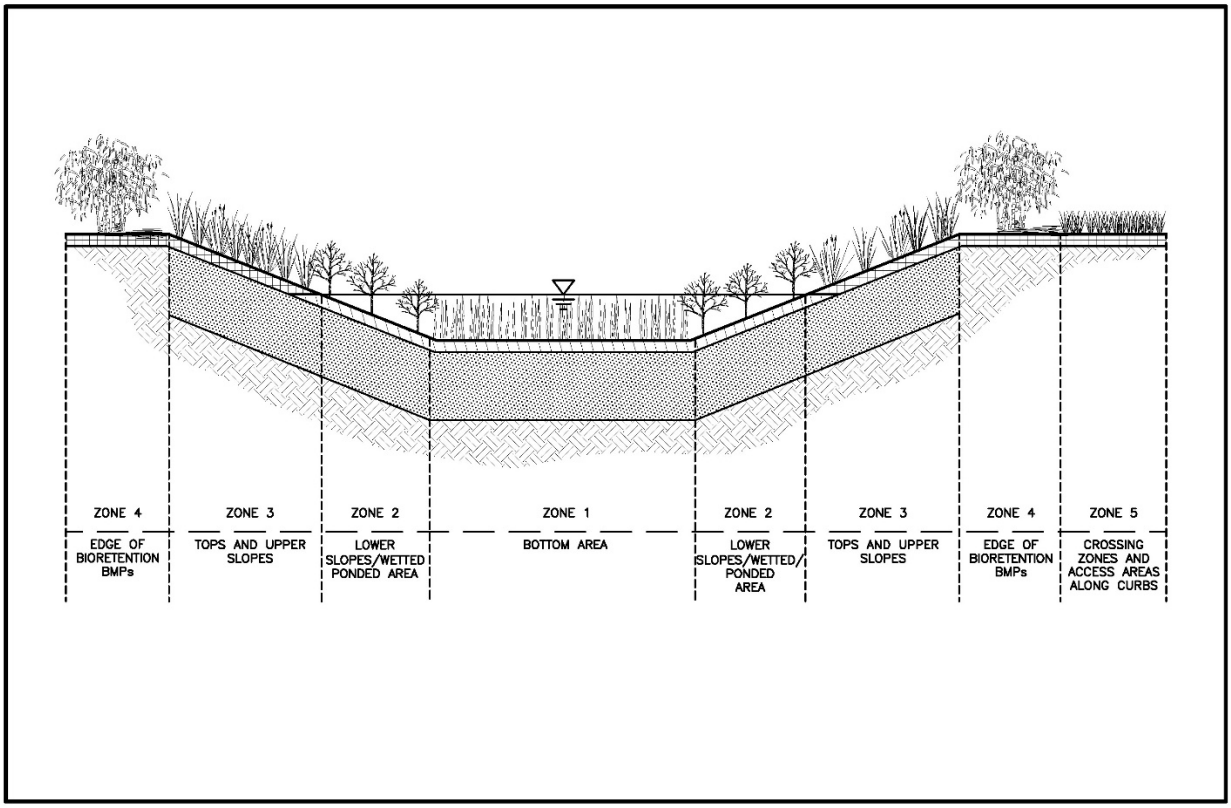

Figure J.1. Bioretention Planting Zones.

Table J.1. Part Shade Plant List Suitable for Bioretention.

EG	DT	NWN	Height from Ground	Scientific Name	Common Name	Planting Zone	Suggested Size/ Spacing	Urban Frontage	Exposure	Design Comments	O&M Code	Additional O&M Comments
SEMI			<24″	*Abelia x grandiflora* 'Prostrata'	Prostrate white abelia	3, 4	1 Gal./30″ o.c.	UF	☼, Ø		E	
	DT		18″–30″	*Aster divaricatus*	White wood aster	3	1 Gal./24″ o.c.		∅Ø		B	
			<24″	*Carex elata* 'Bowles Golden'	Bowles Golden sedge	1, 2	10 Cu. In. Plug/ 9″ o.c.	UF	☼, Ø	Limit to areas of approx. 36″x36″	B	
EG			<24″	*Carex laxiculmis* 'Hobb'	Bunny Blue sedge	1, 2	10 Cu. In. Plug/ 9″ o.c.	UF	Ø		C	
EG	DT	NWN	24″–48″+	*Carex obnupta*	Slough sedge	1, 2	10 Cu. In. Plug/ 9″ o.c.		☼, Ø	Do not intermix with other emergents. Do not plant near intersections. Drought tolerant wetland native.	C	Can be sheared more frequently if overcrowding other occurs. May require supplementary irrigation during prolonged dry periods.
		NWN	24″–36″	*Carex stipata*	Beaked sedge	1, 2	10 Cu. In. Plug/ 9″ o.c.	UF	☼, Ø	Wetland native species. Limit to areas of approx. 36″x36″	B	May require supplementary irrigation during prolonged dry periods. Will die out if mowed or trimmed too regularly.
EG			24″–30″	*Carex testacea* or *dispacea*	Orange New Zealand or Autumn sedge	1, 2	10 Cu. In. Plug/ 9″ o.c.	UF	☼, Ø		C	

Table J.1 (continued). Part Shade Plant List Suitable for Bioretention.

EG	DT	NWN	Height from Ground	Scientific Name	Common Name	Planting Zone	Suggested Size/ Spacing	Urban Frontage	Exposure	Design Comments	O&M Code	Additional O&M Comments
	DT		24″–36″	*Cornus sericea* 'Kelseyii'	Kelsey redstem dogwood	1, 2, 3	2 Gal./30″ o.c.	UF	☼, Ø		E	Stems fragile until established.
		NWN	24″–40″	*Deschampsia caespitosa*	Tufted Hair grass	1, 2	10 Cu. In. Plug/ 9″ o.c.		☼, Ø	Native facultative species; does well in wet and dry conditions. Limit to areas of approx. 36″x36″	B	LOS A: For neater appearance, trim seedheads.
			<24″	*Deschampsia flexuosa* 'Aurea'	Golden crinkled hair grass	1, 2	10 Cu. In. Plug/ 9″ o.c.	UF	☼, Ø	Limit to areas of approx. 36″x36″	B	LOS A: For neater appearance, trim seedheads.
			24″	*Fuchsia magellanica* 'Aurea'	Dwarf Hardy Fuchsia	3, 4	2 Gal./30″ o.c.	UF	∅Ø		E	
			<24″	*Galanthus elwesii*	Giant Snowdrop	3, 4	Bulb	UF	☼, Ø	Prefers part shade. May be short-lived if too hot.	F	
EG	DT	NWN	24″–36″+	*Gaultheria shallon*	Salal	3	1 Gal./24″ o.c.	UF	☼, Ø		E	If height is a problem, salal can be sheared with hedge trimmer.
EG			<24″	*Geum flore-plena* 'Blazing Sunset'	Blazing Sunset Avens	3, 4	1 Gal./10″ o.c.	UF	☼, Ø		DS	
			24″–36″	*Iris pallida* 'Variegata'	Variegated sweet iris	3	1 Gal./18″ o.c.	UF	☼, Ø		A	

Table J.1 (continued). Part Shade Plant List Suitable for Bioretention.

EG	DT	NWN	Height from Ground	Scientific Name	Common Name	Planting Zone	Suggested Size/ Spacing	Urban Frontage	Exposure	Design Comments	O&M Code	Additional O&M Comments
EG	DR	NWN	<24″	*Mahonia repens*	Creeping Oregon holly-grape	3, 4	1 Gal./18″ o.c.	UF	☼, Ø		E	
EG	DR	NWN	24″–36″	*Polystichum munitum*	Western swordfern	3	2 Gal./24″ o.c.	UF	Ø	Limit to group of 3.	B	Cut back before fronds appear.
EG	DT		24″–36″	*Prunus laurocerasus* 'Mount Vernon'	Mount Vernon cherry laurel	3	2 Gal./24″ o.c.	UF	☼, Ø		E	
EG			36″	*Rhododendron* Yak Hybrids, such as 'Ken Janeck'	Yak Hybrid	3	2 Gal./24″ o.c.	UF	☼, Ø	Several other Yak hybrids stay low and neat.	E	LOS A: May produce more flowers if pruned and/or deadheaded after blooming.
EG	DT		<24″	*Sarcococca hookeriana humilis*	Himalayan Sweet Box	3	2 Gal./24″ o.c.	UF	Ø	Winter fragrance.	E	
EG			30″	*Taxus* 'Emerald Spreader'	Emerald Spreader Yew	3	2 Gal./24″ o.c.	UF	☼, Ø		E	
		NWN	<24″	*Tolmiea menziesii*	Youth on Age	1, 2, 3	1 Gal./10″ o.c.		Ø		G	
EG	DT		<24″	*Veronica liwanensis*	Speedwell	3, 4, 5	4″ Pot/12″ o.c.	UF	☼, Ø		E	LOS A: Cut back for neater appearance.

EG = Evergreen
SEMI = Semi-evergreen
DT = Drought Tolerant
DR = Drought Resistant
NWN = Northwest Natives or Cultivars
UF = Urban Frontage (Mixed Use/Commercial) appropriate plants
☼ = Full Sun
Ø = Part Sun/Part Shade
LOS = Level of Service

Table J.2. Sun Plant List Suitable for Bioretention.

EG	DT	NWN	Height from Ground	Scientific Name	Common Name	Planting Zone	Suggested Size/ Spacing	Urban Frontage	Exposure	Design Comments	O&M Code	Additional O&M Comments
SEMI			<24″	*Abelia x grandiflora* ‘Prostrata’	Prostrate white abelia	3, 4	1 Gal./30″ o.c.	UF	☼, Ø		E	
	DT		<24″	*Aster novi-belgii* ‘Wood’s Blue’	Wood’s Blue New York Aster	3	1 Gal./18″ o.c.	UF	☼		B, G	
			24″–36″	*Carex muskingumen-sis*	Palm sedge	1, 2	10 Cu. In. Plug/ 9″ o.c.	UF	☼, Ø	Limit to areas of approx. 36″x36″	B	
			24″–36″	*Carex elata* ‘Bowles Golden’	Bowles Golden sedge	1, 2, 3	10 Cu. In. Plug/ 9″ o.c.	UF	☼, Ø	Limit to areas of approx. 36″x36″	B	
			24″–36″+	*Carex grayi*	Gray’s sedge	1, 2	10 Cu. In. Plug/ 9″ o.c.	UF	☼, Ø	Limit to areas of approx. 36″x36″	B	
		NWN	24″–36″	*Carex stipata*	Beaked sedge	1, 2	10 Cu. In. Plug/ 9″ o.c.	UF	☼, Ø	Wetland native species. Limit to areas of approx. 36″x36″	B	May require supplementary irrigation during prolonged dry periods. Will die out if mowed or trimmed too regularly.
EG			24″–30″	*Carex testacea or dispacea*	Orange New Zealand or Autumn sedge	1, 2, 3	10 Cu. In. Plug/ 9″ o.c.	UF	☼, Ø		C	

Table J.2 (continued). Sun Plant List Suitable for Bioretention.

EG	DT	NWN	Height from Ground	Scientific Name	Common Name	Planting Zone	Suggested Size/ Spacing	Urban Frontage	Exposure	Design Comments	O&M Code	Additional O&M Comments
	DT		24″–36″	*Caryopteris incana* 'Sunshine Blue'	Sunshine Blue Bluebeard	3, 4	1 Gal./18″ o.c.	UF	☼		B OR DF	Cut back to about 18″ above the ground or by half in early spring after new leaves are visible.
	DT	NWN	24″–30″	*Cornus sericea* 'Kelseyii'	Kelsey redstem dogwood	1, 2, 3	2 Gal./30″ o.c.	UF	☼, Ø		E	Stems fragile until established.
		NWN	24″–40″	*Deschampsia caespitosa*	Tufted Hair grass	1, 2	10 Cu. In. Plug/ 9″ o.c.		☼, Ø	Native facultative species; does well in wet and dry conditions. Limit to areas of approx. 36″x36″	B	LOS A: For neater appearance, trim seedheads.
			<24″	*Deschampsia flexuosa* 'Aurea'	Golden crinkled hair grass	1, 2	10 Cu. In. Plug/ 9″ o.c.	UF	☼, Ø	Limit to areas of approx. 36″x36″	B	LOS A: For neater appearance, trim seedheads.
	DT		24″–36″	*Echinacea purpurea*	Coneflower	3	1 Gal./18″ o.c.	UF	☼		B	LOS A: For neater appearance, deadhead.
EG	DT	NWN	24″–36″+	*Gaultheria shallon*	Salal	3	1 Gal./24″ o.c.	UF	☼, Ø		E	If height is a problem, salal can be sheared with hedge trimmer.

Table J.2 (continued). Sun Plant List Suitable for Bioretention.

EG	DT	NWN	Height from Ground	Scientific Name	Common Name	Planting Zone	Suggested Size/ Spacing	Urban Frontage	Exposure	Design Comments	O&M Code	Additional O&M Comments
	DT		<24″	*Hemerocallis* – Later Flowering Varieties	Later flowering daylily varieties	3, 4	1 Gal./15″ o.c.	UF	☼, Ø	Later flowering varieties are not as susceptible to daylily gall midge.	A	LOS A: For neater appearance, deadhead.
EG	DT		<24″	*Geranium x cantabrigiense* 'Cambridge'	Perennial Geranium	3, 4	1 Gal./15″ o.c.	UF	☼, Ø		B	
SEMI	DT		<24″	*Helianthemum* 'Henfield Brilliant'	Sunrose	3, 4	1 Gal./10″ o.c.	UF	☼		B	
EG	DT		24″–36″	*Helictotrichon sempervirens*	Blue oat grass	3	1 Gal./18″ o.c.	UF	☼		C	
EG	DT		<24″	*Ilex x* 'Mondo'	Little Rascal Holly	3, 4	1 Gal./18″ o.c.	UF	☼, Ø		E	
EG	DT	NWN	<24″	*Iris douglasiana*	Pacific Coast Iris	3, 4	1 Gal./18″ o.c.	UF	☼	Many colors available.	G	LOS A: For neater appearance, cut back dead leaves and flower stalks.

Table J.2 (continued). Sun Plant List Suitable for Bioretention.

EG	DT	NWN	Height from Ground	Scientific Name	Common Name	Planting Zone	Suggested Size/ Spacing	Urban Frontage	Exposure	Design Comments	O&M Code	Additional O&M Comments
SEMI	DT	NWN	<24″	*Iris missouriensis*	Rocky Mountain Iris	1, 2	1 Gal./12″ o.c.	UF	☼		G	May require supplementary irrigation during prolonged dry periods. LOS A: For neater appearance, cut back dead leaves and flower stalks.
			24″–36″	*Iris sibirica* cultivars such as ‘Bennerup Blue’	Siberian Iris	1, 2, 3	1 Gal./18″ o.c.	UF			G	LOS A: For neater appearance, cut back dead leaves and flower stalks.
EG	DT	NWN	<24″	*Juncus balticus*	Baltic rush	1, 2	10 Cu. In. Plug/ 9″ o.c.	UF	☼	Wetland native species. Do not use in hot ROW locations.	C	May require supplementary irrigation during prolonged dry periods. Will die off if sheared too frequently. LOS A: Can be sheared more frequently if foliage collapses.

Table J.2 (continued). Sun Plant List Suitable for Bioretention.

EG	DT	NWN	Height from Ground	Scientific Name	Common Name	Planting Zone	Suggested Size/ Spacing	Urban Frontage	Exposure	Design Comments	O&M Code	Additional O&M Comments
EG		NWN	24″–36″	*Juncus effusus* 'Quartz Creek'	Quartz Creek Soft Rush	1, 2	10 Cu. In. Plug/ 9″ o.c.	UF	☼, Ø		C	LOS A: Can be sheared more frequently if foliage collapses.
EG	DT		<24″	*Juniperus conferta* 'Blue Pacific'	Blue Pacific Shore juniper	3, 4	1 Gal./3′ o.c.	UF	☼		E	
	DT	NWN	36″	*Leersia oryzoides*	Rice Cutgrass	1, 2	10 Cu. In. Plug/ 9″ o.c.		☼	Limit to areas of approx. 36″x36″	B	LOS A: For neater appearance, trim seedheads.
EG	DR	NWN	<24″	*Mahonia repens*	Creeping Oregon holly-grape	3, 4	1 Gal./18″ o.c.	UF	☼, Ø		E	
	DR		36″	*Miscanthus sinensis* 'Little Kitten'	Little Kitten Maiden Grass	3	1 Gal./15″ o.c.	UF	☼		B	
	DT		30″	*Nepetax* 'Walker's Low'	Catmint	3	1 Gal./18″ o.c.	UF	☼, Ø		B	
EG			36″	*Rhododendron* Yak Hybrids, such as 'Ken Janeck'	Yak Hybrid	3, 4	2 Gal./30″ o.c.	UF	☼, Ø	Several other Yak hybrids stay low and neat.	E	LOS A: May produce more flowers if pruned and/or deadheaded after blooming.
	DT		24″–36″	*Rudbeckia fulgida* 'Goldsturm'	Black-Eyed Susan	3, 4	1 Gal./18″ o.c.	UF	☼	Late season color accent.	A OR B	

Table J.2 (continued). Sun Plant List Suitable for Bioretention.

EG	DT	NWN	Height from Ground	Scientific Name	Common Name	Planting Zone	Suggested Size/ Spacing	Urban Frontage	Exposure	Design Comments	O&M Code	Additional O&M Comments
	DT		<24″	*Sedum* 'Autumn Joy' or 'Matrona'	Stonecrop	3, 4	1 Gal./12″ o.c.	UF	☼		G	LOS A: Can be cut back by half in June to prevent flopping.
	DT	NWN	<24″	*Solidago canadensis* 'Baby Gold' or *Solidago hybrida* 'Dansolitlem'	Baby Gold or Little Lemon Goldenrod	3, 4	1 Gal./18″ o.c.		☼	Late season color accent.	A	
		NWN	24″–48″	*Spiraea betulifolia* or *Spiraea betulifolia* 'Tor'	Birchleaf spirea	3	1 Gal./24″ o.c.	UF	☼		E	
EG	DT	NWN	<24″	*Sedum oreganum*	Stonecrop	3, 4, 5	4″ Pot/12″ o.c.	UF	☼	Tolerates hot dry sites.	E	
EG	DT		<24″	*Teucrium chamaedrys*	Wall germander	3, 4	1 Gal./18″ o.c.	UF	☼		E	LOS A: For neater appearance trim spent flowers in spring.
EG	DT		<24″	*Thymus serpyllum* 'Elfin'	Elfin creeping thyme	3, 4, 5	4″ Pot/12″ o.c.	UF	☼		F	

EG = Evergreen
SEMI = Semi-evergreen
DT = Drought Tolerant
DR = Drought Resistant
NWN = Northwest Natives or Cultivars
UF = Urban Frontage (Mixed Use/Commercial) appropriate plants
☼ = Full Sun
Ø = Part Sun/Part Shade
LOS = Level of Service

Table J.3. Native Plant List Suitable for Bioretention (Sun to Part Shade includes cultivars).

EG	DT	NWN	Height from Ground	Scientific Name	Common Name	Planting Zone	Suggested Size/ Spacing	Urban Frontage	Exposure	Design Comments	O&M Code	Additional O&M Comments
	DR	NWN	24″–36″	*Aquilegia formosa*	Western Columbine	3, 4	1 Gal./18″ o.c.		☼, Ø		DF	
EG	DT	NWN	<24″	*Arctostaphylos uva-ursi* 'Massachusetts' or 'Pt. Reyes'	Kinnikinnick	3, 4	1 Gal./12″ o.c.	UF	☼, Ø	Possible use at vertical wall or single use low accent. Requires approval by Project Manager and Maintenance prior to use.	E	
	DR	NWN	24″–36″	*Camus leichtlinii or Camus quamash*	Great Camus or Common Camus	3, 4	1 Gal./12″ o.c.		☼, Ø	Plant in groups for effect. Can be planted as a bulb.	DF	
	DR	NWN	24″–48″	*Carex deweyana*	Dewey's sedge	1, 2	10 Cu. In. Plug/ 9″ o.c.		☼, Ø	Grows best on side slopes. Limit to areas of approx. 36″x36″	B	Likely to need supplementary irrigation if planted in full sun.
EG	DT	NWN	24″–48″+	*Carex obnupta*	Slough sedge	1, 2	10 Cu. In. Plug/ 9″ o.c.		☼, Ø	Drought tolerant wetland native. Do not intermix with other emergents. Do not plant near intersections	C	May require supplementary irrigation during prolonged dry periods. Can be sheared more frequently if overcrowding occurs.

Table J.3 (continued). Native Plant List Suitable for Bioretention BMPs (Sun to Part Shade includes cultivars).

EG	DT	NWN	Height from Ground	Scientific Name	Common Name	Planting Zone	Suggested Size/ Spacing	Urban Frontage	Exposure	Design Comments	O&M Code	Additional O&M Comments
	DT	NWN	24″–36″	*Carex pachystachya*	Chamisso sedge	1, 2	10 Cu. In. Plug/ 9″ o.c.		☼, Ø	Grows best on side slopes. Limit to areas of approx. 36″x36″	B	
		NWN	24″–36″	*Carex stipata*	Beaked sedge	1, 2	10 Cu. In. Plug/ 9″ o.c.	UF	☼, Ø	Limit to areas of approx. 36″x36″	B	May require supplementary irrigation during prolonged dry periods. Will die out if mowed or trimmed too regularly.
	DT	NWN	24″–30″	*Cornus sericea* ‘Kelseyii’	Kelsey redstem dogwood	1, 2, 3	2 Gal./30″ o.c.	UF	☼, Ø	Limit to areas of approx. 36″x36″	E	Stems fragile until established.
		NWN	24″–40″	*Deschampsia caespitosa*	Tufted Hair grass	1, 2	10 Cu. In. Plug/ 9″ o.c.		☼, Ø	Native facultative species; does well in wet and dry conditions. Limit to areas of approx. 36″x36″	B	LOS A: For neater appearance, trim seedheads.
	DT	NWN	<24″	*Erigeron peregrinus*	Subalpine fleabane daisy	3, 4	1 Gal./12″ o.c.	UF	☼		DF	
	DT	NWN	36″	*Festuca idahoensis*	Idaho fescue	3, 4	1 Gal./18″ o.c.		☼		DF	
EG	DT	NWN	<24″	*Gaultheria ovatifolia*	Oregon wintergreen	3, 4	1 Gal./24″ o.c.	UF	☼, Ø	If Gaultheria shallon is substituted see additional O&M notes.	E	If height is a problem, can be sheared with hedge trimmer.

Table J.3 (continued). Native Plant List Suitable for Bioretention BMPs (Sun to Part Shade includes cultivars).

EG	DT	NWN	Height from Ground	Scientific Name	Common Name	Planting Zone	Suggested Size/ Spacing	Urban Frontage	Exposure	Design Comments	O&M Code	Additional O&M Comments
EG	DT	NWN	<24″	*Iris douglasiana*	Pacific Coast Iris	3, 4	1 Gal./18″ o.c.	UF	☼	Many colors available.	G	LOS A: For neater appearance, cut back dead leaves and flower stalks.
SEMI	DT	NWN	<24″	*Iris missouriensis*	Rocky Mountain Iris	1, 2	1 Gal./12″ o.c.	UF	☼		G	LOS A: For neater appearance, cut back dead leaves and flower stalks.
EG	DT	NWN	<24″	*Juncus balticus*	Baltic rush	1, 2	10 Cu. In. Plug/ 9″ o.c.	UF	☼	Wetland native species. Do not use in hot ROW locations.	C	May require supplementary irrigation during prolonged dry periods. Will die off if sheared too frequently. LOS A: Can be sheared more frequently if foliage collapses.

Table J.3 (continued). Native Plant List Suitable for Bioretention BMPs (Sun to Part Shade includes cultivars).

EG	DT	NWN	Height from Ground	Scientific Name	Common Name	Planting Zone	Suggested Size/ Spacing	Urban Frontage	Exposure	Design Comments	O&M Code	Additional O&M Comments
EG	DT	NWN	24″–48″+	*Juncus effusus*	Common rush	1, 2	10 Cu. In. Plug/ 9″ o.c.		☼, Ø	Only *Juncus effusus* var. *pacificus* is native. Other varieties of *Juncus effusus*, even cultivars, are invasive and are not recommended for use in stormwater facilities. Do not intermix with other emergents. Do not plant near intersections.	C	
EG		NWN	<24″	*Juncus ensifolius*	Dagger-leaf rush	1, 2	10 Cu. In. Plug/ 9″ o.c.	UF	☼, Ø	Limit to areas of approx. 36″x36″	B	Requires supplementary irrigation in summer to thrive.
EG	DT	NWN	<24″	*Juncus tenuis*	Path rush	1, 2	10 Cu. In. Plug/ 9″ o.c.	UF	☼, Ø	Native facultative species; does well in wet and dry conditions.	C	

Table J.3 (continued). Native Plant List Suitable for Bioretention BMPs (Sun to Part Shade includes cultivars).

EG	DT	NWN	Height from Ground	Scientific Name	Common Name	Planting Zone	Suggested Size/ Spacing	Urban Frontage	Exposure	Design Comments	O&M Code	Additional O&M Comments
EG	DT	NWN	<24″	*Juniperus communis* 'Mondap'	Alpine carpet juniper	4	1 Gal./24″ o.c.	UF	☼		E	May require supplementary irrigation in summer. May require pruning.
EG		NWN	36″	*Ledum glandulosum*	Pacific or trapper's tea	1, 2, 3	5 Gal./36″ o.c.	UF	☼, Ø	Plant near the bottom of swale	E	
EG	DT	NWN	<24″	*Lewisia cotyledon or cultivars*	Siskiyou lewisia	3, 4	1 Gal./12″ o.c.	UF	☼		E	
EG		NWN	36″	*Mahonia aquifolium* 'Orange Flame' or 'Compacta'	Compact tall Oregon grape	3	1 Gal./36″ o.c.	UF	☼, Ø		E	
EG	DR	NWN	<24″	*Mahonia repens*	Creeping Oregon grape	3, 4	1 Gal./18″ o.c.	UF	☼, Ø		E	
		NWN	24″–36″	*Mimulus guttatus*	Yellow monkey-flower	1, 2	1 Gal./18″ o.c.		☼, Ø	Provides temporary color and habitat value. Will die back in late summer or winter but will reseed. Should not be used in large areas and relied upon for water quality treatment.	DF	
EG	DT	NWN	36″	*Pachistima myrsinites*	Oregon boxwood	3	1 Gal./36″ o.c.	UF	☼, Ø		E	

Table J.3 (continued). Native Plant List Suitable for Bioretention BMPs (Sun to Part Shade includes cultivars).

EG	DT	NWN	Height from Ground	Scientific Name	Common Name	Planting Zone	Suggested Size/ Spacing	Urban Frontage	Exposure	Design Comments	O&M Code	Additional O&M Comments
		NWN	<24″	*Potentilla fruticosa* 'Sunset'	Frosty potentilla	3, 4	2 Gal./30″ o.c.	UF	∅Ø		E	
	DT	NWN	<24″	*Potentilla glandulosa* or *Potentilla gracilis*	Sticky cinquefoil or slender cinquefoil	3, 4	1 Gal./18″ o.c.		☼, Ø		DF	
EG		NWN	24″–36″	*Polystichum imbricans* or *Polystichum lonchitis*	Narrow-leaf sword fern or Northern holly fern	3, 4	2 Gal./30″ o.c.	UF	☼, Ø	If *Polystichum munitum* is substituted limit groups to 3 and prune yearly.	B	Cut back before fronds appear.
	DT	NWN	<24″	*Solidago canadensis* 'Baby Gold' or *Solidago hybrida* 'Dansolitlem'	Baby Gold or Little Lemon Goldenrod	3, 4	1 Gal./18″ o.c.		☼	Late season color accent.	A	
		NWN	24″–36″	*Spiraea betulifolia or Spiraea betulifolia* 'Tor'	Birchleaf spirea	3	1 Gal./24″ o.c.	UF	☼		E	
EG	DT	NWN	<24″	*Sedum divergens*	Stonecrop	3, 4	4″ Pot/12″ o.c.	UF	☼, Ø	Tolerates hot dry sites.	E	LOS A: For neater appearance deadhead.

Table J.3 (continued). Native Plant List Suitable for Bioretention BMPs (Sun to Part Shade includes cultivars).

EG	DT	NWN	Height from Ground	Scientific Name	Common Name	Planting Zone	Suggested Size/ Spacing	Urban Frontage	Exposure	Design Comments	O&M Code	Additional O&M Comments
EG	DT	NWN	<24″	*Sedum oreganum*	Stonecrop	3, 4, 5	4″ Pot/12″ o.c.	UF	☼	Tolerates hot dry sites.	E	
EG	DT	NWN	24″–36″	*Xerophyllum tenax*	Bear grass	3	1 Gal/18″ o.c.	UF	☼	Tolerates hot dry sites.	E	

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UF = Urban Frontage (Mixed Use/Commercial) appropriate plants
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LOS = Level of Service

Table J.4. Intersection and View Restriction Plant Palette (under 24 inches in height) Suitable for Bioretention.

EG	DT	NWN	Height from Ground	Scientific Name	Common Name	Planting Zone	Suggested Size/ Spacing	Urban Frontage	Exposure	Design Comments	O&M Code	Additional O&M Comments
			<24″	*Chrysanthe-mum* 'Peach Centerpiece' or 'Bienchen'	Peach Centerpiece or golden chrysanthe-mum	3, 4	1 Gal./15″ o.c.		☼	Late season color accent.	B & G	Pull if scraggly.
	DT		<24″	*Coreopsis lanceolata* 'Sterntaler'	Tickseed	3, 4	1 Gal./15″ o.c.	UF	☼		B & G	
	DT		24″–30″	*Cornus sericea* 'Kelseyii'	Kelsey redstem dogwood	1, 2, 3	1 Gal./30″ o.c.	UF	☼, Ø	Plant in bottom areas for sightlines.	E	Stems fragile until established.
EG	DT		<24″	*Epimedium rubrum or sulphurescens*	Barrenwort	3, 4	4″ Pot/12″ o.c.	UF	Ø	Part shade to shade only without irrigation.	B	Cut back before flower stalks appear.
EG	DT		<24″	*Euonymus fortunei* 'Interbolwi'	Blondy winter-creeper	3, 4	1 Gal./18″ o.c.	UF	☼, Ø		E	
	DT		<24″	*Geranium* 'Gerwat' 'Rozanne'	Rozanne geranium	3, 4	1 Gal./24″ o.c.		☼, Ø		A	LOS A: Can be sheared for neater appearance.
EG			<24″	*Geum flore pleno* 'Blazing Sunset'	Blazing Sunset Avens	3, 4	1 Gal./18″ o.c.	UF	☼, Ø		DS	
SEMI	DT		<24″	*Helianthemum nummularium* 'Wisley Primrose'	Yellow Sunrose	3, 4	1 Gal./12″ o.c.	UF	Ø		B	

Table J.4 (continued). Intersection and View Restriction Plant Palette (under 24 inches in height) Suitable for Bioretention.

EG	DT	NWN	Height from Ground	Scientific Name	Common Name	Planting Zone	Suggested Size/ Spacing	Urban Frontage	Exposure	Design Comments	O&M Code	Additional O&M Comments
EG	DT		24″–36″	*Helictotrichon sempervirens*	Blue oat grass	3	1 Gal./18″ o.c.	UF	Ø	36″ height only when in flower. Airy flowers. Groups of 3 maximum.	C	
EG	DT		<24″	*Ilex x* 'Mondo'	Little Rascal Holly	3, 4	1 Gal./18″ o.c.	UF	☼, Ø		E	
EG		NWN	<24″	*Juncus effusus* 'Carmen's Japan'	Carmen's Japanese rush	1, 2	10 Cu. In. Plug/ 9″ o.c.	UF	☼, Ø		C	
EG			<24″	*Juncus effusus* 'Spiralis'	Corkscrew soft rush	1, 2	10 Cu. In. Plug/ 9″ o.c.	UF	☼, Ø		C	LOS A: Can be sheared more frequently if foliage collapses.
EG			24″–30″	*Juncus patens or Juncus patens* 'Elk blue'	California gray rush	1, 2	10 Cu. In. Plug/ 9″ o.c.	UF	☼, Ø	Resilient wetland species; can survive summer drought and winter inundation. Plant in bottom areas for sightlines	C	LOS A: Can be sheared more frequently if foliage collapses.
EG			<24″	*Liriope muscari* and cultivars	Lily Turf	3, 4	4″ Pot/12″ o.c.	UF	☼, Ø		C	OK to pull clumps for ease of weed control.
EG	DR	NWN	<24″	*Mahonia repens*	Creeping Oregon holly-grape	3	1 Gal./18″ o.c.	UF	☼, Ø		E	

Table J.4 (continued). Intersection and View Restriction Plant Palette (under 24 inches in height) Suitable for Bioretention.

EG	DT	NWN	Height from Ground	Scientific Name	Common Name	Planting Zone	Suggested Size/ Spacing	Urban Frontage	Exposure	Design Comments	O&M Code	Additional O&M Comments
	DT		<24″	*Narcissus* 'Dutch Master' *or* 'King Alfred'	Daffodil	3, 4	Bulb/As Shown	UF	Ø		DS	Cut back foliage in summer.
		NWN	<24″	*Potentilla fruticosa* 'Sunset'	Frosty potentilla	3, 4	2 Gal./30″ o.c.	UF	Ø		E	
EG	DT		<24″	*Veronica liwanensis*	Speedwell	3, 4, 5	4″ Pot/12″ o.c.	UF	Ø		E	LOS A: Cut back for neater appearance.

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Table J.5. Vertical Shrubs and Accent Plants Suitable for Bioretention.

EG	DT	NWN	Height from Ground	Scientific Name	Common Name	Planting Zone	Suggested Size/ Spacing	Urban Frontage	Exposure	Design Comments	O&M Code	Additional O&M Comments
		NWN	25′	*Amelanchier alnifolia*	Service Berry	1, 2, 3	Multi-stem, B&B, 5′–6′ ht.		Ø	Multi-stemmed native species. Can sucker and spread. Single stem species may be available if nursery prunes in advance.	E	May need windowing/ thinning.
			5′	*Cornus sanguinea* 'Midwinter Fire'	Midwinter Fire Dogwood	1, 2, 3	5 gal		☼, Ø		E	Prune 2/3 of all (older) branches to 8″ above ground in March to keep in bounds and to maintain yellow twigs.
		NWN	6′ to 8′	*Cornus sericea* 'Flaviramea'	Yellow-Twig Dogwood	1, 2, 3	5 gal		Ø		E	Prune 2/3 of all (older) branches to 8″ above ground in March to keep in bounds and to maintain red twigs.
			10′	*Hamamelis x intermedia* 'Pallida'	Witch Hazel	3	10 gal		☼, Ø	Vase-shaped open growing form.	E	
			5′	*Hydrangea quercifolia* 'Pee Wee'	Oak-Leaf Hydrangea	3	5 gal		Ø	Late summer flowers. Fall color. Bold leaves in winter.	E	May need windowing/ thinning.

Table J.5 (continued). Vertical Shrubs and Accent Plants Suitable for Bioretention.

EG	DT	NWN	Height from Ground	Scientific Name	Common Name	Planting Zone	Suggested Size/ Spacing	Urban Frontage	Exposure	Design Comments	O&M Code	Additional O&M Comments
EG			3′–4′	*Ilex glabra* 'Shamrock'	Inkberry	1, 2	5 gal.		☼, Ø		E	Female plants need a male pollinator to produce berries.
			3′–12′	*Ilex verticillata* and cultivated varieties	Winterberry	1, 2	5 gal.		☼, Ø		E	Female plants need a male pollinator to produce berries.
EG			8′–12′	*Mahonia* 'Arthur Menzies'	Ornamental Mahonia	3	5 gal		☼, Ø	Upright multi-stemmed.	E	
EG		NWN	6′–10′	*Mahonia aquifolium*	Oregon grape	3	5 gal		☼, Ø	Upright multi-stemmed.	E	
EG			5′	*Osmanthus* 'Goshiki'	Variegated Osmanthus	3	5 gal		Ø	4′ wide. Considered dwarf. New foliage is colorful.	E	May need windowing/ thinning.
			6′	*Physocarpus opulifolius* 'Nanus'	Dwarf Ninebark	1, 2, 3	5 gal		☼, Ø	Even dwarf form may be tall and wide.	E	May need windowing/ thinning.
EG			4′	*Pieris japonica* 'Little Heath'	Little Heath Lily of the Valley	3	3 gal.		Ø	Variegated foliage that emerges pink in spring. Flowers in winter.	E	May need windowing/ thinning.
			15′–20′	*Salix integra* 'Hakuro Nishiki'	Dappled Willow	1, 2, 3	5 gal.		☼, Ø		E	Specify tree form; Prune to ground every other year to keep smaller.

Table J.5 (continued). Vertical Shrubs and Accent Plants Suitable for Bioretention.

EG	DT	NWN	Height from Ground	Scientific Name	Common Name	Planting Zone	Suggested Size/ Spacing	Urban Frontage	Exposure	Design Comments	O&M Code	Additional O&M Comments
			8′–15′	*Sambucus nigra* 'Gerda'	Black Beauty Black Elder	1, 2, 3	5 gal.		☼, Ø		E	
		NWN	6′	*Symphoricarpos albus*	Snowberry	1, 2, 3	5 gal		☼, Ø	Forms thickets.	E	May need windowing/ thinning.
			6′	*Taxodium distichum* 'Peve Minaret'	Dwarf bald cypress	1, 2, 3					E	
EG		NWN	6′	*Vaccinium ovatum*	Evergreen Huckleberry	1, 2, 3	5 gal		☼, Ø		E	
			6′	*Vaccinium* 'Sunshine Blue'	Blueberry	3	5 gal		☼, Ø	Self-pollinating edible fruits. Good fall color.	E	
EG			10′	*Viburnum cinnamomifolium*	Cinnamon Viburnum	3	10 gal		☼, Ø		E	May need windowing/ thinning.
		NWN	7′–12′	*Viburnum edule*	Highbush cranberry	1, 2, 3	5 gal.		☼, Ø		E	

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Table J.6. Groundcovers if Low Profile is Required for Bioretention.

EG	DT	NWN	Height from Ground	Scientific Name	Common Name	Planting Zone	Suggested Size/ Spacing	Urban Frontage	Exposure	Design Comments	O&M Code	Additional O&M Comments
EG	DT		<24″	*Ajuga reptens*	Bugleweed	3, 4	4″ Pot/12″ o.c.	UF	☼, Ø		E	Can be pulled if grows beyond desired boundaries.
EG	DT		<24″	*Epimedium rubrum* or *sulphurescens* or cultivars	Barrenwort	3, 4	4″ Pot/12″ o.c.	UF	Ø		B	Cut back foliage before flower stalks appear.
EG	DT		<24″	*Euonymus fortunei* 'Kewensis'	Winter-creeper euonymous	3, 4	1 Gal./18″ o.c.	UF	☼, Ø		E	Can be mowed to keep low.
SEMI	DT		<24″	*Geranium macrorrhizum* 'Album' or other cultivars	Hardy Geranium	3, 4	1 Gal./18″ o.c.	UF	☼, Ø		B	
EG	DT		<24″	*Pachysandra terminalis*	Japanese Spurge	3, 4	4″ Pot/12″ o.c.	UF	Ø		C	
EG	DT		<24″	*Sibbaldiopsis tridentata (= Potentilla tridentata)*	Three-toothed Cinquefoil	3, 4	4″ Pot/12″ o.c.	UF	Ø		E	
EG	DT		<24″	*Rubus tricolor*	Creeping Chinese Bramble	3, 4	4″ Pot/12″ o.c.	UF	Ø	Tolerates deep shade. Not as aggressive or spiny as other Rubus groundcovers. Red fuzzy stems and shiny leaves.	E	

Table J.6 (continued). Groundcovers if Low Profile is Required for Bioretention.

EG	DT	NWN	Height from Ground	Scientific Name	Common Name	Planting Zone	Suggested Size/ Spacing	Urban Frontage	Exposure	Design Comments	O&M Code	Additional O&M Comments
EG	DT	NWN	<24″	*Sedum divergens*	Stonecrop	3, 4	4″ Pot/12″ o.c.	UF	☼, Ø	Tolerates hot dry sites.	E	LOS A: For neater appearance deadhead.
EG	DT		<24″	*Sedum requieni*	Miniature Stonecrop	3, 4, 5	4″ Pot/12″ o.c.	UF	☼, Ø	Tolerates hot dry sites.	E	
	DT	NWN	<24″	*Vancouveria hexandra*	Inside Out Flower	3, 4	4″ Pot/12″ o.c.	UF	Ø		E	
SEMI			<24″	*Potentilla neumanniana* 'Nana'	Dwarf cinquefoil	3, 4, 5	4″ Pot/12″ o.c.	UF	☼, Ø		E	
EG			<24″	*Ophiopogon japonicus* 'Nanus'	Dwarf mondo grass	3, 4, 5	4″ Pot/12″ o.c.	UF	☼, Ø	Can space at 15″ o.c. for cost saving.	E	

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Table J.7. Steppable Plants Suitable for Bioretention.

EG	DT	NWN	Height from Ground	Scientific Name	Common Name	Planting Zone	Suggested Size/ Spacing	Urban Frontage	Exposure	Design Comments	O&M Code	Additional O&M Comments
EG			<24″	*Ophiopogon japonicus* 'Nanus'	Dwarf mondo grass	3, 4, 5	4″ Pot/12″ o.c.	UF	☼, Ø	Can space at 15″ o.c. for cost saving.	E	
SEMI			<24″	*Potentilla neumanniana* 'Nana'	Dwarf cinquefoil	3, 4, 5	4″ Pot/12″ o.c.	UF	☼, Ø		E	
EG	DT	NWN	<24″	*Sedum oreganum*	Stonecrop	3, 4, 5	4″ Pot/12″ o.c.	UF	☼	Tolerates hot dry sites.	E	
EG	DT		<24″	*Sedum requieni*	Miniature Stonecrop	3, 4, 5	4″ Pot/12″ o.c.	UF	☼, Ø	Tolerates hot dry sites.	E	
EG	DT		<24″	*Thymus serpyllum* 'Elfin'	Elfin creeping thyme	3, 4, 5	4″ Pot/12″ o.c.	UF	☼		F	
EG	DT		<24″	*Veronica liwanensis*	Speedwell	3, 4, 5	4″ Pot/12″ o.c.	UF	Ø		E	LOS A: Cut back for neater appearance.

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Table J.8. Conifer Trees (deciduous and evergreen) Suitable for Bioretention.

Scientific and Common Name	Mature Urban Height	Spread	Under Wires?	Min Strip Width	Planting Zone	Fall Color	SDOT List	Design Comments
Calocedrus decurrens, Incense Cedar	75	15	No	8	3			
Metasequoia glyptostroboides, Dawn Redwood	50	25	No	6	1, 2, 3	Yes		Fast growing deciduous conifer.
Pinus contorta, Shore Pine	45	30	No	5	1, 2, 3			Facultative species that grows well in sandy soils. Found in wetland and upland habitats.
Taxodium distichum, Bald Cypress	55	35	No	8	1, 2, 3	Yes		A deciduous conifer, broadly spreading when mature – columnar when young. Featured in Growth Rates and Performance of Trees in Silva Cells (Urban and Marritz 2016).
Taxodium distichum 'Mickelson,' Shawnee Brave Bald Cypress	55	20	No	6	1, 2, 3	Yes	x	Deciduous conifer – tolerates city conditions.
Thuja plicata 'Excelsa' or 'Hogan,' Western Redcedar	40	15–20	No	8	1, 2, 3			Narrow columnar form.

Table J.9. Small Conifer/Broad-leaved Evergreen Trees Suitable for Bioretention.

Scientific and Common Name	Mature Height	Spread	Under Wires?	Min Strip Width	Planting Zone	Fall Color	SDOT List	Design Comments
Chamaecyparis obtusa gracilis, Slender Hinoki False Cypress	15	6	Yes	5	3			Drought tolerant when established.
Embothrium coccineum, Chilean Flame Tree	30	15	No	5	3			Brilliant orange red flowers in late spring. Tree can sucker.
Eucryphia glutinosa, Brushbush	25	15	Yes	5	3			Semi-evergreen. Best in part shade.
Magnolia grandiflora 'Edith Bogue,' Edith Bogue Magnolia	18	12	Yes	5	1, 2, 3			Excellent BLE magnolia due to hardiness.
Magnolia grandiflora 'Victoria,' Victoria Evergreen Magnolia	25	20	Yes	5	1, 2, 3	N/A	x	
Magnolia maudiae (= Michelia maudiae), NCN	25	20	Yes	5	3			
Magnolia virginiana	35	35		5	1, 2, 3		x	
Quercus hypoleucoides	30	15	No	5	3			
Quercus myrsinifolia, Chinese Evergreen Oak	30	15	No	5	3			

Table J.10. Small/Constrained Site Deciduous Trees Suitable for Bioretention.

Scientific and Common Name	Mature Height	Spread	Under Wires?	Min Strip Width	Planting Zone	Fall Color	SDOT List	Design Comments
Malus 'Red Barron', Red Barron Crabapple	18	8	Yes	4	3	Yes	x	Good for narrow spaces. Red berries.
Malus 'Lancelot' ('Lanzam'), Lancelot Crabapple	15	15	Yes	4	3	Yes	x	Red flower buds, blooming white – red persistent fruit.
Prunus serrulata 'Amanogawa' Japanese Flowering Cherry	20	6	Yes	6	3	Yes		Particularly useful for very narrow planting strips.
Sorbus americana 'Dwarfcrown' Red Cascade Mountain Ash	18	8	Yes	5	3	Yes	x	Nice winter form – white flowers in spring – red clusters of berries.
Trachycarpus fortune Windmill Palm	25	10	Yes	5	3	N/A		Traffic visibility can be a problem with small plants.

Table J.11. Small Deciduous Trees Suitable for Bioretention.

Scientific and Common Name	Mature Height	Spread	Under Wires?	Min Strip Width	Planting Zone	Fall Color	SDOT List	Design Comments
Acer buegerianum, Trident Maple	30	30	Yes	5	3	Yes	x	Must train to a single stem – interesting bark.
Acer circinatum, Vine Maple	25	25	Yes	5	3	Yes	x	Avoid using on harsh sites – native tree.
Acer griseum, Paperbark Maple	30	20	Yes	5	3	Yes	x	Peeling cinnamon colored bark.
Acer tartaricum, Tartarian Maple	20	20	Yes	5	3	Yes		
Acer triflorum, Three-Flower Maple	25	20	Yes	5	3	Yes	x	Multi seasonal interest with tan, exfoliating bark and red, orange/red fall color.
Amelanchier laevis 'Snowcloud,' Snowcloud Serviceberry	25	15	Yes	4	3	Yes		
Asimina triloba, Paw	30	20	Yes	5	1, 2, 3	N/A	x	Burgundy flower in spring before leaves.
Betula nigra 'Little King,' Little King River Birch	10	12	Yes	5	1, 2, 3	Yes		Suitable for enclosed vertical walls.
Carpinus caroliniana, American Hornbeam	25	20	Yes	5	1, 2, 3	Yes	x	Good fall color (variable – yellow, orange, red). Featured in Growth Rates and Performance of Trees in Silva Cells (Urban and Marritz 2016).
Cornus kousa x nuttallii 'Starlight,' Starlight Dogwood	20	20	Yes	4	3	Yes		
Lagerstroemia 'tuscarora,' Tuscarora Hybrid Crape Myrtle	20	20	Yes	4	3	Yes	x	Light cinnamon brown bark lends year-round interest – drought resistant – likes a warm site.
Maackia amurensis, Amur Maackia	30	20	Yes	5	3	N/A	x	Exfoliating bark – flowering in June or July – varies in intensity from year to year. Featured in Growth Rates and Performance of Trees in Silva Cells (Urban and Marritz 2016).

Table J.11 (continued). Small Deciduous Trees Suitable for Bioretention.

Scientific and Common Name	Mature Height	Spread	Under Wires?	Min Strip Width	Planting Zone	Fall Color	SDOT List	Design Comments
Magnolia 'Elizabeth,' Elizabeth Magnolia	30	20	Yes	5	3	N/A	x	Yellowish to cream colored flower in spring.
Magnolia 'Galaxy,' Galaxy Magnolia	25	25	Yes	5	1, 2, 3	Yes	x	Suitable for enclosed vertical walls. Showy pink flowers.
Magnolia kobus 'Wada's Memory,' Wada's Memory Magnolia'	30	20	Yes	5	3	Yes	x	Drought tolerant. Does not flower well when young.
Parrotia persica, Persian Parrotia	30	20	No	5	3	Yes		Blooms before it leafs out – drought tolerant – Varied fall color – reds, oranges and yellows.
Prunus x yedoensis 'Akebono' Akebono Flowering Cherry	25	25	No	6	3	Yes		Fragrant white (sometimes tinged pink) flowers in 3- to 6-flowered clusters. Featured in Growth Rates and Performance of Trees in Silva Cells (Urban and Marritz 2016).
Frangula purshiana, Cascara	30	20	Yes	5	1, 2, 3	Yes	x	Facultative native species. Found in wetland and upland habitats. Can tolerate bioretention street tree environments; however, does not grow as well in narrow, hot ROW locations. Suitable for enclosed vertical walls.
Salix matsudana 'Tortuosa,' Corkscrew willow	30	15	Yes	5	1, 2, 3	Yes		Do not use with underdrain.
Stewartia pseudocamellia, Japanese Stewartia	25	15	Yes	5	3	Yes		Camellia-like flowers in summer. Interesting bark. Slow grower. Featured in Growth Rates and Performance of Trees in Silva Cells (Urban and Marritz 2016).
Styrax japonica, Japanese Snowbell	25	25	Yes	5	3	Yes	x	Reliable and easy to grow, it has plentiful, green 1/2inch seeds. Flowers similar to lily of the valley.

Table J.11 (continued). Small Deciduous Trees Suitable for Bioretention.

Scientific and Common Name	Mature Height	Spread	Under Wires?	Min Strip Width	Planting Zone	Fall Color	SDOT List	Design Comments
Tilia cordata 'Chancole' or 'De Groot,' Chancellor or De Groot Littleleaf Linden	30+	20	No	C = 6, D = 5	3	Yes	x	Pyramidal when young. Fragrant flowers that attract bees. One of the smaller-stature little-leaf lindens.

Table J.12. Medium Columnar Deciduous Trees Suitable for Bioretention.

Scientific and Common Name	Mature Height	Spread	Under Wires?	Min Strip Width	Planting Zone	Fall Color	SDOT List	Design Comments
Acer rubrum 'Bowhall,' Bowhall Maple	40	20	No	6	1, 2, 3	Yes	x	Upright, pyramidal form. Featured in Growth Rates and Performance of Trees in Silva Cells (Urban and Marritz 2016).
Acer cappadocicum Cappadocian Maple	35	25	No	6	3	Yes		Broad-rounded crown. Featured in Growth Rates and Performance of Trees in Silva Cells (Urban and Marritz 2016).
Carpinus betulus 'Fastigiata,' Pyramidal European Hornbeam	40	15	No	5	1, 2, 3	Yes	x	Broadens when older.
Fagus sylvatica 'Dawyck Purple,' Dawyck Purple Beech	40	12	No	6	3	Yes	x	Purple foliage.
Oxydendron arboreum, Sourwood	35	12	No	5	3	Yes	x	Consistent and brilliant fall color.
Nyssa sylvatica, BlackTupelo	40	20	No	6	1, 2, 3	Yes	x	Chunky bark. Takes standing water and drought. Featured in Growth Rates and Performance of Trees in Silva Cells (Urban and Marritz 2016).

Table J.13. Medium Deciduous Trees Suitable for Bioretention.

Scientific and Common Name	Mature Height	Spread	Under Wires?	Min Strip Width	Planting Zone	Fall Color	SDOT List	Design Comments
Acer rubrum 'Karpick,' Karpick Maple	40	20	No	6	1, 2, 3	Yes	x	Finer texture than other narrow forms of columnar maple. Featured in Growth Rates and Performance of Trees in Silva Cells (Urban and Marritz 2016).
Acer truncatum x A. platanoides 'Keithsform' or 'Warrenred,' Norwegian or Pacific Sunset Maple	35	25	No	5	3	Yes	x	Reliable reddish orange fall color. Featured in Growth Rates and Performance of Trees in Silva Cells (Urban and Marritz 2016).
Cladrastis kentukea, Yellowwood	40	40	No	5	3	Yes	x	White flowers in spring, resembling wisteria flower – blooms profusely only every 2 to 4 years – yellow/gold fall color
Cornus controversa 'June Snow,' Giant Dogwood	40	30	No	5	3	Yes	x	Frothy, 6-inch clusters of white flowers in June.
Corylus colurna, Turkish Filbert	40	25	No	5	3	Yes	x	Tight, formal, dense crown – Nice central leader. Not for mixed use areas with high pedestrian traffic dues to significant debris from nuts. Drought tolerant. Plant smaller sizes in order to facilitate establishment.
Magnolia denudata, Yulan Magnolia	40	40	No	5	3	N/A	x	6-inch fragrant white flowers in spring.
Ostrya virginiana, Ironwood	40	25	No	5	3	Yes	x	Hop like fruit – slow growing
Pterostyrax hispida, Fragrant Epaulette Tree	40	30	No	5	3	Yes	x	Pendulous creamy white flowers – fragrant
Ulmus parvifolia 'Emer I,' Athena Classic Elm	30	35	No	5	1, 2, 3	Yes	x	High resistance to Dutch Elm Disease. Drought resistant. Cinnamon colored exfoliating bark.

Table J.14. Medium/Large Broad-leaved Evergreen Trees Suitable for Bioretention.

Scientific and Common Name	Mature Height	Spread	Under Wires?	Min Strip Width	Planting Zone	Fall Color	SDOT List	Design Comments
Lithocarpus densiflorus, Tanoak	50	20	No	6	3			
Quercus Ilex, Holly Oak	40	30	No	5	3	N/A	x	Underside of leaf is silvery-white. Often has a prominent umbrella form. Prune for form.
Umbellularia californica, Oregon Myrtlewood	60	30	No	5	1, 2, 3			Drought tolerant native in S. OR. Fruit looks like miniature limes.

Table J.15. Medium/Large Deciduous Trees Suitable for Bioretention.

Scientific and Common Name	Mature Height	Spread	Under Wires?	Min Strip Width	Planting Zone	Fall Color	SDOT List	Design Comments
Acer campestre 'Evelyn,' Queen Elizabeth Hedge Maple	40	30	No	5	1, 2, 3	Yes	x	More upright branching than the species.
Acer freemanii 'Autumn Blaze,' Autumn Blaze Maple	50	40	No	6	1, 2, 3	Yes	x	Cross between red and silver maple – fast growing with good fall color. Featured in Growth Rates and Performance of Trees in Silva Cells (Urban and Marritz 2016).
Acer rubrum 'Scarsen,' Scarlet Sentinel Maple	40	25	No	6	1, 2, 3	Yes	x	Leaves are darker green and larger than those of other Red Maples and hold up well in summer heat. Upright branch habit. Featured in Growth Rates and Performance of Trees in Silva Cells (Urban and Marritz 2016).
Aesculus x carnea 'Briottii,' Red Horse Chestnut	30	35	No	6	3	N/A	x	Do not use near greenways or bicycle routes due to litter. Resists heat and drought better than other horse chestnuts.
Betula nigra, River Birch	40	30	No	5	1, 2, 3	Yes		Excellent flaky bark. Resistant to Bronze Birch Borer.
Cercidiphyllum japonicum, Katsura tree	45	40	No	8	1, 2, 3	Yes		
Eucommia ulmoides, Hardy Rubber Tree	50	40	No	6	3	N/A	x	Dark green, very shiny leaves – insignificant fall color.
Fagus sylvatica 'Rohanii,' Purple Oak Leaf Beech	50	30	No	6	3	N/A	x	Purple leaves with wavy margins.
Ginko biloba 'Autumn Gold,' Autumn Gold Ginkgo	45	35	No	6	3	Yes	x	Narrow when young.
Gleditsia triacanthos 'Draves' Street Keeper Honey Locust	50	20	No	8	1,2,3	Yes		Tolerant of a wide range of soils and urban conditions. Featured in Growth Rates and Performance of Trees in Silva Cells (Urban and Marritz 2016).

Table J.15 (continued). Medium/Large Deciduous Trees Suitable for Bioretention.

Scientific and Common Name	Mature Height	Spread	Under Wires?	Min Strip Width	Planting Zone	Fall Color	SDOT List	Design Comments
Gymnocladus dioicus 'Espresso-JFS' Espresso™ Kentucky Coffee Tree	50	35	No	8	3	Yes		Very coarse branches—extremely large bi-pinnately compound leaf. Featured in Growth Rates and Performance of Trees in Silva Cells (Urban and Marritz 2016).
Nothofagus antarctica, Antarctic Beech	50	35	No	5	3	No	x	Rugged twisted branching and petite foliage.
Quercus frainetto, Italian Oak	50	30	No	6	3	N/A	x	Drought resistant—green, glossy leaves in summer.
Sophora japonica 'Regent,' Japanese Pagodatree	45	40	No	6	3	Yes	x	Has a rapid growth rate and tolerates city conditions, heat, and drought.
Tilia cordata 'Greenspire,' Greenspire Linden	40	30	No	6	3	Yes	x	Symmetrical, pyramidal form. Fragrant flowers.
Ulmus parvifolia 'Emer II,' Allee Elm	45	35	No	5	1, 2, 3	Yes	x	Exfoliating bark and good fall color — Resistant to Dutch Elm Disease.

Table J.16. Large Deciduous Columnar Trees Suitable for Bioretention.

Scientific and Common Name	Mature Height	Spread	Under Wires?	Min Strip Width	Planting Zone	Fall Color	SDOT List	Design Comments
Acer nigrum 'Green Column,' Green Column Black Sugar Maple	50	10	No	6	3	Yes	x	
Ginko biloba 'Princeton Sentry,' Princeton Sentry Ginkgo	40	15	No	6	3	Yes	x	Prune for form.
Quercus bicolor Swamp White Oak	60	45	No	8	1,2,3	Yes		Can withstand some standing water in the winter. Featured in Growth Rates and Performance of Trees in Silva Cells (Urban and Marritz 2016).
Quercus robur 'fastigiata,' Skyrocket Oak	40	15	No	6	3	N/A	x	

Table J.17. Large Deciduous Trees Suitable for Bioretention.

Scientific and Common Name	Mature Height	Spread	Under Wires?	Min Strip Width	Planting Zone	Fall Color	SDOT List	Design Comments
Acer saccharum 'Commemoration' or 'Bonfire' Commemoration or Bonfire Sugar Maple	50	35	No	6	1, 2, 3	Yes	x	Resistant to leaf tatter.
Fagus sylvatica, Green Beech	50	40	No	6	3	Yes	x	Silvery-grey bark. Can't handle root disturbance.
Fagus sylvatica 'Asplenifolia,' Fernleaf Beech	60	50	No	6	3	Yes	x	Can't handle root disturbance.
Ginkgo biloba 'Magyar,' Magyar Ginkgo	50	25	No	6	3	Yes	x	More upright and narrow than 'Autumn Gold.' Needs training when young.
Liriodendron tulipifera, Tulip Tree	60+	30	No	8	1, 2, 3	Yes	x	Fast-growing tree.
Platins x acerifolia 'Bloodgood,' Bloodgood London Planetree	50+	40	No	8	1, 2, 3	N/A	x	More anthracnose resistant than other varieties—large tree that needs space. Featured in Growth Rates and Performance of Trees in Silva Cells (Urban and Marritz 2016).
Quercus bicolor, Swamp White Oak	60	45	No	8	1, 2, 3	N/A	x	Shaggy peeling bark. Wet-soil tolerant.
Quercus coccinea, Scarlet Oak	60	40	No	6	3	Yes	x	Good fall color.
Quercus imbricaria, Shingle Oak	60	50	No	6	3	N/A	x	Leaves can persist throughout the winter.
Quercus rubra, Red Oak	60	45	No	8	1, 2, 3	Yes	x	Fast growing oak—large tree that needs space. Heavy acorn producer.
Tilia tomentosa, Silver Linden	60	50	No	6	3	Yes		Larger leaves than Littleleaf Linden. Fragrant flowers.
Ulmus 'Frontier' or 'Morton Glossy,' Frontier or Triumph Elm	50	35	No	6	1, 2, 3	Yes	x	Resistant to Dutch elm disease.

Table J.17 (continued). Large Deciduous Trees Suitable for Bioretention.

Scientific and Common Name	Mature Height	Spread	Under Wires?	Min Strip Width	Planting Zone	Fall Color	SDOT List	Design Comments
Zelkova serrata 'Greenvase' or 'Village Green' Green Vase or Village Green Zelkova	45	40	No	6	3	Yes	x	Exfoliating bark. Dark green leaves turn orange-red and purple in fall. Featured in Growth Rates and Performance of Trees in Silva Cells (Urban and Marritz 2016).

J-2. Plants for Biofiltration Swales

Table J.18. Plants Tolerant of Saturated Soil Conditions or Standing Water in Biofiltration Swales.

EG	DT	NWN	Agg[a]	Scientific Name	Common Name	BMP Comments: Application	BMP Comments: Mowable
	DT		A	*Agrostis* spp.	Bentgrass	S	M
SEMI	DT	NWN		*Agrostis exarata*	Spike bentgrass	S	M
	DT		A	*Agrostis alba* or *gigantea*	Redtop	S	M
EG	DT		A	*Agrostis tenuis* or *capillaris*	Colonial bentgrass	S	M
EG				*Alopecurus aequalis*	Shortawn foxtail	S	M
EG				*Alopecurus geniculatus*	Water foxtail	S	M
EG			A	*Alopecurus pratensis*	Meadow foxtail	S	M
EG	DT	NWN		*Bromus carinatus*	California brome	S	M
SEMI				*Carex densa*	Dense sedge		
EG		NWN		*Carex obnupta*	Slough sedge		
SEMI				*Carex stipata*	Sawbeak sedge		
SEMI				*Eleocharis palustris*	Spike rush		
EG	DT	NWN		*Elymus glaucus*	Blue wildrye	S	M
EG	DT	NWN		*Elymus mollis*	Dune wildrye	S	M
		NWN		*Glyceria borealis*	Northern mannagrass		
		NWN		*Glyceria elata*	Tall mannagrass		
				Glyceria grandis	American mannagrass		
EG	DT		A	*Juncus effusus*	Soft (common) rush		
SEMI	DT			*Juncus patens*	Spreading rush		
SEMI	DT			*Juncus tenuis*	Slender rush		
EG			A	*Poa trivialis*	Rough-stalked bluegrass	S	M
SEMI		NWN		*Scirpus acutus*	Hardstem bulrush		
SEMI	DT	NWN		*Scirpus microcarpus*	Small-fruited bulrush		

EG = Evergreen

SEMI = Semi-evergreen

DT = Drought Tolerant/Resistant

NWN = Northwest Natives or Cultivars

A = Aggressive

S = Allowable as seed

M = Mowable

[a] Aggressive category indicates plants to be used with caution or avoided in confined sites (e.g., right-of-way plantings), near greenbelts, etc., due to maintenance concerns.

Note: Plants with mature height over 3′ should be grouped in masses no wider than 12′ mature width with openings of minimum 10′ between masses.

Note: Designer needs to respond to the size and aspect of the individual BMP when selecting plants to be used.

Table J.19a. Plants Suitable for the Upper Side Slopes of a Biofiltration Swale – Groundcovers.

EG	DT	NWN	Agg[a]	Scientific Name	Common Name	BMP Comments: Application	BMP Comments: Mowable
EG	DT	NWN	A	*Achillea millefolium*	Common yarrow		
	DT	NWN		*Arctostaphylos uva-ursi*	Kinnikinnick		
	DT	NWN		*Allium Cernum*	Nodding onion		
SEMI	DT			*Epimedium grandiflorum*	Epimedium		
EG	DT			*Euonymus fortunei*	Wintercreeper		
EG	DT	NWN	A	*Fragaria chiloensis*	Beach strawberry		
		NWN		*Lupinus latifolius*	Broadleaf lupine		
	DT			*Omphalodes verna*	Creeping forget-me-not		
EG	DT		A	*Rubus calycinoides*	Creeping raspberry		
EG	DT	NWN		*Sedum oreganum*	Oregon stonecrop		
EG	DT	NWN		*Sedum divergens*	Cascade stonecrop		
EG	DT		A	*Trifolium repens*	White lawn clover	S	M

EG = Evergreen
SEMI = Semi-evergreen
DT = Drought Tolerant/Resistant
NWN = Northwest Natives or Cultivars
A = Aggressive
S = Allowable as seed
M = Mowable

[a] Aggressive category indicates plants to be used with caution or avoided in confined sites (e.g., right-of-way plantings), near greenbelts, etc., due to maintenance concerns.

Note: Plants with mature height over 3′ should be grouped in masses no wider than 12′ mature width with openings of minimum 10′ between tall plant masses.

Note: Designer needs to respond to the size and aspect of the individual BMP when selecting plants to be used.

Table J.19b. Plants Suitable for the Upper Side Slopes of a Biofiltration Swale – Grasses (Drought Tolerant, Minimum Mowing).

EG	DT	NWN	Agg[a]	Scientific Name	Common Name	BMP Comments: Application	BMP Comments: Mowable
EG				*Buchloe dactyloides*	Buffalo grass	S	M
EG	DT			*Festuca* spp. (e.g., Many Mustang, Silverado)	Dwarf tall fescues	S	M
EG				*Festuca amethystine*	Tufted fescue	S	
EG	DT		A	*Festuca arundinacea*	tall fescue grass	S	M
EG	DT			*Festuca ovina duriuscula* (e.g., Reliant, Aurora)	Sheep fescue		
EG	DT	NWN		*Festuca idahoensis*	Idaho fescue		
EG	DT	NWN	A	*Festuca rubra*	Creeping red fescue	S	M
EG	DT		A	*Festuca rubra var. commutata*	Chewings fescue	S	M
EG	DT			*Helictotrichon sempervirens*	Blue oatgrass		

EG = Evergreen
SEMI = Semi-evergreen
DT = Drought Tolerant/Resistant
NWN = Northwest Natives or Cultivars
A = Aggressive
S = Allowable as seed
M = Mowable

[a] Aggressive category indicates plants to be used with caution or avoided in confined sites (e.g., right-of-way plantings), near greenbelts, etc., due to maintenance concerns.

Note: Plants with mature height over 3′ should be grouped in masses no wider than 12′ mature width with openings of minimum 10′ between tall plant masses.

Note: Designer needs to respond to the size and aspect of the individual BMP when selecting plants to be used.

Table J.20. Plants Suitable for Wet Biofiltration Swales.

EG	DT	NWN	Agg[a]	Scientific Name	Common Name	BMP Comments: Application	BMP Comments: Mowable
SEMI	DT	NWN		*Agrostis exarata*	Spike bentgrass	S	M
EG	DT		A	*Agrostis tenuis* or *capillaris*	Colonial bentgrass	S	M
				Alopecurus aequalis	Shortawn foxtail	S	M
				Alopecurus geniculatus	Water foxtail	S	M
				Eleocharis spp.	Spike rush		
SEMI				*Carex densa*	Dense sedge		
EG		NWN		*Carex obnupta*	Slough sedge		
SEMI		NWN		*Carex stipata*	Sawbeak sedge		
				Carex spp.	Sedge		
EG	DT		A	*Festuca arundinacea var.*	Tall fescue grass	S	M
EG	DT	NWN	A	*Festuca rubra*	Creeping red fescue	S	M
				Glyceria occidentalis	Western mannagrass		
EG	DT		A	*Juncus effusus*	Soft (common) rush		
SEMI	DT			*Juncus patens*	Spreading rush		
SEMI	DT	NWN		*Juncus tenuis*	Slender rush		
EG			A	*Lolium perenne* – Var. dwarf	Dwarf ryegrass	S	
SEMI		NWN		*Oenanthe sarmentosa*	Water parsley		
SEMI		NWN		*Scirpus acutus*	Hardstem bulrush		
SEMI	DT	NWN		*Scirpus microcarpus*	Small-fruited bulrush		

EG = Evergreen

SEMI = Semi-evergreen

DT = Drought Tolerant/Resistant

NWN = Northwest Natives or Cultivars

A = Aggressive

S = Allowable as seed

M = Mowable

[a] Aggressive category indicates plants to be used with caution or avoided in confined sites (e.g., right-of-way plantings), near greenbelts, etc., due to maintenance concerns.

Note: Plants with mature height over 3′ should be grouped in masses no wider than 12′ mature width with openings of minimum 10′ between tall plant masses.

Note: Designer needs to respond to the size and aspect of the individual BMP when selecting plants to be used.

J-3. Plants for Sand Filters

Table J.21a. Plants Suitable for Sand Filters – Basin Sides.

EG	DT	NWN	Agg[a]	Scientific Name	Common Name	BMP Comments: Application	BMP Comments: Mowable
	DT	NWN		*Achillea millefolium*	Yarrow	S	
EG	DT			*Agrostis alba*	Redtop	S	M
EG	DT	NWN		*Agrostis exerata*	Spike bentgrass	S	M
EG	DT			*Agrostis palustris*	Creeping bentgrass	S	M
	DT			*Alopecurus pratensis*	Meadow foxtail	S	M
EG	DT	NWN		*Bromus carinatus*	California Brome	S	M
	DT	NWN		*Calamagrostis nutkaensis*	Pacific reed grass		
EG	DT	NWN		*Elymus glaucus*	Blue wildrye	S	M
EG	DT	NWN		*Elymus mollis*	Dune wildrye	S	M
EG	DT	NWN	A	*Juncus effusus*	Soft rush	S	
	DT	NWN		*Lupinus albicaulus*	Sickle keeled lupine	S	
EG	DT	NWN		*Luzula multiflora*	Field woodrush	S	
	DT		A	*Poa palustris*	Fowl bluegrass	S	M
EG			A	*Poa pratensis*	Kentucky bluegrass	S	M

EG = Evergreen
SEMI = Semi-evergreen
DT = Drought Tolerant/Resistant
NWN = Northwest Natives or Cultivars
A = Aggressive
S = Allowable as seed
M = Mowable

[a] Aggressive category indicates plants to be used with caution or avoided in confined sites (e.g., right-of-way plantings), near greenbelts, etc., due to maintenance concerns.

Note: Plants with mature height over 3′ should be grouped in masses no wider than 8′ mature size with openings of min. 10′ between tall plant masses.

Note: Designer needs to respond to the size and aspect of the individual BMP when selecting plants to be used.

Table J.21b. Plants Suitable for Sand Filters – Pond Bottom (Sand Surface).

EG	DT	NWN	Agg[a]	Scientific Name	Common Name	BMP Comments: Application	BMP Comments: Mowable
EG	DT			*Agrostis tenuis*	Colonial bentgrass (Highland strain good)	S	M
	DT			*Buchloe dactyloides*	Buffalo grass	S	M
	DT	NWN		*Camassia leichlinii or quamash*	camas		
EG	DT	NWN		*Carex mertensii*	Merten's sedge	S	
EG	DT	NWN		*Festuca elatior (arundinacea)*	Tall fescue	S	M
EG	DT	NWN		*Festuca elatior* "Many Mustang," "Silverado"	Dwarf tall fescues	S	M
EG	DT	NWN		*Fescue roemeri (idahoensis)*	Roemer's or Idaho fescue	S	
EG	DT	NWN		*Festuca rubra*	Red fescue	S	M
SEMI	DT	NWN		*Iris missouriensis*	Rocky Mountain iris		
EG	DT	NWN		*Juncus tenuis*	Slender rush	S	
EG	DT			*Lolium perenne*	Perennial ryegrass	S	M
EG	DT	NWN		*Luzula parviflora*	Small flowered woodrush	S	
EG	DT			*Trifolium repens*	White lawn clover	S	M
EG	DT			*Zoysia tenuifolia*	Korean grass	S	M

EG = Evergreen
SEMI = Semi-evergreen
DT = Drought Tolerant/Resistant
NWN = Northwest Natives or Cultivars
A = Aggressive
S = Allowable as seed
M = Mowable

[a] Aggressive category indicates plants to be used with caution or avoided in confined sites (e.g., right-of-way plantings), near greenbelts, etc., due to maintenance concerns.

Note: Plants with mature height over 3′ should be grouped in masses no wider than 8′ mature size with openings of min. 10′ between tall plant masses.

Note: Designer needs to respond to the size and aspect of the individual BMP when selecting plants to be used.

J-4. Plants and Trees for Wet Ponds

Table J.22a. Plants and Trees Suitable for Wet Pond Peripheries – Trees to Provide Shading.[a]

EG	DT	NWN	Agg[b]	Scientific Name	Common Name	BMP Comments: Application[c]	BMP Comments: Mature Height
	DT	NWN		*Acer circinatum*	Vine maple	W	25′
				Betula nigra	River birch	W	40′
EG		NWN		*Myrica californica*	Pacific wax myrtle		18′
				Nyssa sylvatica	Tupelo	W	40′
		NWN		*Oemleria cerasiformis*	Indian plum		10′
		NWN		*Prunus emarginata*	Wild cherry		40′
				Taxus brevifolia	Pacific yew		40′
EG	DT	NWN		*Thuja plicata*	Western redcedar	W	40′

EG = Evergreen
SEMI = Semi-evergreen
DT = Drought Tolerant/Resistant
NWN = Northwest Natives or Cultivars
A = Aggressive
W = Wet Tolerant

[a] If BMP has a liner, designer should review plants accordingly; trees generally are not appropriate to liner conditions.

[b] Aggressive category indicates plants to be used with caution or avoided in confined sites (e.g., right-of-way plantings), near greenbelts, etc., due to maintenance concerns.

[c] Tolerant of occasional saturated soils or minimal inundation (<6″ depth) for short periods (<72 hours).

Note: Plants with mature height over 3′ should be grouped in masses no wider than 8′ mature size with openings of min. 10′ between tall plant masses.

Note: Designer needs to respond to the size and aspect of the individual BMP when selecting plants to be used.

Note: Many factors contribute to waterfowl use of ponds and adjacent areas. Designers should investigate site-specific conditions and best practice methods to discourage waterfowl use as necessary.

Table J.22b. Plants and Trees Suitable for Wet Pond Peripheries – Small Trees/High Shrubs with Fibrous Roots for Berms.

EG	DT	NWN	Agg[a]	Scientific Name	Common Name	BMP Comments: Application[b]	BMP Comments: Mature Height
		NWN		*Acer circinatum*	Vine maple	W	25′
		NWN		*Amelanchier alnifolia*	Serviceberry		25′
EG	DT			*Arbutus unedo*	Strawberry tree		25′
		NWN		*Comus Stolonifera*	Red twig dogwood	W	20′
		NWN		*Corylus comuta* var. *cornuta*	Filbert		20′
		NWN		*Physocarpus capitatus*	Pacific ninebark		12′
		NWN	A	*Rubus spectabillis*	Salmonberry	W	8′
		NWN		*Sambucus racemosa*	Red elderberry		10′
				Vaccinium opulus	Highbush cranberry		10′
				Vaccinium spp.	Blueberry		4′–12′

EG = Evergreen
SEMI = Semi-evergreen
DT = Drought Tolerant/Resistant
NWN = Northwest Natives or Cultivars
A = Aggressive
W = Wet Tolerant

[a] Aggressive category indicates plants to be used with caution or avoided in confined sites (e.g., right-of-way plantings), near greenbelts, etc., due to maintenance concerns.

[b] Tolerant of occasional saturated soils or minimal inundation (<6″ depth) for short periods (<72 hours).

[c] If BMP has a liner, designer should review plants accordingly; trees generally are not appropriate to liner conditions.

Note: Plants with mature height over 3′ should be grouped in masses no wider than 8′ mature size with openings of min. 10′ between tall plant masses.

Note: Designer needs to respond to the size and aspect of the individual BMP when selecting plants to be used.

Note: Many factors contribute to waterfowl use of ponds and adjacent areas. Designers should investigate site-specific conditions and best practice methods to discourage waterfowl use as necessary.

Table J.22c. Plants and Trees Suitable for Wet Pond Peripheries – Low Shrubs and Grasses with Fibrous Roots for Berms.

EG	DT	NWN	Agg[a]	Scientific Name	Common Name	BMP Comments: Application[b]	BMP Comments: Mature Height
EG		NWN		*Arctostaphylos uva-ursi*	Kinnikinnick		0.5′
				Cistus spp.	Rock rose		2′–4′
SEMI		NWN		*Deschampsia cespitosa*	Tufted hairgrass		3′
EG	DT			*Festuca arundinacea*	Tall fescue grass		3′
EG	DT			*Festuca ovina duriuscula* (e.g., Reliant, Aurora)	Sheep fescue		1′
		NWN		*Festuca rubra*	Red fescue	W	0.5′
EG		NWN		*Gaultheria shallon*	Salal		4′
				Helictotrichon sempervirens	Blue oatgrass		3′
EG		NWN		*Ledum groenlandicum*	Labrador tea	W	5′
				Polystichum munitum	Sword fern	W	4′
		NWN	A	*Symphoricarpus albus*	Snowberry		5′
			(A)	e.g., *Miscanthis, Pennisetum*	Ornamental grasses		varies

EG = Evergreen
SEMI = Semi-evergreen
DT = Drought Tolerant/Resistant
NWN = Northwest Natives or Cultivars
A = Aggressive
W = Wet Tolerant

[a] Aggressive category indicates plants to be used with caution or avoided in confined sites (e.g., right-of-way plantings), near greenbelts, etc., due to maintenance concerns.

[b] Tolerant of occasional saturated soils or minimal inundation (<6″ depth) for short periods (<72 hours).

[c] If BMP has a liner, designer should review plants accordingly; trees generally are not appropriate to liner conditions.

Note: Plants with mature height over 3′ should be grouped in masses no wider than 8′ mature size with openings of min. 10′ between tall plant masses.

Note: Designer needs to respond to the size and aspect of the individual BMP when selecting plants to be used.

Note: Many factors contribute to waterfowl use of ponds and adjacent areas. Designers should investigate site-specific conditions and best practice methods to discourage waterfowl use as necessary.

J-5. References

Urban, J., and L. Marritz. 2016. Growth Rates and Performance of Trees in Silva Cells. https://www.deeproot.com/silvapdfs/resources/SC2/articles/Growth-Rates-and-Performance-of-Trees-in-Silva-Cells.pdf