Stormwater Management Manual for Eastern Washington

July 2024

DEPARTMENT OF ECOLOGY
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Stormwater Management Manual for Eastern Washington

Chapter 1 - Introduction

Chapter 2 - Core Elements for New Development and Redevelopment

Chapter 3 - Preparation of Stormwater Site Plans

Chapter 4 - Hydrologic Analysis and Design

Chapter 5 - Runoff Treatment BMP Design

Chapter 6 - Flow Control BMP Design

Chapter 7 - Construction Stormwater Pollution Prevention

Chapter 8 - Source Control

Prepared by:

Washington State Department of Ecology
Water Quality Program

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Executive Summary of the 2024 Revisions

The *Stormwater Management Manual for Eastern Washington* (SWMMEW) provides guidance on the measures necessary to control the quantity and quality of stormwater runoff. Local jurisdictions use this manual to set stormwater requirements for new development and redevelopment projects. Land developers and designers use this manual to design permanent stormwater control plans, develop construction stormwater pollution prevention plans, and determine stormwater infrastructure for their project. Businesses use this manual to help design their stormwater pollution prevention plans.

The greatest use of the SWMMEW has been through National Pollutant Discharge Elimination System (NPDES) stormwater permits. The Municipal Stormwater General Permit for eastern Washington incorporates and references the SWMMEW. The Industrial Stormwater General Permit, Construction Stormwater General Permit, Boatyard General Permit, and the Sand and Gravel General Permit reference the SWMMEW. Since 2005, Ecology has reissued or issued for the first time all of these NPDES stormwater permits. The 2024 revisions to the SWMMEW will continue to help permittees comply with these permits.

Types of Revisions

Statewide Consistency

One focus of the 2024 update was to provide consistent statewide guidance, where appropriate. This included evaluating both the content and layout of the guidance in the SWMMWW and SWMMEW, and editing for statewide consistency where appropriate.

Usability Enhancements

A second focus of the 2024 update was to enhance the usability, which will result in improved implementation of the stormwater permits that rely on this guidance. Enhancements include:

- Continuing to embrace the online user (i.e. maintaining the interactive online format)
- Consolidating repetitive information
- Revising text for clarity
- Reordering sections for a better flow of concepts

Significant Changes

Ecology also identified the following significant changes that were made in order to continue to provide the best guidance available:

1. **New Development and Redevelopment Project Thresholds:** The thresholds for applying the Core Elements to new development and redevelopment projects have been updated. The updated text includes thresholds at both the "Project Level" and the "Core Element Level". The updated thresholds replace the previous "regulatory threshold" of 1

acre that was previously in the Eastern Washington Municipal Stormwater Permit.

See 2.3 Applicability of the Core Elements, 2.4.5 CE5: Runoff Treatment, and 2.4.6 CE6: Flow Control.

2. **Project Exemptions:** The text describing the exemptions from Core Elements has been updated to ensure that the project scope does not exceed the intention of these limited exemptions.

   See 2.2 Exemptions.

3. **Wetlands:** A new Core Element to protect wetlands from stormwater, as well as an appendix with detailed guidance for complying with the Core Element have been added.

   See 2.4.8 CE8: Wetlands Protection and Appendix 2-D: Wetland Protection Guidelines.

4. **Light Rail Guideways as PGIS:** The manual has been updated to identify Light Rail guideways (both elevated and non-elevated) as a pollution generating impervious surface. Light Rail guideways are also identified as a site type that requires metals treatment.

   See the Glossary and 6.1.2 Choosing Your Runoff Treatment BMPs.

5. **Light Rail BMPs:** The following BMPs have been added as options for Source Control and Flow Control for Light Rail projects and activities:

   - BMP F6.70: Light Rail Elevated Guideway Dispersion
   - S453 BMPs for Washing Light Rail Elevated Guideways
   - S454 BMPs for Washing Light Rail Vehicles

6. **Climate Change:** A new topic for climate change guidance has been added. The topic includes a high level overview of the impacts of climate change on stormwater patterns, and suggestions from Ecology for how to help mitigate for climate change using stormwater management techniques.

   See 1.1.5 Climate Change Impacts on Stormwater Management.

7. **Nutrients and Toxic Organics:** New guidance for Nutrients and Toxic Organics - including pollutants from rubber preservatives (e.g. 6PPD-q), Polycyclic Aromatic Hydrocarbons (PAHs), Polychlorinated Biphenyls (PCBs), and Per- and Polyfluoroalkyl Substances (PFAS) has been added to the manual. The updated guidance includes background information on what land uses and/or activities can introduce the pollutant to stormwater, and some suggestions on the types of BMPs that may provide either Source Control or Runoff Treatment for the pollutant.

   See 1.1.6 Stormwater Pollutants and Their Adverse Impacts.

8. **Source Control BMPs - PCB Edits:** The following Source Control BMPs have been updated to include guidance for preventing pollution from PCBs in building materials:

- S424 BMPs for Roof / Building Drains at Manufacturing and Commercial Buildings
- S431 BMPs for Washing and Steam Cleaning Vehicles / Equipment / Building Structures
- S438 BMPs for Construction Demolition
- S451 BMPs for Building Repair, Remodeling, Painting, and Construction

9. **Bioretention:** The guidance within BMP F6.23: Bioretention has been updated to include the option to use the High Performance Bioretention Soil Mix (HPBSM). The design guidance was also updated to clarify the design infiltration rate to use for all three bioretention soil mix options.

   See BMP F6.23: Bioretention.

10. **UIC Program Guidelines:** The UIC Program Guidelines have been updated for general clarity, as well as targeted edits for deep UIC wells. The edits to the deep UIC wells topic includes guidance for deep UIC wells within sensitive groundwater areas, guidance for requirements for deep UIC wells in wellhead protection areas, and the associated registration process requirements.

    See Chapter 5 - UIC Program Guidelines and 5.15 Deep UIC Wells.

Other Updates

For a more comprehensive list of the updates, please see the "Chart of Changes" and "Response to Comments" topics in the "Additional Resources" folder within the interactive online SWMMEW.

How to Find Corrections, Updates, and Additional Information

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.

Ecology intends to incorporate errata changes within the text of the interactive online version of the 2024 SWMMEW. Other updates, such as new technical information (emerging guidance), FAQs, and/or training videos, may be posted as "Additional Resources" with the interactive online manual. The "Additional Resources" can be accessed from the navigation pane of the interactive online manual, but will not be incorporated within the manual text until Ecology officially updates the publication.

Ecology will not use the interactive online version to make revisions in key policy areas – such as the thresholds and Core Elements in Chapter 2 - Core Elements for New Development and Redevelopment. Please check the interactive online version periodically for corrections and updates.

Public Involvement Leading Up to the 2024 SWMMEW

Ecology provided public involvement opportunities and received public comments in preparation of the 2024 SWMMEW through individual user feedback, listening sessions, meetings with experts in selected fields, a preliminary draft public comment period, and a formal draft public comment period.

- **Ongoing Individual User Feedback**

  Since the release of the 2019 SWMMEW, Ecology has collected feedback in the form of emails and phone calls from individual manual users. Ecology took note of common questions, and has provided clarification in the edits.

- **Meetings With Experts**

  In a few cases, Ecology met with internal and external experts to discuss needed changes to the SWMMEW. For example, Ecology held meetings to discuss the updates to Appendix 2-D: Wetland Protection Guidelines.

- **Fall 2021: Open House**

  In the Fall of 2021, Ecology hosted a virtual open house regarding proposed usability and consistency updates to the SWMMWW and SWMMEW.

- **February 2022: Early input received**

  Ecology received early input for consideration from stakeholders.

- **Spring 2022: Listening Sessions**

  In the Spring of 2022, Ecology hosted virtual listening sessions regarding early thoughts on the proposed SWMMEW updates.

- **Fall 2022: Preliminary Draft, with Public Comment Period**

  In the Fall of 2022, Ecology provided preliminary draft sections of the SWMMEW for informal public comment, and hosted virtual workshops with presentations on the preliminary draft topics. Ecology considered the comments received while finalizing the formal draft.

- **Summer 2023: Formal Draft, with Public Comment Period**

  In the Summer of 2023, Ecology provided a formal draft package of the 2024 SWMMEW for public comment. Ecology considered the comments received and made the final changes to the 2024 SWMMEW. Ecology has issued a response to comments with the final version of the 2024 SWMMEW.

Acknowledgments

Ecology gratefully acknowledges the valuable time, comments, and expertise provided by the people listed below who contributed to the 2024 Stormwater Management Manual for Eastern Washington (SWMMEW). Ecology is solely responsible for any errors, omissions, and final decisions related to the 2024 SWMMEW.

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Cover Photos

Cover, clockwise from bottom:

- A bioretention BMP in full bloom in the City of Spokane. Photo provided by Trey George, City of Spokane.
- A permeable pavement sidewalk awaiting pedestrians in the City of Renton. Photo provided by David Mora, Washington State Department of Ecology.
- A lined bioretention BMP along an urban trail system provides Runoff Treatment prior to discharge via an underdrain to offsite drywells. Photo provided by Trey George, City of Spokane.
- A rock-lined infiltration swale awaiting adjacent vegetative stabilization in the City of Richland. Photo provided by Brian Pope, City of Richland.
- A four-level bioretention BMP is tucked along the base of a steep hill to treat runoff from a major arterial and residential right-of-ways. Photo provided by Trey George, City of Spokane.

- A decant facility in the City of Spokane Valley. Photo provided by David Mora, Washington State Department of Ecology.

Spine, top to bottom:

- A stormwater treatment park using bioretention soil media in an artistic configuration in the City of Spokane. Photo provided by Trey George, City of Spokane.
- A rock-lined infiltration swale along the roadway in the City of Spokane. Photo provided by Trey George, City of Spokane.
- Filter fabric providing storm drain inlet protection during construction in the City of Richland. Photo provided by David Mora, Washington State Department of Ecology.

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Chapter 1 - Introduction

1.1 Introduction to Stormwater Management in Eastern Washington

1.1.1 About This Manual

Objective of the Manual

The objective of this manual is to provide guidance on the measures necessary to control the quantity and quality of stormwater produced by new development and redevelopment. The goal of the measures is to comply with water quality standards and contribute to the protection of beneficial uses of the receiving waters. Application of appropriate Core Elements (CEs) and Best Management Practices (BMPs) identified in this manual are necessary but sometimes insufficient measures to achieve these objectives. See 1.1.4 Effects of Urbanization on Stormwater for further information about the impacts of development on water quality.

Water quality standards include:

- Chapter 173-200 of the Washington Administrative Code (WAC), Water Quality Standards for Groundwaters of the State of Washington
- Chapter 173-201A WAC, Water Quality Standards for Surface Waters of the State of Washington
- Chapter 173-204 WAC, Sediment Management Standards

Manual Content

This manual identifies Core Elements for new development and redevelopment projects of all sizes, and provides guidance for preparing and implementing Stormwater Site Plans. These requirements are, in turn, satisfied by the application of BMPs as detailed in this manual. Projects that follow this approach will apply reasonable, technology-based BMPs and water quality-based BMPs to reduce the adverse impacts of stormwater.

This manual includes the following:

- *Guidance for applying Core Elements (CEs) to new and redevelopment project sites.* CEs provide protection of receiving waters in a variety of ways, including preparation of Stormwater Site Plans, pollution prevention during the construction phase of a project, control of potential pollutant sources, treatment of runoff, control of stormwater flow volumes, protection of wetlands, and long-term operation and maintenance. The CEs applicable to a project vary depending on the type and size of the proposed project.
- *Guidance for designing and maintaining Best Management Practices (BMPs) that can be used to meet the CEs*. BMPs are schedules of activities, prohibitions of practices, maintenance procedures, managerial practices, or structural features that prevent or reduce pollutants or other adverse impacts to waters of Washington State. BMPs are

divided into those for short-term control of stormwater from construction sites, and those addressing long-term management of stormwater at developed sites. Long-term BMPs are further subdivided into those covering management of the volume and timing of stormwater flows (Flow Control), prevention of pollution from potential sources (Source Control), and treatment of runoff to remove sediment and other pollutants (Runoff Treatment).

- *Guidance on how to prepare and implement Stormwater Site Plans.* The Stormwater Site Plan is a comprehensive report that describes existing site conditions, explains development plans, examines potential off-site effects, identifies applicable Core Elements, and proposes stormwater BMPs for both the construction phase and long-term stormwater management. The project proponent submits the Stormwater Site Plan to state and local permitting authorities with jurisdiction, who use the plan to evaluate a proposed project for compliance with stormwater requirements.

Manual Applicability

This manual is applicable to all types of land development – including residential, commercial, industrial, and roads. Manuals with a more-specific focus, such as WSDOT's Highway Runoff Manual (WSDOT, 2014), that have been determined to be equivalent to this manual, may provide more appropriate guidance to the intended audience.

More Stringent Requirements

Federal, state, and local permitting authorities with jurisdiction can require more stringent measures that are deemed necessary to meet locally established goals, state water quality standards, or other established natural resource or drainage objectives. Water cleanup plans or Total Maximum Daily Loads (TMDLs) may also identify more stringent measures needed to restore water quality in an impaired water body.

Equivalent Manuals

Some regulations or programs (e.g. the Phase I Municipal Stormwater Permit, the UIC Program) may allow the use of an "equivalent manual" for compliance with that regulation or program. When a regulation or program allows the use of equivalent manuals, that regulation or program will dictate the steps necessary for an alternative technical manual to gain equivalency for use in that regulation or program. If it is an Ecology regulation or program, an Ecology review is often (but not always) required.

Refer to the regulation or program you are complying with for details on if equivalent manuals are allowed, and if so, which alternative technical manuals are considered equivalent for use with that specific regulation or program.

Use of This Manual for Retrofits

This manual can also help identify options for retrofitting BMPs into existing developed areas. Retrofitting BMPs into existing developed areas will be necessary in many cases to meet federal Clean Water Act and state Water Pollution Control Act (Chapter 90.48 RCW) requirements.

While the Washington State Department of Ecology (Ecology) has guidance for redevelopment, there is no specific guidance for retrofits outside of redevelopment. Application of BMPs from this manual is encouraged for retrofits. However, there can be site constraints that make the strict application of these BMPs as retrofits difficult. In these instances, the BMPs presented here can be modified using best professional judgment to provide reasonable improvements in stormwater management.

Exclusion of Conveyance Design

Design guidance for conveyance systems is not included in this manual. Conveyance design is covered in standard engineering references.

1.1.2 Applicability to Eastern Washington

This manual is applies to all of eastern Washington. This includes the area bounded on the west by the Cascade Mountains crest; on the north by the Canadian border; on the east by the Idaho border; and on the south by the Oregon border. At the southern end of Washington's Cascade Mountain range where the crest does not follow county borders, this manual is applicable to all of Yakima and Klickitat Counties.

The following counties are included in the area described above:

- Adams
- Asotin
- Benton
- Chelan
- Columbia
- Douglas
- Ferry
- Franklin
- Garfield
- Grant
- Kittitas
- Klickitat
- Lincoln
- Okanogan
- Pend Oreille
- Spokane
- Stevens
- Walla Walla

- Whitman
- Yakima

1.1.3 Comparison of the Stormwater Management Manuals for Eastern and Western Washington

After crossing from western to eastern Washington from any mountain pass, one thing is apparent: eastern Washington is very different from western Washington in terms of climatic conditions, vegetation, and landscape. In many regards, eastern Washington is more similar to Idaho and Montana than to western Washington, with its cold, snowy winters; hot, dry summers; strong winds; rugged mountain landscapes; high desert plateaus; rolling hills of wheat and fruit; lakes; and abundance of flat agricultural land.

This manual was developed to address conditions that are unique to eastern Washington with respect to designing stormwater BMPs such as the following:

- The Phase II Municipal Stormwater National Pollutant Discharge Elimination System Permit for eastern Washington requires retention of the 10-year stormwater runoff on-site, resulting in minimal discharge to municipal drainage systems. Some jurisdictions require retention of larger storms.
- Many developed sites in the region drain directly to underground injection control (UIC) wells.
- Storms generally occur as short-duration, high-intensity events.
- In some areas with intense agricultural use, groundwater levels can fluctuate due to irrigation in the summer months, with reductions of several feet in the winter when irrigation is shut off.

Both this manual and the *Stormwater Management Manual for Western Washington* (SWMMWW) are based on the same standard: protecting water quality. However, consideration of the unique characteristics of eastern Washington such as those listed above has led to different approaches in the two manuals for selecting, sizing, and designing stormwater BMPs.

The BMPs in Chapter 7 - Construction Stormwater Pollution Prevention and Chapter 8 - Source Control of this manual (e.g., BMP C120: Temporary and Permanent Seeding) have been designated with an "E" in the title to indicate that, while the BMP is provided in both manuals, the design guidance herein may have been revised to address eastern Washington conditions. The manuals are also organized differently, with this manual consisting of eight chapters and the SWMMWW consisting of five volumes. The eight Core Elements in this manual (see Chapter 2 - Core Elements for New Development and Redevelopment) include the same goals as the nine Minimum Requirements in the SWMMWW, but the organization is different.

1.1.4 Effects of Urbanization on Stormwater

Introduction

Managing stormwater may not seem necessary in arid and semiarid regions where rainfall is generally a welcomed event. However, the quality and habitat function of receiving waters in arid and semiarid climates are affected by pollutants carried by stormwater runoff and by the changes in the patterns of runoff from the land following development. Hydrologic and water quality changes caused by urbanization can result in irreversible changes to the biological systems that were supported by the natural hydrologic system.

Hydrologic Changes

Just as the landscape of eastern Washington includes prairies, pine forests, the shrub-steppe, channeled scablands, and vast areas of irrigated and dryland agriculture, the hydrology of streams in eastern Washington varies tremendously. Average annual precipitation varies from 6 inches to > 60 inches. Streambed material varies from basalt rock to highly erodible loess soils. Many streams flow only during the relatively wet winter and spring seasons or only during a runoff-producing rainstorm or snowmelt event. The hydrology of other streams has been altered by seasonal irrigation practices.

Regardless of the hydrologic and geologic setting, streams can be impacted by urbanization of their watersheds. As development occurs, land is cleared and impervious surfaces such as roads, parking lots, rooftops, and sidewalks are added. Roads are cut through slopes and low spots are filled. The natural soil structure is lost due to grading and compaction during construction. Drainage patterns are irrevocably altered. Maintained landscapes that have much higher runoff characteristics often replace the native vegetation. The accumulation of these changes may affect the natural hydrology by means of the following actions:

- Increasing the peak flow rates of runoff
- Increasing the total volume of runoff
- Decreasing the time it takes for runoff to reach a natural receiving water
- Increasing stream velocities
- Reducing groundwater recharge
- Increasing the frequency and duration of high streamflows
- Increasing inundation of wetlands during and after wet weather
- Reducing streamflows and wetland water levels during the dry season

Figure 1.1: Changes in Hydrology after Development illustrates some of these hydrologic changes. As a consequence of these changes in hydrology, stream channels may experience both increased flooding and reduced base flows. Natural riffles, pools, gravel bars, and other areas may be altered or destroyed. Increased channel erosion, loss of hydraulic complexity, degradation of habitat, and changes in the composition of species present in receiving waters may follow.

These changes do not result from any one project; they are the cumulative effect of all of the development in a watershed.

From a stream morphology standpoint, smaller flood events that approximate bankfull conditions and occur naturally every year or two (1.5- to 2-year frequency) are the most influential discharges and most easily changed with added urban runoff. It is these smaller flood events that shape the channel and are referred to as “effective flows” because over time they move the most sediment and transform the dimensions of a stream channel. When effective flows increase in size, duration, and frequency, the most common impact is changes in channel morphology to accommodate the rise in erosive energy delivered to receiving streams on an annual basis.

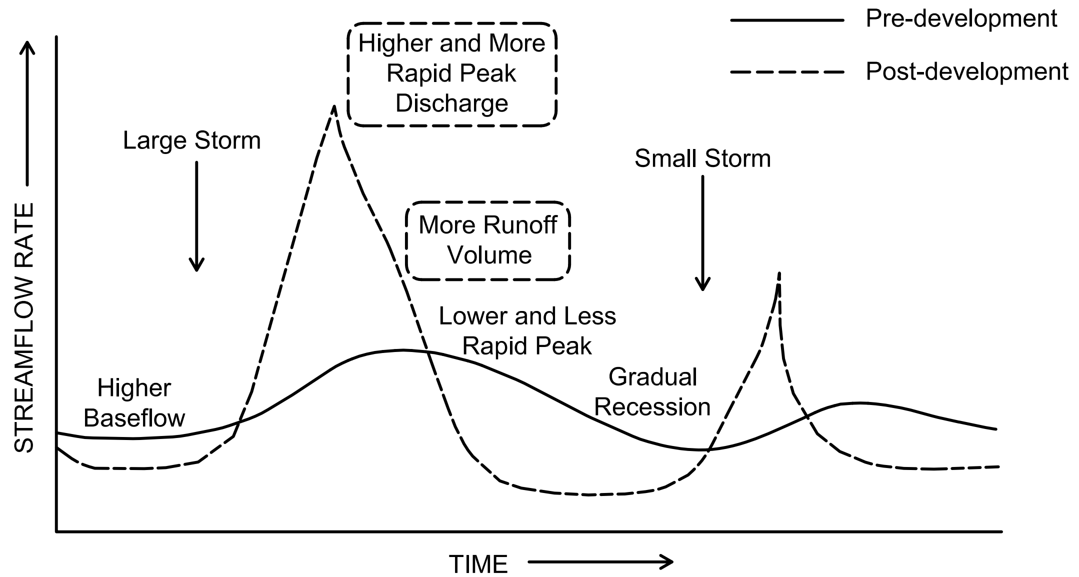
Research in streams in arid, semiarid, and humid climate settings has shown that this accommodation commonly takes place by widening and down cutting of the streambed, damaging habitats and potentially reducing biologic diversity. Research has shown that as developed impervious areas reach 5% of land cover within a watershed, the connection between runoff from impervious areas and channel response through erosion begins to occur ((Hajda et al., 1999); (Hollis, 1975); and (Booth, 1991)).

The intent of Flow Control is to prevent increases in the stream channel erosion rates that are characteristic of natural conditions by releasing runoff from the proposed development condition in a manner that delivers approximately the same amount of erosive energy to the stream as it received under predeveloped or receives under existing conditions.

Flow Control in this manual is targeted to smaller water bodies, especially first to third order streams or water bodies with contributing watershed areas of less than 100 square miles. These streams are most susceptible to changes in runoff patterns caused by development. In larger water bodies, the location of the development activity plays a greater role: in general, development that occurs nearer to a large stream channel and that does not encroach on the natural floodplain has less of an effect than development activities in the upper watershed, which are instead likely to impact smaller tributary stream channels.

This manual includes guidance on stormwater management practices for controlling excess runoff volume from individual sites through Flow Control BMPs.

Figure 1.1: Changes in Hydrology after Development



(Schueler, 1987)

NOT TO SCALE

DEPARTMENT OF ECOLOGY State of Washington

Changes in Hydrology after Development

Revised July 2016

Water Quality Changes

Urbanization also causes an increase in the types and quantities of pollutants in surface and groundwaters. Runoff from urban areas contains many different types of pollutants, depending on the nature of the activities in those areas. Many studies monitoring urban runoff have found that land use is an important determinant of runoff quality ((USEPA, 1983); (Strecker et al., 1997); (Maestre et al., 2005); and (Pitt, 2011). In 2015, Ecology synthesized the stormwater monitoring data collected by Western Washington Phase I stormwater permittees under the 2007 NPDES permit (Ecology, 2015). Ecology evaluated pollutant detection rates, concentrations, and discharge patterns with landuse and season. This local dataset plus early national efforts represent forty years of progressive understanding about pollutants that can be transported by runoff. They demonstrate that runoff is highly variable across seasons, storm events, land uses and that even the methods used to collect samples adds considerable complexity to the runoff story. Although no two storm events will be the same, there are patterns to weather, the natural environment, and in human activities that yield patterns in stormwater runoff transported pollutants. (Ecology, 2015) reported that metals, diesel hydrocarbons, and nutrients exhibit some 'buildup' during the dry season (May through September). However, equally 'ubiquitous' parameters such as PAHs and phthalates did not exhibit a significant seasonal difference and instead may be a consistent source throughout the year.

Across the evaluated land uses, nearly all water and storm sediment samples contain fecal indicator bacteria, metals (arsenic, copper, lead, magnesium, and zinc), polycyclic aromatic hydrocarbons (PAH's), nitrogen, phosphorus, and solids. Commercial and industrialized land uses generally have higher concentrations of these pollutants compared to the residential areas with the exception of nutrients.

The runoff from roads and highways is contaminated with pollutants from vehicles, spills, and fugitive materials. Typical pollutants include oil and grease, PAHs, lead, zinc, copper, cadmium, sediments (soil particles), discarded or escaped trash, tire particles and road salts. Commercial and industrial areas where traffic congestion and vehicle use is routine are priority areas for intercepting key stormwater pollutants such as sediment, PAHs, and toxic metals (cadmium, chromium, copper, lead, manganese, zinc) ((Lundy et al., 2012); (Ma et al., 2017); and (Müller et al., 2020)). In the state of Washington, the Washington State Department of Transportation (WSDOT) collects and analyzes water quality data for highway stormwater runoff. The *WSDOT NPDES Municipal Stormwater Permit Final Highway Runoff Characterization Report* (WSDOT, 2015b) summarizes recent highway runoff monitoring data, showing measured pollutant loadings for five highway sites in rural, urbanized, and highly urbanized areas. This WSDOT report includes state-specific highway runoff pollutant concentrations for total suspended solids (TSS), fecal indicator bacteria, chloride, hardness, phosphorus, orthophosphate, nitrate-nitrite, total Kjeldahl nitrogen (TKN), total and dissolved copper, zinc, lead, and cadmium; total petroleum hydrocarbons (TPH), PAHs, and phthalates.

Stormwater may become contaminated by activities as a result of contact with materials stored outside, spills and leaks from equipment or materials used onsite, contact with materials during loading, unloading or transfer from one location to another, and from airborne contaminants. Runoff from industrial areas typically contains even more types of heavy metals, sediments, and a broad range of man-made organic pollutants, including phthalates, PAH’s, and other petroleum hydrocarbons. Heavy metals and PAHs from industrial, commercial and mixed residential land uses pose the highest risks for environmental impact ((Ma et al., 2017) and (Müller et al., 2020)).

Residential areas contribute the same road-based pollutants to runoff, as well as herbicides, pesticides, nutrients (from fertilizers), bacteria and viruses (from animal waste). Fecal indicator bacteria are often associated with sediments carried into receiving waters, although they can reproduce on their own in nutrient right waters or be released by wildlife or domesticated animals directly to waters. All of these contaminants can seriously impair beneficial uses of receiving waters.

Regardless of the eventual land use conversion, the sediment load produced by a construction site can turn the receiving waters turbid and be deposited over the natural sediments of the receiving water. Pollutants expected in the stormwater from construction activity include sediment, pH, nutrients, and petroleum products.

The pollutants from urbanized areas can be dissolved in the water column or attached to particulates and may reach streambeds, lakes, wetlands, or marine estuaries if they are not controlled or removed. Sediment remains a high risk pollutant and an indicator and carrier for other pollutants such as fecal indicator bacteria, nutrients, metals, organic pollutants, and microplastics.

While many hundreds of pollutants may be detected and transported in stormwater runoff, the relative abundance and the posed risks to aquatic life and human health are important in prioritizing stormwater management action. This manual provides guidance on Best Management Practices (BMPs) for reducing the impacts of pollutant-laden stormwater from individual sites through Source Control BMPs, Construction Stormwater BMPs, and Runoff Treatment BMPs.

Temperature Changes

Urbanization also tends to cause changes in water temperature. Removal of trees and shrubs both within and outside riparian areas allows direct heating of impervious surfaces and exposed water surfaces such as streams and ponds raising temperatures well above healthy thresholds for aquatic life. Rapid stream warming due to warm stormwater runoff is less prevalent in Washington because summer rain storms are not as common in Washington as other states. In fact, the native vegetation have evolved for summer dormancy to handle the long seasonal droughts. In winter, stream temperatures may lower due to loss of riparian cover.

Urbanization also contributes to excessive summer stream temperatures through reduced groundwater recharge due to impervious surfaces. Less groundwater recharge means the sources of cool groundwater inputs to streams are reduced year round. There is also concern that the replacement of warmer groundwater inputs with colder surface runoff during colder periods may have biological impacts.

Biological Changes

The hydrologic and water quality changes described above result in changes to the biological systems that were supported by the natural hydrologic system. In particular, aquatic life is greatly affected by urbanization. Habitats are drastically altered when a stream changes its physical configuration and substrate due to increased flows. Natural riffles, pools, gravel bars and other areas are altered or destroyed. These and other alterations produce a habitat structure that is very different from the one in which the resident aquatic life evolved. For example, high gravel spawning areas, particularly those needed for salmonids and invertebrates, are lost when fine sediments imbed stream gravels and suffocate salmon redds. The complex food web and biodiversity is destroyed and replaced by a biological system that can tolerate the changes.

However, that biological community is typically not as complex, is less desirable, and is unstable due to the ongoing rapid changes in the new hydrologic regime.

The biological communities in wetlands are also severely impacted and altered by the hydrological changes. Relatively small changes in the natural water elevation fluctuations can cause dramatic shifts in vegetative and animal species composition.

A rise in water temperature can have direct lethal effects. It reduces the maximum available dissolved oxygen and may cause algae blooms that further reduce the amount of dissolved oxygen in the water.

Toxicity of Stormwater

Some of the pollutants transported by stormwater may be toxic to aquatic life. Toxic pollutants in the water column and sediments are known to include pesticides, soaps, and metals that can have immediate and long-term lethal impacts. In Puget Sound a prime example is when the polluted sediment in urban bays causes lesions and cancers in bottom fish. Extensive work finding and defining effective Source Control, Flow Control, and Runoff Treatment BMP options to manage toxicity in stormwater is needed to sufficiently protect water quality. It is crucial that regulatory agencies continue to investigate, use, and improve upon practices available to achieve greater water quality protection.

A pattern of toxicity in small streams has been under investigation for several years with no obvious causes other than vehicle related stormwater ((Scholz et al., 2011); (Spromberg and Scholz, 2011); and (Feist et al., 2017)).

Recent developments in analytical chemistry have allowed researchers to identify a previously unknown pollutant called 6PPD-quinone (6PPD-q) that is responsible for acute coho mortality ((Peter et al., 2018) and (Tian et al., 2020)). 6PPD-q is a reaction byproduct of the antioxidant 6PPD that has been added since the 1950s to car and truck tires to preserve the rubber matrix from cracking (DTSC et al., 2022). Lab studies have shown 6PPD-q to be lethal at very low concentrations to coho salmon in particular as well as rainbow trout and brook trout ((McIntyre et al., 2021) and (Tian et al., 2022)). Despite the widespread use and presence of 6PPD in tires and on roadways, the prevalence of 6PPD-q in aquatic areas is unknown. At this time, our understanding of what eventually happens to 6PPD and 6PPD-q in the environment is incomplete but evolving as this chemical of emerging concern has received a great deal of academic attention worldwide since its discovery in 2020.

The Washington State Legislature directed Ecology in 2021 to write a synopsis report (Ecology, 2022) on where priority areas are that are affected by this newly identified contaminant and on stormwater best management practices (BMPs) for reducing toxicity to aquatic life. Currently, Ecology's stormwater program has allocated state Legislative proviso funds to science and engineering studies to fill critical data gaps in understanding chemical behavior of 6PPD-q in stormwater runoff and sediments in conveyance systems, and effectiveness of the BMPs to manage them. Ecology anticipates periodic updates to the Emerging Guidance section of the interactive online version of the stormwater management manuals as these studies are completed. The peer reviewed literature and these studies will be important to learn from to write and adapt guidance over time. The rate of field studies is anticipated to increase and then level off in the next decade as more information on fate, transport, and effects of 6PPD-q is generated and a world-wide consensus is developed.

The Role of Land Use and Lifestyles

Land use is tied to site development standards and where development occurs. This manual is not intended to direct those land use decisions or delve deeply into those topics. Most land use decisions occur prior to the project being proposed. This manual focuses on the management of the project. This manual can provide site development strategies to reduce the pollutants generated and the hydrologic disruptions caused by development.

The engineered stormwater conveyance, treatment, and detention systems advocated by this and other stormwater manuals can reduce the impacts from development to water quality and hydrology. However, they cannot replicate the natural hydrologic functions of the natural watershed that existed before development, nor can they remove enough pollutants to replicate the water quality of pre-development conditions. Ecology understands that despite the application of appropriate practices and technologies identified in this manual, some degradation of urban and suburban receiving waters will continue, and some beneficial uses will continue to be impaired or lost due to new development. This is because land development, as practiced today, is incompatible with the achievement of sustainable ecosystems. Unless development methods are adopted that cause significantly less disruption of the hydrologic cycle, the cycle of new development followed by beneficial use impairments will continue.

Researchers (May et al., 1997) and regulators [e.g. (King County, 1996)] have speculated on the amount of natural land cover and soils that should be preserved in a watershed to retain sufficient hydrologic conditions to prevent stream channel degradation, maintain base flows, and contribute to achieving properly functioning conditions for salmonids. There is some agreement that preserving a high percentage (possibly 65 to 75%) of the land cover and soils in an undisturbed state is necessary. To achieve these high percentages in urban, urbanizing, and suburban watersheds, a dramatic reduction is necessary in the amount of impervious surfaces and artificially landscaped areas to accommodate our preferred housing, play, and work environments, and most significantly, our transportation choices.

Surfaces created to provide “car habitat” comprise the greatest portion of impervious areas in land development. The sheer magnitude of uncontrolled runoff from old infrastructure near streams with sensitive biota is challenging to address in the near term. There are multiple management approaches that use infiltration, sorption, filtration and/or capture of tire debris that are presumed to provide the necessary treatment from "car habitat". These management approaches for runoff from "car habitat" will need to consider local conditions and the variety of BMPs from Source Control, Flow Control, and Runoff Treatment. In order to make appreciable progress in reducing impervious surfaces in a watershed, we must reduce the density of our road systems, alter our road construction standards, reduce surface parking, and rely more on transportation systems that do not require such extensive impervious surfaces (rail, bicycles, walking).

Reducing the extent of impervious surfaces and increasing natural land cover in watersheds are also necessary to solve the water quality problems of sediment, temperature, toxicants, and bacteria. Changing public attitudes toward chemical use and preferred housing are also necessary to achieve healthy water ecosystems.

Until we are successful in applying land development techniques that result in matching the natural hydrologic functions and cycles of watersheds, management of the increased surface runoff is necessary to reduce the impact of the changes. Biological impacts in streams can occur at even low levels of development associated with rural areas where stormwater runoff has not been properly managed. Improving our stormwater detention, treatment, and source control management practices should help reduce the impacts of land development in urban and rural areas. We must also improve the operation and maintenance of our engineered systems so that they function as well as possible. This manual is Ecology's latest effort to apply updated knowledge in these areas.

The question yet to be answered is whether better management – including improved treatment and detention techniques – of the increased surface runoff from developed areas can work in combination with preservation of high percentages of natural vegetation and soils on a watershed scale to yield a minimally altered hydrologic and water quality regime that protects the water-related natural resources.

In summary, implementing improved engineering techniques and drastic changes in where and how land is developed and how people live and move across the land are necessary to achieve the goals in the federal Clean Water Act - to preserve, maintain, and restore the beneficial uses of our nation's waters.

1.1.5 Climate Change Impacts on Stormwater Management

Climate Change Trends and Predictions in Washington State

Climate change and its impact on stormwater management has become a significant topic of discussion and research in recent years.

A growing number of research and repeated model simulation results indicate that changes in global, national, and Washington State climates have cascading impacts on water resources, infrastructure, agriculture, human health, and more. Washington State, local government agencies, businesses, and communities have been preparing for climate change and potential mitigation options. We have already started experiencing climate-related hazards, and more impacts are inevitable. The intensity of the predicted changes and damages from those changes depend on our mitigation actions and preparedness.

Stormwater Management in a Changing Climate

Climate change impacts on stormwater and receiving water ecosystems

Climate change impacts, especially precipitation pattern changes, pose increasing challenges in stormwater management and receiving water ecosystems . Wetter winters and more frequent and intense heavy rainfall events mean an increasing possibility for these events to overwhelm existing stormwater facilities that were sized based on historic rainfall data, resulting in more frequent and intense flooding, and more pollutant loads (e.g. particles, toxic chemicals and bacteria) carried with stormwater.

Frequency and intensity of extreme events (i.e. heavy rainfall, or atmospheric river events) are increasing. These events often severely damage infrastructure and receiving water bodies, resulting in costly repairs. The flood damages caused by extreme atmospheric river events cost tens to hundreds of millions of dollars; one atmospheric river event in January 2009 (size 3-8 inches of rainfall) resulted in $125 million in damages.

Challenges to developing regional stormwater management recommendations to mitigate for climate change

Although climate change models generally predict increases in heavy rainfalls and drought in summer, the uniqueness and variability of local conditions limit developing regional recommendations for engineering design. Local agencies also face challenges, such as those listed here, when developing climate change preparation strategies:

- Multiple Global Climate Models (GCMs) paired with different greenhouse gas emission and action scenarios produce a rather wide range of projections with high uncertainty, sometimes conflicting with each other. Additionally, coarse spatial scaled GCM projections would need to be downscaled to the local level, which brings another layer of uncertainty and challenges, especially to medium and small size communities.
- Climate change projections don't necessarily provide information required for management decisions. Stormwater engineers and managers need local hourly rainfall total and flashiness information, not seasonal or annual rainfall data, to select and size stormwater conveyance systems and Runoff Treatment and Flow Control BMPs.
- Stormwater managers need analytical and management tools. For example, stormwater BMPs are not sized to fully capture extreme storm events. Stormwater managers in areas with poorly draining soil (i.e. till soil) will be challenged to adequately quantify the potential effectiveness of low impact development (LID) to mitigate for future stormwater discharges.

Ecology's recommendations for stormwater management to mitigate for climate change

Despite high uncertainties, variations, and limited information and resources at the local level, some actions and planning can be taken based on best available science and tools. Based on the data available, Ecology recommends the following actions to help mitigate the impacts of climate change on stormwater management design:

- **Develop a flexible and multi-objective strategy** allowing cost-effective and adaptive management to handle large uncertainty and variability.
- **Prepare for more extreme events** such as drought and atmospheric river events, which pose more hazardous risks, rather than annual average change.
- **Improve awareness** of how climate change can damage infrastructure, communities, and the economy significantly without proper climate adaptation and preparedness.
- **Apply more LID**, rather than managing the stormwater at the end of pipe or receiving water bodies. Consider the long-term and multiple benefits of low impact development in the decision making process in comparison to the flood damage and recovery cost that may result from extreme storm events.
- **Maintain and increase natural ecosystem areas** by zoning, land acquisition, wetland protection, riparian restoration, and forest restoration.
- **Develop local rebate, credit, fee in lieu, and/or stormwater banking programs** for rainwater mitigation, stormwater reuse, rain gardens, tree planting, reforestation, and land

conservation and acquisition.

- **Local agencies should stay current on new research** and recommendations, and consider if increased stormwater regulations should be implemented that would lower the design thresholds to require stormwater management BMPs or expanded retrofit requirements.
- **Place stormwater regional facilities** in more vulnerable locations.
- **Preserve and enhance the capacity of existing BMPs** through regular inspection, maintenance, and retrofits.
- **Perform a critical assessment of existing infrastructure** to understand how many facilities experience flooding, and their anticipated failure to perform with future rainfall intensities.
- **Consider changing Flow Control BMP design requirements** by doing one or more of the following:
    - Sizing Flow Control BMPs based on local future precipitation projections.
    - When local future precipitation projections are not available, historic rainfall data can be still used. Upsize BMPs when possible by changing the Flow Control goals to capture larger storms (e.g. 100 yr peak flow instead of 50 yr) in more vulnerable areas. For example:
        - Upsizing Flow Control BMPs by a factor (set locally)
        - Scaling design storms used to size Flow Control BMPs by a factor (set locally)
        - Designing Flow Control BMPs for larger storm events (e.g. 100 yr peak flow instead of 50 yr peak flow)

Related Information

While there are not yet regulations on how to prepare for climate change impacts to stormwater management by state or federal agencies, many Washington state local agencies and communities have proactively developed and conducted innovative approaches to improve climate resiliency of stormwater systems. More information can be found at the following web addresses:

- UW Climate Impacts Group webpage and publications including State of Knowledge:

  https://cig.uw.edu/

- UW CIG Sea Level Rise Visualizations webpage:

  https://cig.uw.edu/projects/interactive-sea-level-rise-data-visualizations/

- Washington Stormwater Center Stormwater-Climate Resiliency Workshop webpage:

  https://www.wastormwatercenter.org/stormwater-climate-resiliency/

1.1.6 Stormwater Pollutants and Their Adverse Impacts

Many types of pollutants come in contact with stormwater, and then make their way into receiving waters. Some particularly concerning types of stormwater pollutants are total suspended solids (TSS), oil and grease, nutrients, pesticides, other insoluble organics (PCBs, PAHs, phthalates, 6PPD-q), pathogens, biochemical oxygen demand (BOD), heavy metals, salts (chlorides), trash, and plastics ((USEPA, 1995), (Field et al., 1997), (Strecker et al., 1997), (Ecology, 2015), (DeGasperi et al., 2018), (Langness et al., 2022), and (Ecology, 2022)).

New and redevelopment project requirements focus on TSS, Phosphorus, Dissolved Metals (i.e. Metals treatment), and Oil Control. This section offers guidance for additional pollutants, for projects that strive to address pollutants beyond those required for new and redevelopment projects.

Bacteria and Viruses

Stormwater can contain disease-causing bacteria and viruses, although not at concentrations found in untreated sanitary sewage. Shellfish subjected to stormwater discharges near urban areas are usually unsafe for human consumption.

Research has shown that the concentrations of fecal indicator bacteria in stormwater, particularly during dry seasons, is highest from high density residential, commercial, and industrial areas.

Biochemical Oxygen Demand (BOD)

Biochemical Oxygen Demand (BOD) is a measure of the oxygen demand from organic, nitrogenous, and other materials that are consumed by bacteria present in receiving waters. BOD in the water may deplete oxygen in the process, threatening higher organisms such as fish. BOD concentrations differ by land use and seasons and are somewhat higher in commercial areas and during dry seasons.

Heavy Metals

Stormwater can contain heavy metals such as lead, zinc, cadmium, chromium, and copper at concentrations that may pose toxicity to fish and other aquatic life. Research in Puget Sound has shown that metals and toxic organics concentrate in sediments and at the water surface (microlayer) where they interfere with the reproductive cycle of many biotic species and cause tumors and lesions in fish. In stormwater runoff, metals associated with sediments are much higher than dissolved in the water and show land use differences; higher in industrial, commercial, and high density residential areas.

Nutrients (Nitrogen and Phosphorus)

Nutrient (i.e. nitrogen and phosphorus) compounds can cause excessive growth of aquatic vegetation in freshwater and marine waters. Managing nutrient loading in stormwater runoff benefits the receiving water by reducing unhealthy growth rates of the aquatic vegetation.

In general, stormwater in urban areas has relatively low nutrient concentrations. However, urban and urbanizing watersheds produce a larger annual volume of runoff which could contribute greatly to annual nutrient loads to receiving waters. During the 2009-2013 cycle of Ecology's Phase I Municipal Stormwater Permit, Western Washington permittees collected regional stormwater runoff water quality data including nutrient concentrations. Ecology's recommendations based on those results are below.

Nitrogen

The national median concentration of Total Nitrogen (TN) in stormwater reported in the previous study (Collins et al., 2010) ranged between 1.3 and 3.2 mg/L (n = 3765), and it was 1.28 mg/L in Western Washington (Ecology, 2015). There were also some incidents reported in Western Washington when total nitrogen concentration exceeded 5-10 mg/L. These incidents are likely related to illicit discharge, and occurred mainly in the commercial and industrial land use areas.

Both national and Western Washington data show that the majority of nitrogen in urban stormwater is particulate or organic nitrogen. This suggests that effective nitrogen reduction must include particulate and organic nitrogen management. Western Washington data also shows that the composition of nitrogen (particulate, organic, or inorganic forms of nitrogen) varies between landuse types. Commercial and industrial landuse types have a significantly higher organic nitrogen fraction in TN whereas residential areas have a mixed nitrogen composition with more inorganic (nitrite-nitrate and ammonia) nitrogen fraction in TN (Ecology, 2015). Therefore, Ecology recommends different nitrogen management practices by landuse types and by dominant nitrogen form.

Source Control BMP Recommendations for Nitrogen

Source Control BMPs are typically the most cost-effective management tools for preventing nitrogen in stormwater. Ecology therefore recommends implementing the following Source Control BMPs to the maximum extent practicable before considering additional structural (i.e. Runoff Treatment and/or Flow Control) BMPs.

- Particulate and organic nitrogen management recommendations:

  The most common particulate and organic nitrogen sources to urban stormwater are vegetative debris, soil organic matter, food-related waste, pet waste, and illicit discharge of these. These recommendations will likely be effective in commercial, industrial, high density residential, mixed, or open space areas.

  - catch basin maintenance including removal of vegetative debris (e.g. dead leaves) (See Appendix 8-B: Management of Street Waste Solids and Liquids)
  - street sweeping to remove vegetative debris from street surfaces (see S430 BMPs for Urban Streets)
  - erosion control for soils that do not have established vegetative cover (see 7.4.3 Construction Runoff BMPs)
  - illicit discharge prevention (see S108 BMPs for Correcting Illicit Discharges to Storm Drains)
  - proper disposal of pet waste (see S440 BMPs for Pet Waste)
  - regular conveyance system maintenance and cleaning to remove residual particulate solids from the system.

- Inorganic nitrogen management recommendations:

  Most common inorganic nitrogen sources to urban stormwater are over-application and illicit discharge of landscaping fertilizer. These recommendations will likely be effective in residential areas and any area with heavy landscape maintenance activities (e.g. golf courses).

  - proper timing and frequency of landscaping fertilization (see S443 BMPs for Fertilizer Application)
  - regular conveyance system maintenance and inspection to repair any cracks

Structural (Runoff Treatment and/or Flow Control) BMP Recommendations for Nitrogen

- For particulate, organic, and total nitrogen, any Runoff Treatment BMP with filtration, sedimentation, or biological process are recommended. BMPs within this manual that provide these types of treatment include Basic Treatment BMPs, as described in 6.1.2 Choosing Your Runoff Treatment BMPs.
- For inorganic nitrogen, Runoff Treatment BMPs with biological processes (i.e. plant uptake or microbial processes) are recommended.
- Total nitrogen load from stormwater to the surface water can also be reduced by reducing the volume of stormwater discharge (e.g. through infiltration and/or plant uptake).

Phosphorus

The median concentration of total phosphorus in stormwater was 110 ug/L (0.1 mg/L), and industrial land use areas showed the highest total phosphorus concentration (mainly in a particulate P form) (Ecology, 2015).

Source Control BMP Recommendations for Phosphorus

The *Source Control BMP Recommendations for Nitrogen* (listed above) are also recommended for total phosphorus management (including particulate, organic, and inorganic phosphorus).

Structural (Runoff Treatment and/or Flow Control) BMP Recommendations for Phosphorus

- See 6.1.2 Choosing Your Runoff Treatment BMPs for Ecology's guidance on Runoff Treatment BMPs for total phosphorus removal.
- Total phosphorus load from stormwater to the surface water can also be reduced by reducing the volume of stormwater discharge (e.g. through infiltration and/or plant uptake).

Oil and Grease

Oil and grease can be toxic to aquatic life. Concentrations in stormwater from commercial and industrial areas often exceed Ecology guidelines of:

- 10 mg/L maximum daily average,
- 15 mg/L maximum at any time, and
- no ongoing or frequently recurring visible sheen.

pH

A measure of the alkalinity or acidity that can be toxic to fish if it varies appreciably from neutral pH, which is 7.0.

Total Suspended Solids

This represents particulate solids such as eroded soil, heavy metal precipitates, and biological solids (all considered as conventional pollutants), which can cause sedimentation in streams and turbidity in receiving surface waters. These sediments can destroy the desired habitat for fish and can impact drinking water supplies. The sediment may be carried to streams, lakes, or other receiving waters where they may be toxic to aquatic life and make dredging necessary. Removing TSS from stormwater can be an effective way to treat other stormwater pollutants, such as nutrients, BOD, bacteria, and toxic organic contaminants as some of them move as part of the particulate or are adsorbed in the surface of particulate solids.

Toxic Organics

Toxic organics may be present in stormwater runoff with known and unknown sources in urban and rural areas. For example, a study found 19 of the U.S. Environmental Protection Agency's 121 priority pollutants present in the runoff from Seattle streets. The most frequently detected pollutants were pesticides, phenols, phthalates, and polycyclic aromatic hydrocarbons (PAHs).

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 matrices including municipal and industrial stormwater effluent. Specifically, PFAS has been detected in the stormwater of urban industrial catchments 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.

Pollutants from Rubber Preservatives (Including 6PPD-q)

Recent identification of 6PPD-q as a toxic chemical carried by stormwater is described in 1.1.4 Effects of Urbanization on Stormwater. 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 is added to tires as a chemical antioxidant preservative for decades.

Currently there is a great deal of effort 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, a couple studies conducted locally, before 6PPD-q was identified, found filtering highway runoff through the default bioretention soil mix (see BMP F6.23: Bioretention) was 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). Studies currently underway are evaluating the potential treatment effectiveness of sorption and other filtration techniques using a variety of medias and BMPs. Implementing a wide range of stormwater management strategies, many covered by this manual's chapters on 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 reduce 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 more clear.

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 by the concentrations and rates of detection in stormwater samples vary widely. PAHs were monitored by the Phase I Western Washington municipal stormwater permitees under the 2007 permit and summarized by (Ecology, 2015). 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.

Polychlorinated Biphenyls (PCBs)

Polychlorinated biphenyls (PCBs) are synthetic chemicals that were manufactured in the United States between 1929 and 1979. Due to their non-flammability, chemical stability, and electrical insulating properties, PCBs were used in many industrial and commercial applications including building materials (e.g. exterior paints, caulk and other joint materials, roofing, and siding) to improve flexibility, adhesion, and durability.

PCBs are persistent, bioaccumulative, and toxic (PBT) chemicals that are ubiquitous in the environment and are detected in water, air, soil, sediment, and animal tissue samples. PCBs bioaccumulate and are considered one of the most significant toxic chemicals in Puget Sound, impacting salmon populations and their predators, Southern Resident Killer Whales.

PCBs in building materials can be released into the environment during demolition and renovation, routine maintenance (such as cleaning and power washing), and contaminated site remediation. Although PCBs are continually released into the environment from exterior PCB-containing building materials exposed to weather, it's expected that PCBs are released 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).

Ecology's *PCB Chemical Action Plan* (Ecology, 2015b) recommended developing and promoting best management practices (BMPs) to address PCBs in building materials (both those in use and those slated for remodel or demolition) to reduce exposure to people and to prevent PCBs from entering stormwater. Ecology developed *How to Find and Address PCBs in Building Materials* (Ecology, 2024). *How to Find and Address PCBs in Building Materials* is guidance for property owners, developers, and contractors to help them identify, characterize, and abate PCB-containing building materials. *How to Find and Address PCBs in Building Materials* also describes BMPs to protect stormwater during demolition or renovation activities, or while properties are awaiting re-development.

Another resource that identifies Runoff Treatment BMPs for PCBs is *A BMP Tool Box For Reducing Polychlorinated Biphenyls (PCBs) and Mercury (Hg) in Municipal Stormwater* (SFEI, 2010).

1.1.7 Types of Best Management Practices (BMPs) for Stormwater Management

What are BMPs?

The method by which this manual controls the adverse impacts of development and redevelopment is through the application of Best Management Practices (BMPs).

BMPs are defined as schedules of activities, prohibitions of practices, maintenance procedures, and structural and/or managerial practices, that when used singly or in combination, prevent or reduce the release of pollutants and other adverse impacts to waters of Washington State.

The primary *purpose* of using BMPs is to protect beneficial uses of water resources by:

- reducing pollutant loads and concentrations,
- reducing discharges (volumetric flow rates) that cause stream channel erosion, and
- reducing deviations from natural hydrology.

The *quantifiable methods* that BMPs use to prevent or reduce the release of pollutants and other adverse impacts to waters of Washington State are:

- Flow Control: Flow Control refers to reducing (or controlling) the flow and duration of stormwater runoff.

- Runoff Treatment: Runoff Treatment refers to removing pollutants from stormwater runoff.
- Source Control: Source Control refers to preventing pollutants from entering stormwater runoff.

The *types* of BMPs that this manual refers to are:

- Flow Control BMPs
- Runoff Treatment BMPs
- LID BMPs
- Source Control BMPs
- Construction BMPs

If it is found that, after the implementation of BMPs advocated in this manual, beneficial uses are still threatened or impaired, then additional controls may be required. BMPs that involve construction of engineered structures are often referred to as facilities in this manual.

Note that some individual BMPs may behave as multiple BMP types. For example, depending on the site-specific design, Bioretention may act as both a Flow Control BMP and a Runoff Treatment BMP, and depending on installation size and location, may also act as an LID BMP.

Flow Control BMPs

Flow Control BMPs refer to BMPs that are installed for the purpose of reducing stormwater surface runoff flows and durations.

Flow Control BMPs are defined as drainage facilities designed to mitigate the impacts of increased surface and stormwater runoff flow rates generated by development. Flow Control BMPs are designed either to hold water for a considerable length of time and then release it by evaporation, plant transpiration, and/or infiltration into the ground, or to hold runoff for a short period of time, releasing it to the conveyance system at a controlled rate.

See the following sections for additional information on Flow Control BMPs:

- 6.1.3 Choosing Your Flow Control BMPs
- Chapter 6 - Runoff Treatment, Flow Control, and LID BMP Library

Runoff Treatment BMPs

Runoff Treatment BMPs refer to BMPs that are installed for the purpose of removing pollutants from stormwater runoff.

Runoff Treatment BMPs remove pollutants from stormwater runoff by simple gravity settling, centrifugal separation, filtration, biological uptake, and media or soil adsorption. The pollutants of concern include sand, silt, and other suspended solids; metals such as copper, lead, and zinc; nutrients (e.g., nitrogen and phosphorous); certain bacteria and viruses; and organics such as petroleum hydrocarbons and pesticides.

Ecology further classifies Runoff Treatment BMPs into the following categories:

- Pretreatment BMPs
- Oil Control BMPs
- Phosphorus Treatment BMPs
- Metals Treatment BMPs
- Basic Treatment BMPs

See the following sections for additional information on Runoff Treatment BMPs:

- 6.1.2 Choosing Your Runoff Treatment BMPs
- Chapter 6 - Runoff Treatment, Flow Control, and LID BMP Library

LID BMPs

LID (Low Impact Development) BMPs refer to BMPs that are installed for the purpose of mimicking the pre-disturbance hydrologic processes of infiltration, filtration, storage, evaporation and transpiration.

LID BMPs are defined as distributed stormwater management practices, integrated into a project design, that emphasize pre-disturbance hydrologic processes of infiltration, filtration, storage, evaporation and transpiration.

LID BMPs provide a combination of Runoff Treatment and/or Flow Control benefits, but are defined as their own "type" of BMP due to the additional hydrologic benefits they provide. Some of these additional benefits are difficult to model at an individual site level, but have been demonstrated to have a significant cumulative impact when distributed across large areas. The distributed nature is an important distinction of LID BMPs, and ensures that stormwater is mitigated near the location where it originates.

Source Control BMPs

Source Control BMPs refer to BMPs that are installed for the purpose of preventing pollution, or other adverse effects of stormwater, from occurring.

Source Control BMPs are defined as a structure or operation intended to prevent pollutants from coming into contact with stormwater through physical separation of areas or careful management of activities that are sources of pollutants.

It is generally more cost-effective to use Source Control BMPs to prevent pollutants from entering runoff, than to use Runoff Treatment BMPs to remove pollutants. However, since Source Control BMPs cannot prevent all impacts, some combination of measures will always be needed.

Ecology further classifies Source Control BMPs as operational or structural:

- Operational Source Control BMPs are *non-structural* practices that prevent or reduce pollutants from entering stormwater. Examples include formation of a pollution prevention team, good housekeeping practices, preventive maintenance procedures, spill prevention and cleanup, street sweeping, employee training, inspections of pollutant sources, and record keeping. They can also include process changes, raw material/product changes, and recycling wastes.

- Structural Source Control BMPs are *physical, structural, or mechanical* devices or facilities intended to prevent pollutants from entering stormwater. Examples include:
    - Enclosing and/or covering the pollutant source (e.g., within a building or other enclosure, a roof over storage and working areas, temporary tarp).
    - Physically segregating the pollutant source to prevent run-on of uncontaminated stormwater.
    - Devices that direct contaminated stormwater to appropriate treatment BMPs (e.g., discharge to a sanitary sewer if allowed by the local sewer authority).

See the following sections for additional information on Source Control BMPs:

- 8.1 Choosing Your Source Control BMPs
- Chapter 8 - Source Control

Construction Stormwater BMPs

Construction Stormwater BMPs refer to BMPs that are installed during the construction phase of a project to protect water quality. Ecology further classifies Construction Stormwater BMPs as Construction Source Control BMPs and Construction Runoff BMPs.

Construction Stormwater BMPs include treatment systems, operating procedures, and practices associated with construction activities to control:

- Stormwater
- Groundwater
- Spillage or leaks
- Sludge or waste disposal
- Drainage from raw material storage

Examples of Construction Stormwater BMPs include stabilized construction entrances, silt fences, check dams, and sediment traps.

See Chapter 7 - Construction Stormwater Pollution Prevention for additional information on Construction Stormwater BMPs.

1.1.8 Presumptive versus Demonstrative Approaches to Protecting Water Quality

Project proponents are often required to document the technical basis for their stormwater BMP designs. This includes:

- how stormwater BMPs were selected;
- the pollutant removal performance expected from the selected BMPs;

- the scientific basis, technical studies, and/or modeling which supports the performance claims for the selected BMPs; and
- an assessment of how the selected BMP will comply with State Water Quality Standards and satisfy State AKART requirements and Federal technology-based treatment requirements.

There are two approaches that a project proponent may use to document the technical basis for their stormwater BMP designs: the Presumptive approach and the Demonstrative approach. Both the Presumptive and Demonstrative approaches are based on using best available science to protect water quality.

The Presumptive Approach

Using the Presumptive approach, project proponents may use the methods described in this manual to choose and design their stormwater BMPs. This manual is intended to provide technically sound stormwater management practices which are presumed to protect water quality and instream habitat, and meet the environmental objectives of the regulations discussed in this Volume.

The Demonstrative Approach

Using the Demonstrative approach, project proponents may choose to not follow the practices in this manual, then demonstrate that the project will not adversely impact water quality by collecting and providing appropriate supporting data to show that the alternative approach is protective of water quality and satisfies State and federal water quality laws.

The Relationship Between the Presumptive and Demonstrative Approaches

Figure 1.2: Relation Between Environmental Science and Standards in Stormwater Regulations graphically depicts the relation between the Presumptive approach and the Demonstrative approach for achieving the environmental objectives of the standards. Both the Presumptive and Demonstrative approaches are based on best available science and result from existing Federal and State laws that require stormwater treatment systems to be properly designed, constructed, maintained and operated to:

1. Prevent pollution of state waters and protect water quality, including compliance with state Water Quality Standards.
2. Satisfy state requirements for all known available and reasonable methods of prevention, control and treatment (AKART) of wastes prior to discharge to waters of the State.
3. Satisfy the federal technology based treatment requirements under 40 CFR part 125.3.

Under the Demonstrative approach, the timeline and expectations for providing technical justification of stormwater management practices will depend on the complexity of the individual project and the nature of the receiving environment. In each case, the project proponent may be asked to document to the satisfaction of the permitting agency or other approval authority that the practices they have selected will result in compliance with the water quality protection requirements of the permit or other local, State, or Federal water-quality-based project approval condition. This approach may be more cost effective for large, complex or unusual types of projects.

Project proponents that choose to follow the stormwater management approaches contained in Ecology approved stormwater technical manuals are presumed to have satisfied this demonstration requirement and do not need to provide technical justification to support the selection of BMPs for the project. Following the stormwater management practices in this manual means adhering to the guidance provided for proper selection, design, construction, implementation, operation and maintenance of BMPs. Approved stormwater technical manuals for the Presumptive approach include this manual and other equivalent stormwater management guidance documents approved by Ecology. This approach will generally be more cost effective for typical development and redevelopment projects.

Figure 1.2: Relation Between Environmental Science and Standards in Stormwater Regulations

Standards

Water Pollution Control Act
(Chapter 90.48 RCW)

Discharges to state waters shall not cause pollution, which is defined as an alteration of the physical, chemical or biological properties of State waters which would impair beneficial uses. Requires the use of AKART and BMPs approved by Ecology.

Federal Clean Water Act

Restore and maintain the chemical, physical, and biological integrity of the Nation's waters.

- State water quality standards (water-quality based treatment requirements)
- Federal technology-based treatment requirements
- NPDES permits
- 303(d) impaired water body list and water clean-up plans

Others

Endangered Species Act
- Properly functioning conditions

Hydraulics Code (HPA)
Safe Drinking Water Act (UIC)

Presumptive Approach

The Stormwater Management Manual for Western Washington provides a default set of stormwater practices based on current science which satisfy State and Federal stormwater requirements.

Considerations:
- More predictable, practices are approved across jurisdictions
- Costly studies, etc. are not required as they may be under the demonstrative approach

Demonstrative Approach

Project sponsor and approval agency individually review and condition proposed projects to meet federal and state stormwater standards based on current science.

Considerations:
- Lacks predictability and can be very time consuming
- For large, complex projects may reduce costs and/or improve environmental protection

Science

Hydrology

- When native vegetation is removed and replaced with impervious surfaces (roads or buildings) there is an increase in stormwater runoff and other drastic alterations to the natural hydrology.
- Increased flows lead to increased flooding and stream bank and stream bed erosion.
- Unless mitigated, adverse high flow impacts occur at even low levels of urban development: 4% to 10% total impervious area.
- Transportation infrastructure (including parking areas) represents 50% and 75% of the impervious surface area within any single watershed.

Water Quality

- More than one-third of the State's urban streams, creeks, and embayments are impaired due to stormwater runoff.
- Stormwater runoff from construction activities can contain large amounts of sediments and suspended solids which are harmful to fish and other aquatic life.
- Untreated stormwater from roads and urban areas can adversely impact water quality due to sediments, toxic metals, pesticides, herbicides, oils and greases, and possible human pathogens including fecal coliform bacteria.
- Untreated stormwater runoff from roads and urban areas can be toxic to aquatic life including fish.

DEPARTMENT OF
ECOLOGY
State of Washington

Relation Between Environmental Science and Standards in Stormwater Regulations

Revised June 2016

1.2 Relationship of This Manual to Regulations and Programs

1.2.1 The Manual's Role as Technical Guidance

The *Stormwater Management Manual for Eastern Washington* (the SWMMEW, this manual) is not a regulation. This manual does not have any independent regulatory authority and it does not establish new environmental regulatory requirements. Its "Requirements" and BMPs become required through:

- Ordinances and rules established by the state and local governments; and
- Permits and other authorizations issued by local, state, and federal authorities.

Current law and regulations require the design, construction, operation, and maintenance of stormwater systems that prevent pollution of State waters. This manual is a guidance document that provides local governments, State and Federal agencies, developers, and project proponents with a stormwater management strategy to apply at the project level. If this strategy is implemented correctly, in most cases it should result in compliance with existing regulatory requirements for stormwater – including compliance with the Federal Clean Water Act, Federal Safe Drinking Water Act, and State Water Pollution Control Act.

This manual provides generic, technical guidance on measures to:

- prevent pollutants from coming into contact with stormwater,
- control the quantity and quality of stormwater runoff from construction sites, and
- control the quantity and quality of stormwater runoff from new development and redevelopment projects.

These measures are considered to be necessary to achieve compliance with State water quality standards and to contribute to the protection of the beneficial uses of the receiving waters (both surface and ground waters). Stormwater management techniques applied in accordance with this manual are presumed to meet the technology-based treatment requirement of State law to provide all known available and reasonable methods of treatment, prevention, and control (AKART; RCW 90.52.040, and RCW 90.48.010).

This technology-based treatment requirement does not excuse any discharge from the obligation to apply additional stormwater management practices as necessary to comply with State water quality standards. The State water quality standards include: Chapter 173-200 WAC, Water Quality Standards for Groundwaters of the State of Washington; Chapter 173-201A WAC, Water Quality Standards for Surface Waters of the State of Washington; and Chapter 173-204 WAC, Sediment Management Standards.

Following this manual is not the only way to properly manage stormwater runoff. A municipality may adopt, or a project proponent may choose to implement other methods to protect water quality; but in those cases, they assume the responsibility of providing technical justification that the chosen methods will protect water quality (see 1.1.8 Presumptive versus Demonstrative Approaches to Protecting Water Quality).

1.2.2 Applicable Federal and State Regulations

The federal Clean Water Act, the federal Safe Drinking Water Act, and the state Water Pollution Control Act (Chapter 90.48 RCW) are the primary federal and state regulations that directly apply to management of stormwater discharges. These laws are aimed at protecting water quality by controlling the amount of pollutants discharged to surface and ground waters. Other regulatory programs such as the federal Endangered Species Act and state Hydraulics Act also commonly require project proponents to properly manage stormwater to protect water quality and habitat.

1.2.3 AKART

What is AKART?

RCW 90.48.010 requires the use of "all known available and reasonable methods by industries and others to prevent and control the pollution of the waters of the state of Washington." This statutory requirement is generally known by the acronym AKART.

The Underground Injection Control Program, in WAC 173-218-030, further defines AKART as the most current methodology that can be reasonably required for preventing, controlling, or abating the pollutants associated with a discharge.

How Does AKART Relate to This Manual?

Per WAC 173-218-030, this manual may be used as a guideline, to the extent appropriate, for developing best management practices (BMPs) to apply AKART for stormwater discharges to Underground Injection Control wells.

New development and redevelopment sites can use this manual to select, design, document, install, and maintain stormwater BMPs to fulfill their statutory obligation to provide “all known available and reasonable methods by industries and others to prevent and control the pollution of the waters of the State of Washington".

1.2.4 Municipal Stormwater Permits

What are the Municipal Stormwater Permits?

Ecology issues the Municipal Stormwater Permits to regulate stormwater discharges from municipal separate storm sewer systems (MS4s). These permits are used to meet both federal and state requirements:

- The federal Clean Water Act made it unlawful to discharge pollutants, including stormwater, from a point source into waters of the U.S. unless a National Pollutant Discharge Elimination System (NPDES) permit is obtained. Ecology has authority delegated under the NPDES permit program by the Environmental Protection Agency (EPA), and is therefore in charge of administering the NPDES permits within Washington State.
- State requirements are in addition to the federal requirements, and require a State Waste Discharge Permit for disposal of waste material into "waters of the state," which include

rivers, lakes, streams, and all underground waters and aquifers. A State Waste Discharge Permit may be required for facilities that have stormwater runoff to surface waters.

To control discharges from MS4s, Ecology has combined the two permits described above into the Municipal Stormwater Permits. There are three Municipal Stormwater Permits in Washington state:

- Phase I (for medium and large MS4s)
- Western Washington Phase II (for smaller MS4s in western Washington)
- Eastern Washington Phase II (for smaller MS4s in eastern Washington)

The Municipal Stormwater Permits are programmatic, and detail what is required for a Permittee to be in compliance with the federal and state requirements. Topics (in general) include:

- Public education and outreach
- Public involvement and participation
- Illicit discharge detection and elimination
- Controlling runoff from new development, redevelopment, and construction sites
- Municipal operations and maintenance

For more information, or to view the Municipal Stormwater Permits, refer to the following website:

https://ecology.wa.gov/Regulations-Permits/Permits-certifications/Stormwater-general-permits/Municipal-stormwater-general-permits.

How do the Municipal Stormwater Permits Relate to This Manual?

The Municipal Stormwater Permits refer to this manual primarily for the site planning process, BMP selection, and design criteria for controlling runoff from new development, redevelopment, and construction sites. Permittees may use the methods described in this manual to meet some of their Permit requirements. If a Permittee chooses to deviate from the site planning process, BMP selection, or design criteria in this (or an Ecology approved equivalent) manual, they must demonstrate that their alternative will protect water quality, meet the federal statutory requirement to reduce pollutants to the maximum extent practicable (MEP), and satisfy the state requirement to apply all known, available, and reasonable methods of pollution control.

Chapter 2 - Core Elements for New Development and Redevelopment provides guidance for the requirements within Appendix 1 of the Eastern Washington Phase II Municipal Stormwater Permit.

Other subjects within the Municipal Stormwater Permits that this manual provides additional guidance for include:

- Operation and maintenance of BMPs
- Source control
- Comprehensive stormwater planning

1.2.5 Municipalities Not Subject to the Municipal Stormwater Permits

Who Are the Municipalities Not Subject to the Municipal Stormwater Permits?

As described in 1.2.4 Municipal Stormwater Permits, certain municipalities and other entities are required by state and federal law to be permitted under an Ecology Municipal Stormwater Permit. For a full list of Permittees under Ecology's Municipal Stormwater Permits, refer to the following website:

https://ecology.wa.gov/Regulations-Permits/Permits-certifications/Stormwater-general-permits/Municipal-stormwater-general-permits

This section is directed at those municipalities that are NOT listed at the website above. Because they are not required to have an Ecology Municipal Stormwater Permit, they are not required by state or federal law to adopt stormwater programs. However, UIC program requirements still apply if UIC wells are used to manage stormwater, whether a municipality is covered under a municipal stormwater permit or not.

How do the Municipalities Not Subject to the Municipal Stormwater Permits Relate to This Manual?

Ecology encourages municipalities not subject to Municipal Stormwater Permits to adopt stormwater programs. This would include adoption of ordinances, Core Elements, and BMPs equivalent to those in this manual.

1.2.6 Industrial Stormwater Permits

What are Industrial Stormwater Permits?

Ecology issues Industrial Stormwater Permits to regulate stormwater discharges from industrial facilities. The permits are used to meet both federal and state requirements:

- The federal Clean Water Act made it unlawful to discharge pollutants, including stormwater, from a point source into waters of the U.S. unless a National Pollutant Discharge Elimination System (NPDES) permit is obtained. Ecology has authority delegated under the NPDES permit program by the Environmental Protection Agency (EPA), and is therefore in charge of administering the NPDES permits within Washington State.
- State requirements are in addition to the federal requirements, and require a State Waste Discharge Permit for disposal of waste material into "waters of the state," which include rivers, lakes, streams, and all underground waters and aquifers. A State Waste Discharge Permit is also required for certain industrial users that discharge industrial waste into sanitary sewer systems. A State Waste Discharge Permit may be required for facilities that have stormwater runoff to surface waters.

To control discharges from industrial facilities, Ecology has combined the two permits described above into the Industrial Stormwater Permits. Ecology issues three types of Industrial Stormwater Permits:

- *Industrial Stormwater General Permit:* The Industrial Stormwater General Permit (ISGP) is a general permit written to apply to a range of industrial facilities of various types.
- *Industrial Stormwater Individual Permit:* An individual permit is a permit that is written for and issued to a specific facility. EPA regulations require that industries not covered under a general permit must apply for an individual stormwater permit.
- *Industry-Specific General Permit:* An industry-specific general permit is a permit that can apply to all industries of a similar type. Examples of industry-specific general permits that include stormwater are the Sand and Gravel General Permit and the Boatyard General Permit.

The development of an Industrial Stormwater Pollution Prevention Plan (SWPPP) by each facility is a key Industrial Stormwater Permit requirement. The Industrial SWPPP requirements include:

- Identifying the potential sources of pollutants that may contaminate stormwater.
- A description and implementation of operational and structural Source Control BMPs to reduce the stormwater pollutants and comply with the permit.

The Industrial Stormwater Permits also includes requirements for:

- Effluent limitations for certain types of industrial facilities, and certain discharges to 303(d) impaired waterbodies;
- Monitoring: All industrial facilities are required to conduct quarterly monitoring and sampling. There are additional monitoring requirements for certain, identified industry groups;
- Application of additional Source Control and Runoff Treatment BMPs to control pollutants further if certain "benchmark" levels of pollutants, as identified in the permit, are exceeded;
- Reporting and Recordkeeping;
- Operation and Maintenance

For more information, or to view the ISGP, refer to the following website:

http://www.ecy.wa.gov/programs/wq/stormwater/industrial/index.html.

How Do the Industrial Stormwater Permits Relate to This Manual?

The Industrial Stormwater Permits refer to this manual primarily for Best Management Practices (BMP) design criteria.

The ISGP requires Industrial SWPPPs to include certain mandatory BMPs, including those BMPs identified as "applicable" to specific industrial activities in Chapter 8 - Source Control of this manual. Industrial facilities with new development or redevelopment must also evaluate whether Flow Control and/or Runoff Treatment BMPs are necessary for compliance with Municipal

Stormwater Permit requirements. BMPs must be consistent with this manual, or other stormwater management guidance documents that are approved by Ecology and incorporated into the ISGP. Industrial facilities may also use alternative BMPs if their Industrial SWPPP includes documentation that the BMPs selected are demonstrably equivalent to practices contained in stormwater technical manuals approved by Ecology, including the proper selection, implementation, and maintenance of all applicable and appropriate best management practices for on-site pollution control.

ISGP facilities are required to update their Industrial SWPPPs and perform corrective actions if stormwater monitoring results exceed “benchmark” or indicator values. Facilities that trigger corrective actions under the ISGP, or otherwise need to update their SWPPP, should consider:

1. “Recommended” operational and structural Source Control BMPs listed in Chapter 8 - Source Control.
2. Runoff Treatment BMPs listed in Chapter 6 - Runoff Treatment, Flow Control, and LID BMP Library.
3. Erosion and sediment control BMPs listed in Chapter 7 - Construction Stormwater Pollution Prevention (e.g., if turbidity, sediment, or associated pollutants need to be addressed).
4. Manufactured Treatment Devices that have been evaluated through Ecology’s TAPE or C-TAPE program.
5. BMPs that are “demonstrably equivalent”, as defined by the ISGP.

1.2.7 Construction Stormwater General Permit

What is the Construction Stormwater General Permit?

Ecology issues the Construction Stormwater General Permit (CSWGP) to regulate stormwater discharges from construction activities. This permit is used to meet both federal and state requirements:

- The federal Clean Water Act made it unlawful to discharge pollutants, including stormwater, from a point source into waters of the U.S. unless a National Pollutant Discharge Elimination System (NPDES) permit is obtained. Ecology has authority delegated under the NPDES permit program by the Environmental Protection Agency (EPA), and is therefore in charge of administering the NPDES permits within Washington State.
- State requirements are in addition to the federal requirements, and require a State Waste Discharge Permit for disposal of waste material into "waters of the state," which include rivers, lakes, streams, and all underground waters and aquifers. A State Waste Discharge Permit may be required for facilities that have stormwater runoff to surface waters.

To control discharges from construction activities in Washington State, Ecology has combined the two permits described above into the Construction Stormwater General Permit.

The CSWGP requires application of stabilization and structural practices to reduce the potential for erosion and the discharge of sediments from the site. Coverage under the CSWGP is generally required for any clearing, grading, or excavating if the project site discharges:

- Stormwater from the site into surface water(s) State, or
- Into storm drainage systems that discharge to a surface water(s) of the State.

  And

- Disturbs one or more acres of land area (including off-site disturbance acreage as authorized by the permit), or
- Disturb less than one acre of land area, if the project or activity is part of a larger common plan of development or sale.

Any construction activity discharging stormwater that Ecology determines to be a significant contributor of pollutants to waters of the State may also require permit coverage, regardless of project size, at the discretion of the agency.

For more information or to view the Construction Stormwater General Permit refer to the following website:

http://www.ecy.wa.gov/programs/wq/stormwater/construction/index.html.

How does the Construction Stormwater General Permit Relate to This Manual?

Two essential requirements within the CSWGP are the design and implementation of Construction Stormwater BMPs, and preparation and execution of Construction Stormwater Pollution Prevention Plans (SWPPPs). This manual provides guidance that may be used for both of those requirements in Chapter 7 - Construction Stormwater Pollution Prevention.

1.2.8 Underground Injection Control (UIC) Program

What is the UIC Program?

One of the provisions of the federal Safe Drinking Water Act is to protect underground sources of drinking water (USDW). In 1984, the Washington State Department of Ecology (Ecology) received authority from the United States Environmental Protection Agency (EPA) to administer Part C of the federal Safe Drinking Water Act (42 U.S.C Sec. 300 (h) et. Seq.) to protect the resources and environment of the state (see RCW 43.21A.445).

The Underground Injection Control (UIC) Program received authority to regulate the discharges of nonhazardous fluids into the subsurface by UIC wells.

Ecology adopted Chapter 173-218 WAC to implement the program; however, the UIC program rule protects all groundwater, not just USDW. The EPA organizes UIC wells into six classes. The Ecology UIC Program regulates Class II, Class III, Class IV (under CERCLA), and Class V on Washington state lands, except for UIC wells located on tribal land. UIC wells used to manage stormwater are considered Class V wells. For more information, visit Ecology's web page for the UIC Program at the following web address:

https://ecology.wa.gov/Regulations-Permits/Guidance-technical-assistance/Underground-injection-control-program

The UIC Program has two requirements:

1. The nonendangerment standard of WAC 173-218-080 must be met at all times, prohibiting discharges that allow movement of fluids containing contaminants to reach the groundwater.
2. All UIC facility owners/operators must register their UIC well(s) using Ecology's online registration application that can be found at the following web address:

   https://ecology.wa.gov/Regulations-Permits/Guidance-technical-assistance/Underground-injection-control-program/Register-UIC-wells-online

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:

1. A bored, a drilled or driven shaft, or an excavated hole whose depth is greater than the largest surface dimension; or
2. An excavated hole whose depth is greater than the largest surface dimension, or
3. An improved sinkhole; which is a natural crevice or depression with no surface drainage that has been modified by humans to receive stormwater , or
4. 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.

Examples of UIC wells (or subsurface infiltration systems) are the following:

1. Drywells
2. Drain Fields
3. Infiltration trenches with perforated pipe
4. Stormwater infiltration chambers or galleries with the intent to infiltrate stormwater
5. French drains that are designed in part to discharge surface water into the ground
6. Bioretention systems intending to infiltrate water from a perforated pipe below the treatment soil
7. Other similar devices that discharge into the ground

The following are not UIC wells:

- Buried pipe and/or tile networks that serve to collect water and discharge that water to a drainage system or to a receiving surface water
- Surface infiltration basins and flow dispersion stormwater facilities
- Infiltration trenches designed without perforated pipe or a similar mechanism
- Bioretention systems transporting water via a perforated pipe to a closed drainage system or to a receiving surface water

When stormwater is discharged into the ground via one of the UIC wells described above, that well is classified as a Class V injection well and must comply with Ecology's UIC rule.

The UIC rule (Chapter 173-218 WAC) applies to all Class V UIC wells that receive stormwater discharges. These wells must be sited, designed, constructed, managed, operated, and maintained according to the requirements of the UIC rule.

If all stormwater runoff from the project site discharges to a Class V UIC well, the discharge is regulated by the UIC rule, not by the Municipal Stormwater Permit, and the Core Elements for new development and redevelopment do not apply. A UIC well is singular and distinct, along with its associated BMPs, and are regulated separately from a stormwater discharge system, permitted or not. See Chapter 5 - UIC Program Guidelines for details on the rules, registration requirements, regulations, nonendangerment standard, treatment requirements, and operation and maintenance guidelines for UIC wells.

Ecology considers “all stormwater runoff” to mean thatcalculations show that the 100-yr, 3-hr storm OR the 100-yr, 72-hr storm, whichever is larger, is fully infiltrated. This allows for the possibility that a storm event larger than used in the calculations could occur and water could bypass the UIC and discharge to the MS4.

How Does the UIC Program Relate to This Manual?

This manual presents several BMPs to infiltrate stormwater (see 6.5 Infiltration BMPs). If the project design includes an infiltration BMP that is classified as a UIC well by the UIC Program, that BMP design must be in compliance with the UIC Program requirements and any other applicable regulatory requirements.

Ecology's UIC Program refers designers to this manual (or other approved Stormwater Manuals) for design guidance for infiltration BMPs and Source Control BMPs, as well as for determining the level of Runoff Treatment that is required prior to infiltrating stormwater. Chapter 5 - UIC Program Guidelines provides further guidance on complying with the UIC Program.

1.2.9 Endangered Species Act

What is the Endangered Species Act?

The Endangered Species Act (ESA) is a federal law that provides for the conservation of threatened and endangered plants and animals and the habitats in which they are found. The lead federal agencies for implementing the ESA are the U.S. Fish and Wildlife Service (FWS) and the National Marine Fisheries Service, National Oceanic and Atmospheric Administration (NOAA Fisheries Service). The FWS maintains a list of domestic and foreign endangered species. Species include birds, insects, fish, reptiles, mammals, crustaceans, flowers, grasses, and trees.

The law requires federal agencies, in consultation with the FWS and/or the NOAA Fisheries Service, to ensure that actions they authorize, fund, or carry out are not likely to jeopardize the continued existence of any listed species or result in the destruction or adverse modification of designated critical habitat of such species. The law also prohibits any action that causes a "taking" of any listed species of endangered fish or wildlife. The prohibition against “taking” a listed species includes destruction of critical habitat.

For more information, or to view the Endangered Species Act in its entirety, refer to the following website:

https://www.fws.gov/endangered/laws-policies/.

How Does the Endangered Species Act Relate to This Manual?

Although the ESA does not directly refer to this manual, project proponents may find the guidance and methods advocated in this manual useful to minimize the impacts from their projects, resulting in the project not "taking" a listed species.

Potential impacts that may be minimized by using the guidance in this manual include discharges containing sediment, turbidity, or abnormal pH. Specific adverse impacts include:

- Suffocation of eggs or fry.
- Displacement and elimination of aquatic invertebrates used for food.
- Reduction in the biodiversity of aquatic invertebrates.
- Reduction of foraging abilities in turbid water.
- Irritation of gill tissue that can lead to disease or death.
- Filling of resting or feeding areas, or spawning gravels with sediment.

The stranding of listed species behind erosion and sediment control features or the impairment of their access into certain areas due to the presence of erosion and sediment control features could also be determined to be a take under ESA.

1.2.10 Section 401 Water Quality Certifications

What is a Section 401 Water Quality Certification?

Section 401 of the federal Clean Water Act (CWA) requires project proponents applying for a federal license or permit for a project that may result in discharge into waters of the United States to submit a 401 Water Quality Certification to the certifying authority. The Department of Ecology has the authority in Washington to review and approve, approve with conditions, or deny proposed projects, actions, and/or activities with discharges into waters of the United States. Tribal governments and the EPA have this authority for tribal and non-state lands.

The 401 Water Quality Certification is issued by the certifying authority after evaluating the proposed project and determining that the project will meet state water quality standards, coastal resource protection requirements, fish and wildlife habitat standards, and other applicable regulations. Examples of federal permit applications that require a 401 Water Quality Certification are:

- a US Army Corps of Engineers (USACE) Section 404 Permit: Regulates the discharge of dredged or fill material into waters of the United States, including wetlands. Activities in waters of the United States regulated under this permit include fill for development, water resource projects (such as dams and levees), infrastructure development (such as highways and airports) and mining projects. A Section 404 Permit is required before dredged or fill material may be discharged into waters of the United States, unless the activity is exempt from Section 404 regulation (e.g. certain farming and forestry activities). See 1.2.11 Section 404 Permits for more information.

- a Federal Energy Regulatory Commission (FERC) License or Permit: FERC issues licenses and permits for hydropower projects and pipelines. For example, a license for a non-federal dam owner to use public waters for energy generation, or a permit to construct a pipeline. FERC licenses and permits specify the conditions for construction, operation, and maintenance of the project. When final, a license or permit is enforceable by FERC.

- a Section 402 NPDES Permit issued by the EPA in Washington State: These can be individual or general NPDES permits issued by the U.S. EPA within a state. Examples include a municipal separate storm sewer system (MS4) permit on a military base, federally operated dams on the Snake and Columbia Rivers, and tribal governments operating wastewater treatment plants on tribal land.

Project review is often a collaborative process between Ecology, the permitting federal agency, and the project proponent.

For more information, refer to the following website:

https://ecology.wa.gov/401

How Does a Section 401 Water Quality Certification Relate to This Manual?

For projects that require a Section 401 Water Quality Certification, Ecology must determine that the proposed project will not violate State water quality standards. In order to make such a determination, Ecology may do a more specific review of the potential impacts of stormwater discharges from both the construction phase of the project and the completed project. As a result of that review, Ecology may condition the 401 Water Quality Certification to require:

- Application of the Core Elements and BMPs in this manual; and/or

- Application of more stringent requirements.

1.2.11 Section 404 Permits

What is a Section 404 Permit?

Section 404 of the Clean Water Act establishes a program to regulate the discharge of dredged or fill material into waters of the United States, including wetlands. Activities in waters of the United States regulated under this program include fill for development, water resource projects (such as dams and levees), infrastructure development (such as highways and airports), and mining projects.

For Section 404 Permits, the U.S. Army Corps of Engineers (USACE) reviews a proposed project to determine if an individual Section 404 Permit is required, or if the project can be authorized under a Nationwide Permit. Nationwide Permits are general permits that cover a number of specific activities and allow for a streamlined process. Both Section 404 Permits and Nationwide

Permits also need Section 401 Certification from Ecology (see 1.2.10 Section 401 Water Quality Certifications).

For more information, refer to the following website:

https://www.epa.gov/cwa-404/permit-program-under-cwa-section-404

How Does a Section 404 Permit Relate to This Manual?

The USACE may require a project applying for a Section 404 Permit to implement one or more of the following, as a condition of the Section 404 Permit approval.

- The Core Elements and BMPs in this manual; and/or
- More stringent requirements.

1.2.12 Water Quality Standards

What are Water Quality Standards?

Water quality standards are provisions that describe the desired condition of a waterbody or the level of protection mandated to achieve the desired condition. These standards form a legal basis for controlling pollution entering receiving waters from a variety of sources (e.g., industrial facilities, wastewater treatment plants, and storm sewers).

Water Quality Standards consist of the following:

- Designated uses of the waterbody. The designated use specifies the goals and expectations for how each water body is used. Typical designated uses include:
    - Protection and propagation of fish, shellfish, and wildlife
    - Recreation
    - Public drinking water supply
    - Agricultural, industrial, navigational, and other purposes.
- Criteria to protect designated uses. Water quality criteria can be numeric (e.g., the maximum pollutant concentration levels permitted in a waterbody) or narrative (e.g., a criteria that describes the desired conditions of a waterbody being “free from” certain negative conditions).
- Antidegradation requirements to protect existing uses and high quality waters. One of the principal objectives of the Clean Water Act is to “maintain the chemical, physical and biological integrity of the Nation's waters.” Antidegradation requirements provide a framework for maintaining and protecting water quality that has already been achieved.

  Designated uses and water quality criteria are the primary tools used to achieve the objectives and goals of the Clean Water Act, and antidegradation requirements complement these tools by providing a framework for maintaining existing uses, for protecting waters that are of a higher quality than necessary to support the Clean Water Act goals, and for protecting waters identified by states and authorized tribes as Outstanding National Resource Waters (ONRWs).

- General policies to address implementation issues.

For more information or to view Washington State's Water Quality Standards, refer to the following WACs:

- Water Quality Standards for discharges to surface water: Chapter 173-201A WAC
- Water Quality Standards for discharges to groundwater: Chapter 173-200 WAC

How Do Water Quality Standards Relate to This Manual?

Many Ecology-issued permits and programs refer to Water Quality Standards when describing how to determine if a project is in compliance with the permit or program. Project proponents often use the BMPs detailed in this manual to gain compliance.

General stormwater permittees are given a presumption of compliance with Water Quality Standards if they meet all permit conditions and fully implement all applicable and appropriate on-site pollution control BMPs as contained in, or demonstrably equivalent to practices contained in, this manual. Demonstrated site specific discharge violations remove the presumption of compliance.

1.2.13 Hydraulic Project Approvals

What Are Hydraulic Project Approvals?

Since 1943, anyone planning certain construction projects or activities in or near state waters has been required to obtain a Hydraulic Project Approval (HPA) permit. The Washington Department of Fish and Wildlife (WDFW) administers the HPA program under Chapter 77.55 RCW and regulations under Chapter 220-660 WAC, which was specifically designed to protect fish life. WDFW issues thousands of HPAs each year for activities including work on bulkheads, piers, docks, culverts, bridges, and sediment dredging projects.

WDFW Habitat Biologists are available to assist with the application process.

For more information, refer to the following website:

http://wdfw.wa.gov/licensing/hpa/.

How Do Hydraulic Project Approvals Relate to This Manual?

An HPA may be required for stormwater discharges related to a project that may alter the natural flow or bed of state waters.

In order to minimize the impacts from stormwater discharges from these projects, WDFW may require:

- Compliance with the provisions of this manual; or
- Application of more stringent requirements that they determine are necessary to meet their statutory obligations to protect fish and their aquatic habitat.

1.2.14 Aquatic Use Authorizations

What are Aquatic Use Authorizations?

State-owned aquatic lands are managed by the Washington State Department of Natural Resources (DNR) under authority of RCW 79.105-79.140, and in accordance with Chapter 332-30 WAC for the benefit of the citizens Washington State. These public lands lie beneath our state's navigable waters and include tidelands and bedlands of marine waters, and shorelands and bedlands of lakes and rivers. They were set aside for us at statehood and, to this day, DNR manages them to preserve their environmental integrity that is linked to our quality of life. Projects taking place on or over state-owned aquatic lands require an Aquatic Use Authorization from DNR.

Project proponents apply for an Aquatic Use Authorization by submitting the online Joint Aquatic Resources Permit Application (JARPA) and Attachment E: Aquatic Use Authorization on DNR-managed Aquatic Lands. The Governor's Office for Regulatory Innovation and Assistance has built an online form to accept both JARPA and HPA applications, see https://www.epermitting.wa.gov/.

On the JARPA, DNR will work with applicants to determine:

- If the project will be located on state-owned aquatic lands,
- If the land is available,
- If the proposed use is appropriate, and
- How to construct the project to avoid or lessen impacts to aquatic resources.

DNR's Aquatic Resources Program is unique, acting as a landlord on behalf of the state. DNR will work with the project proponent on the details of the authorization document, which includes determining the type and terms of the use authorization. Examples of types of authorizations include licenses, leases, rights-of-entry, or easements. Examples of terms include amount of rent, survey requirements, insurance, performance security and other site-specific conditions that apply to the proposal.

For more information, refer to the following website:

https://www.dnr.wa.gov/programs-and-services/aquatics/leasing-and-land-transactions.

How Do Aquatic Use Authorizations Relate to This Manual?

A valid Aquatic Use Authorization is required for stormwater outfalls, pipes, and associated infrastructure located on state-owned aquatic lands. The terms of the Aquatic Use Authorization may require:

- Compliance with the provisions of this manual; or
- Application of more stringent requirements that DNR determines are necessary to meet their statutory obligations to protect the quality of state-owned aquatic lands and attached or embedded resources.

1.2.15 Total Maximum Daily Loads (TMDLs)

What are Total Maximum Daily Loads?

Under section 303(d) of the Clean Water Act, states, territories and authorized tribes, collectively referred to in the act as "states," are required to develop lists of impaired waters. These are waters for which technology-based regulations and other required controls are not stringent enough to meet the Water Quality Standards set by states. The law requires that states establish priority rankings for waters on the lists and develop Total Maximum Daily Loads (TMDLs) for these waters.

A TMDL is the calculation of the maximum amount of a pollutant allowed to enter a waterbody so that the waterbody will meet and continue to meet Water Quality Standards for that particular pollutant. A TMDL determines a pollutant reduction target and allocates load reductions necessary to the source(s) of the pollutant.

The objective of a TMDL is to determine the loading capacity of the waterbody, and to allocate that load among different pollutant sources so that the appropriate control actions can be taken and Water Quality Standards achieved. The TMDL process is important for improving water quality because it serves as a link in the chain between Water Quality Standards and implementation of control actions designed to attain those standards.

For more information, refer to the following website:

https://ecology.wa.gov/Water-Shorelines/Water-quality/Water-improvement/Total-Maximum-Daily-Load-process

How Do Total Maximum Daily Loads Relate to This Manual?

Requirements described in this manual can be superseded or added to through the adoption of actions and requirements identified in a TMDL. However, it is likely that at least some TMDLs will require use of BMPs in this manual.

1.2.16 Other Regulations and Programs

This section contains information on regulatory requirements not covered earlier in this chapter that may affect a project proponent's stormwater management design and/or implementation. The information contained herein is not all-encompassing of every regulatory requirement that might apply to a project, but is intended to help project proponents be aware of other requirements that may impact their project.

Local Jurisdiction Requirements

Local jurisdictions have the option of applying more stringent requirements than those in this manual. Project proponents should always check with the local jurisdiction to determine the stormwater requirements that apply to their project.

Jurisdictions may have interconnected systems. Neighboring jurisdictions are encouraged to work together to establish consistent design criteria for stormwater facilities since the climatic, geologic, and hydrologic variation among neighboring jurisdictions is likely to be minimal.

Growth Management Act

The Growth Management Act (GMA) requires local governments to ensure that planned growth and development occurs in a manner which properly manages stormwater and protects critical areas and water resources. New development and redevelopment codes based on this manual, or equivalent, may be a way for municipalities to demonstrate GMA compliance.

Requirements for Stormwater Discharges to Public Sanitary Sewers, Septic Systems, Dead-End Sumps, and Industrial Waste Treatment Systems

Stormwater Discharges to Sanitary Sewers

Discharging stormwater to a public sanitary sewer is normally prohibited, as this tends to overload the sewage treatment plant during storm events when flows are already high. Direct discharge of relatively uncontaminated or treated stormwater to the receiving water typically poses less of a threat to the environment than the pass through of solids that may occur at the sewage treatment plant during storm events, if the stormwater discharged to the sanitary sewer. Stormwater discharge to the sanitary sewer requires the approval of the local Sewer Authority if Ecology has delegated the authority to set pretreatment requirements. If the Sewer Authority has not received such authority, the business or public agency that wishes to discharge stormwater to the sanitary sewer must apply for a State Waste Discharge Permit.

In setting pretreatment requirements, the local Sewer Authority or Ecology must operate within state regulations (Chapter 173-216 WAC – State Waste Water Discharge Permit Program) which in turn must comply with federal regulations (40 CFR Part 403.5 – National Pretreatment). These regulations specifically prohibit discharge of the following:

- Any materials that pass through the municipal treatment plant untreated or interfere with its operation.
- Any materials that create a fire or explosion hazard, including, but not limited to, waste-streams with a closed cup flash point of less than 140 degrees Fahrenheit or 60 degrees Centigrade using the test methods specified in 40 CFR 261.21.
- Any materials that will cause corrosive structural damage to the Publicly Owned Treatment Works (POTW), but in no case discharges with pH lower than 5.0, or greater than 11, unless the works is specifically designed to accommodate such discharges; and the discharge authorized by a permit issued under Chapter 173-216 WAC. (See WAC 173-216-060 (2) (iv)).
- Solid or viscous pollutants in amounts that will cause obstruction to the flow in the POTW resulting in interference.
- Heat in amounts that will inhibit biological activity in the POTW resulting in interference, but in no case heat in such quantities that the temperature at the POTW Treatment Plant exceeds 40 degrees Centigrade (104 degrees Fahrenheit) unless the system is specifically designed to accommodate such discharge, and the discharge is authorized by a permit under Chapter 173-216 WAC. (See WAC 173-216-060 (2) (v)).

- Petroleum oil, nonbiodegradable cutting oil or products of mineral oil origin in amounts that will cause interference or pass through the treatment plant.
- Pollutants that result in the presence of toxic gases, vapors, or fumes within the POTW in a quantity that may cause acute worker health and safety problems.
- Any trucked or hauled pollutants, except at discharge points designated by the POTW.
- Any discharge which would violate the dangerous waste regulations, Chapter 173-303 WAC (see WAC 173-216-060(1)).
- Any of the following discharges, unless approved by the department under extraordinary circumstances, such as lack of direct discharge alternatives due to combined sewer service or need to augment sewage flows due to septic conditions: (WAC 173-216-060(2)(vii)):
    - Noncontact cooling water in significant volumes.
    - Stormwater, and other direct inflow sources.
    - Wastewater significantly affecting system hydraulic loading, which do not require treatment or would not be afforded a significant degree of treatment by the system.

Discharges of stormwater authorized under Chapter 173-216 WAC, typically limit flows entering the sanitary sewer based on the available hydraulic capacity of the collection system or the treatment plant by the combined flow of sanitary sewage and stormwater. The allowable concentrations of particular materials such as metals and grease vary with the particular sewer system. Discharges must comply with all local government limits. The project proponent must contact both the POTW and the regional water quality program to find out what discharge limits apply to a particular sewerage system.

Stormwater Discharges to an Industrial Waste Treatment System

The operator(s) of the industrial waste treatment system may treat the polluted stormwater, depending on the NPDES permit constraints for the particular industrial waste treatment system.

Stormwater Discharges to Dead-end Sumps

Do not discharge substances that cause a violation of water quality standards to a septic system, surface water, or groundwater. If a sanitary or industrial wastewater treatment system is not available, an alternative is the use of a dead-end sump. Sumps are tanks with drains that can be periodically pumped for appropriate disposal. Depending on the composition of the waste, it may or may not be considered Dangerous Waste.

Uniform Fire Code Requirements

Storage of flammable, ignitable, and reactive chemicals and materials must comply with the stricter of local zoning codes, local fire codes, the Uniform Fire Code, Uniform Fire Code standards or the National Electric Code.

Ecology Requirements for Generators of Dangerous Wastes

The State's Dangerous Waste Regulations (Chapter 173-303 WAC) cover accumulation, storage, transportation, treatment and disposal of dangerous wastes. Of interest to this manual are those businesses or public agencies that accumulate the waste at their building until taken from the site by a contract hauler.

For more information on applicable requirements for dangerous wastes, contact Ecology's Hazardous Waste and Toxics Reduction Program.

Standards for Solid Waste Containers

Standards for solid waste containers are identified in WAC 173-350-300, On-site Storage, Collection, and Transportation Standards.

Coast Guard Requirements for Marine Transfer of Petroleum Products

Federal regulations 33 CFR Parts 153, 154 and 155 cover, respectively, general requirements on spill response, spill prevention at marine transfer facilities, and spill prevention for vessels. These regulations specify technical requirements for transfer hoses, loading arms, closure, and monitoring devices. The regulations also cover small discharge containment; they require the use of "fixed catchments, curbing, and other fixed means" at each hose handling and loading arm area and each hose connection manifold area.

The regulations also require an operations plan and specify its general contents. The plan shall describe the responsibilities of personnel, nature of the facility, hours of operation, sizes and numbers of vessels using the facility, nature of the cargo, procedures if spills occur, and petroleum transfer procedures. The plan must also include a description and location of equipment for monitoring, containment, and fire fighting.

See also *NFPA 30A: Code for Motor Fuel Dispensing Facilities and Repair Garages* (NFPA, 2012).

Washington State/Federal Emergency Spill Cleanup Requirements

Washington State Requirements

The Oil and Hazardous Substance Spills Act of 1990 and the Oil Spill Prevention and Response Act of 1991 (Chapter 90.56 RCW) authorized Ecology to develop effective oil spill response regulations.

The Facility Contingency Plan and Response Contractor Standards (Chapter 173-182 WAC)

This Ecology regulation applies to all oil handling facilities (including pipelines) that are on or near navigable waters and transfer bulk oil by tank, ship, or pipeline. It contains the following elements:

- Standards for contingency plan content
- Procedures to determine the adequacy of contingency plans

- Requirements for periodic review
- Standards for cleanup and containment contractors

The Facility Oil Handling Standards (Chapter 173-180 WAC) establish minimum standards for safe oil transfer operation to meet a zero spill goal using scalable efforts that emphasize oil spill prevention, minimize human and operator errors, limit size of potential spills, and facilitate coordinated planning of local, state, regional and tribal communities.

In accordance with WAC 173-303-350 of Ecology's Dangerous Waste Regulations, generators of dangerous wastes must have a Contingency Plan that includes:

- Actions to be taken in the event of spill
- Descriptions of arrangements with local agencies
- The name of the owner's Emergency Coordinator
- A list of emergency equipment available
- An evaluation plan for business personnel

For more information on disposal requirements for solid and dangerous wastes, contact Ecology's Hazardous Waste and Toxics Reduction Program.

Federal Requirements

The Oil Pollution Act of 1990 (33 U.S.C. 2701-2761) amended the Clean Water Act and addressed the wide range of problems associated with preventing, responding to, and paying for oil pollution incidents in navigable waters of the United States. It created a comprehensive prevention, response, liability, and compensation regime to deal with vessel and facility caused oil pollution to navigable waters.

Spill Prevention Control and Countermeasure (SPCC) Plans

Federal Regulations require that owners or operators of facilities engaged in drilling, producing, gathering, storing, processing, refining, transferring, or consuming oil and oil products have a Spill Prevention and Control Plan (SPCC) if the facility has:

- an aggregate capacity greater than 1,320 gallons, or
- a total below-ground capacity in excess of 42,000 gallons.

WSDA Pesticide Regulations

The Washington State Department of Agriculture (WSDA) administers pesticide laws under the Washington Pesticide Control Act (Chapter 15.58 RCW) and Washington Pesticide Application Act (Chapter 17.21 RCW), and regulations under Chapter 16-228 WAC. The requirements relevant to water quality protection include:

- All aquatic labeled pesticides are 'restricted use' which requires a license for purchase or application. A WSDA license (https://agr.wa.gov/services/licenses-permits-and-certificates/pesticide-license-and-recertification/pesticide-and-spi-licensing) is required for persons who apply pesticides from concentrates and bulk materials unless under direct on-site supervision by a licensed applicator. A pesticide license is not required in the following examples for application of pesticide products available from retail locations:
    - People using commonly available ready-to-use pesticide products on their own or their employer's property.
    - Grounds maintenance people using only commonly available ready-to-use pesticide products on an occasional basis not amounting to a regular occupation.
    - Governmental employees who apply commonly available ready-to-use pesticide products pesticides without utilizing any kind of motorized or pressurized apparatus.
- Licensed applicators must undergo continuing education to keep their license.
- No person shall pollute streams, lakes, or other water supplies while loading, mixing or applying pesticides.
- No person shall transport, handle, store, load, apply, or dispose of any pesticide, pesticide container, or apparatus in such a manner as to pollute water supplies or waterways, or cause damage or injury to land, including humans, desirable plants, and animals.
- All pesticide applications shall be made in accordance with the Federal Insecticide, Fungicide, and Rodenticide Act product label.

For more information on pesticide application and disposal requirements, the following publications may be useful:

Suspended, Canceled and Restricted Pesticides (USEPA, 1985)

Best Management Practices for Agricultural Chemicals (Ecology, 2005)

Focus on Pesticide Containment Areas - Reducing and Managing Wastes from Pesticide Containment Areas (Ecology, 2010)

Spill Reporting and Cleanup in Washington State: A Guide for Pesticide Secondary Containment (Ecology, 1994)

Focus on Dangerous Waste - Safe Handling of Empty Containers (Ecology, 2016d)

Step by Step Fact Sheet for Hazardous Waste Generators (Ecology, 2003)

Air Quality Regulations

Regulation of air pollutant emissions in Washington is controlled by seven local air pollution control agencies, three Ecology regional offices and two Ecology programs (Central Program's Industrial Section, and Nuclear and Mixed Waste Program). All of the local air pollution agencies and the regional offices enforce local, state and federal air pollution regulations. The Industrial Section of Ecology's Central Program enforces state and federal air pollution regulations at chemical pulp mills and aluminum reduction facilities. The Nuclear and Mixed Waste Program enforces state and federal air pollution regulation on the Hanford Nuclear Reservation.

Whether it is to control the generation of fugitive emissions or point source (smoke stack) emissions, new and existing sources of air pollutants must comply with the requirements contained in their air pollution permits, regulatory orders, and local, state, and federal air pollution regulations. This will minimize the effects of each facility's emissions on stormwater.

Fugitive Particulate Matter Emissions

The local and state air pollution control agencies require that all reasonable precautions be taken to prevent fugitive particulate matter (windblown dust) from becoming airborne when handling, loading, transporting, and storing particulate material. Particulate materials of concern can include grain and grain dust, saw dust, coal, gravel, crushed rock, cement, and boiler fly ash.

Some of the local authorities take the general requirement to control fugitive emissions further. For example, the Puget Sound and Benton County Air Pollution Control Agencies have defined what "reasonable precautions" means for various dust causing activities in their jurisdictions.

Some actions that have been defined as "reasonable precautions" to prevent fugitive particulate emissions include:

- paving of parking and storage areas,
- minimizing the area of land that has been cleared for a housing development,
- various housekeeping activities (such as sweeping paved areas),
- minimization of the accumulation of mud and dust,
- preventing mud and dust from being tracked onto public roads, and
- stabilization of material piles and open, cleared land areas with water sprays, chemical stabilizers or other means that minimize dust generation.

All air authorities require sand blasting and spray painting activities be performed indoors with proper air pollution controls in use or, if that is not possible, out of doors but within acceptable, temporary enclosures.

Gaseous Air Pollutant Emissions

Gaseous air pollutants are controlled at the point of origin through add-on emission controls or pollution prevention measures. Each emission point at a plant generally has emission limits that must be complied with.

Sources of gaseous air pollutants can include petroleum storage tank breather and pressure release systems, combustion units (boilers and heaters), commercial printers, can manufacturers, steel mills, pulp and paper plants, auto body repair shops, etc. Examples of gaseous air pollutants that can be emitted include acetone, methylene chloride, styrene, nitrogen oxides, benzene, carbon monoxide, alcohol, organic sulfides and petroleum, and chlorinated solvents.

Some gaseous pollutants can be washed out of the air during rainstorms and enter stormwater. Others are photochemically degraded or converted in the air to other compounds that can be removed by rainfall or by settling on the ground. Gaseous air pollutants such as sulfur dioxide react in the air to generate acidic particulate matter. These particulates are usually removed from the atmosphere by settling out or being washed out of the air. In the case of sulfur oxides, this removal usually occurs at some distance (tens to hundreds of miles) from the facility that emitted the pollutant.

Ecology Waste Reduction Program

The 1990 Hazardous Waste Reduction Act, Chapter 70.95C RCW, established a goal to reduce dangerous waste generation by 50 percent. The primary means for achieving this goal is through implementation of a pollution prevention-planning program, also established in the Act. Facilities that generate in excess of 2,640 pounds of dangerous waste per year, or who are required to report under the Toxic Release Inventory (TRI) of Title III of the Superfund Amendments and Reauthorization Act (SARA), are subject to this law. Some 650 facilities in Washington currently participate in this planning program.

Pollution prevention planning is an activity that involves:

- Inventorying substances used and dangerous waste generated;
- Identifying opportunities to prevent pollution;
- Analyzing the feasibility of these prevention opportunities; and
- Setting goals for hazardous substance use reduction and dangerous waste reduction, recycling and treatment.

Ecology promotes pollution prevention through initiatives other than planning. Several campaigns targeting specific industries have been conducted and more are being planned. These campaigns have a joint focus of pollution prevention and regulatory compliance, and help target future technical assistance. Ecology provides technical assistance through its regional offices, with emphasis on the reduction of hazardous substance use and dangerous waste generation. Site visits, phone consultations, and workshops are some of the ways assistance is provided to businesses and government entities.

Pollution prevention has emerged as a key strategy for protecting the environment. Business, industry and government alike recognize the benefits of prevention rather than end-of-pipe controls. Many factors, including regulatory compliance, cost savings, worker safety and reduced liabilities help validate pollution prevention as an approach to be incorporated into all business practices.

Chapter 2 - Core Elements for New Development and Redevelopment

2.1 Introduction to the Core Elements

This chapter describes the Core Elements for stormwater management for new development projects and redevelopment projects. 2.3 Applicability of the Core Elements should be consulted to determine which of the Core Elements apply to any given project. Figure 2.1: Flow Chart for Determining Requirements for New Development and Figure 2.2: Flow Chart for Determining Requirements for Redevelopment should be consulted to determine whether the Core Elements apply to new surfaces, replaced surfaces, or new and replaced surfaces. Chapters 6 through 8 of this manual present Best Management Practices (BMPs) for use in meeting the Core Elements.

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These Core Elements are applicable to new development and redevelopment projects that meet the regulatory threshold(s) of the Phase I or Phase II Municipal Stormwater Permits.

Depending on the type and size of the proposed project, different combinations of the Core Elements or UIC Program regulations apply. See Chapter 5 - UIC Program Guidelines for information on the UIC Program regulations.

In general, small projects are required to control erosion and sedimentation from construction activities and to apply simpler approaches to Runoff Treatment and Flow Control of stormwater runoff from the developed site. Controlling flows from small projects is important because the cumulative effect of uncontrolled flows from many small projects can be as damaging as those from a single large project.

Large projects must provide erosion and sedimentation control during construction, permanent control of stormwater runoff from the developed site through selection of appropriate BMPs, and other measures to reduce and control the on-site and off-site impacts of the project.

Project proponents shall apply whatever technology is necessary to comply with state water quality standards, Chapter 173-201A WAC, or state groundwater standards, Chapter 173-200 WAC. Additional treatment requirements to meet those standards may be required by federal, state, or local jurisdictions. The requirements of these Core Elements do not excuse the project proponent from the obligation to meet applicable water quality standards.

2.2 Exemptions

The purpose of this section is to identify activities whose resulting surfaces may be considered “exempt” from the Core Elements, even though those surfaces, per the definitions in the Glossary, would be considered replaced hard surfaces or land disturbed.

Unless otherwise indicated in this section, the surfaces that result from the activities described below are exempt from the Core Elements. Exempt surfaces do not need to be included when evaluating the Project Level Thresholds or Core Element Level Thresholds as described in 2.3 Applicability of the Core Elements.

The following list further defines how these exemptions may be used:

- A project may combine different types of exempt activities. If the project includes only exempt activities, then the whole project is exempt.
- If the “exempt” activity is part of, directly related to, or caused by a new development or redevelopment project, then it is not considered an exempt activity. It is considered part of the new development or redevelopment project.
- If an exempt activity requires making an ADA update per the federal Americans with Disabilities Act requirements, then the ADA update is considered part of the exempt activity, and the exemption applies to the surfaces disturbed for the ADA update. Note that this exemption does not extend to additional work, such as extending a sidewalk beyond what is necessary for the ADA update.

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Forest Practice Activities

Forest practices regulated under Title 222 WAC, except for Class IV-General forest practices that are conversions from timberland to other uses, are exempt from the provisions of the Core Elements.

The text in this box originates from one or more of the following Permits:
Appendix 1 of the Phase I / Phase II Municipal Stormwater Permits
Construction Stormwater General Permit

Commercial Agriculture Activities

Commercial agriculture activities involving working the land for production are generally exempt. However, the conversion from timberland to agriculture, and the construction of impervious surfaces are not exempt.

The text in this box originates from one or more of the following Permits:
Appendix 1 of the Phase I / Phase II Municipal Stormwater Permits
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Oil and Gas Field Activities

Construction of drilling sites, waste management pits, and access roads, as well as construction of transportation and treatment infrastructure such as pipelines, natural gas treatment plants, natural gas pipeline compressor stations, and crude oil pumping stations are exempt. Operators are encouraged to implement and maintain Best Management Practices (BMPs) to minimize erosion and control sediment during and after construction activities to help ensure protection of surface water quality during storm events.

The text in this box originates from one or more of the following Permits:
Appendix 1 of the Phase I / Phase II Municipal Stormwater Permits
Construction Stormwater General Permit

Pavement Maintenance Activities

Pavement maintenance activities include only targeted pavement repairs or maintenance. The limits of the exempt surfaces include only the area that must be disturbed to repair or maintain the pavement.

Pavement maintenance activities do not:

- change the characteristics of a roadway (e.g. changing a four-way intersection to a roundabout).
- increase the traffic capacity of a roadway or parking area (e.g. include restriping to add lanes or parking spaces).
- expand the area of coverage (i.e. add new hard surfaces).

The following pavement maintenance activities are exempt from all Core Elements:

- pothole patching, square cut patching, or other targeted preservation work,
- overlaying (including grinding and overlaying, so long as base course is not exposed) existing asphalt or concrete pavement. Examples of overlay materials include bituminous surface treatment (BST or “chip seal”), asphalt, or concrete,
- shoulder grading,
- reshaping/regrading drainage systems (including adding curb/gutter and/or wedge curbs),
- crack sealing, and
- vegetation maintenance associated with the road right-of-way.

The following pavement maintenance activities are subject to only 2.4.2 CE2: Construction Stormwater Pollution Prevention Plan (SWPPP):

- Removing and replacing a concrete or asphalt roadway to base course or subgrade or lower without expanding the impervious surfaces.
- Repairing the roadway base or subgrade.
- Overlaying existing gravel with bituminous surface treatment (BST or “chip seal”), asphalt, or concrete without expanding the area of coverage, or overlaying BST with asphalt, without expanding the area of coverage. For this type of pavement maintenance activity, the exemption applies under the following conditions only:
    - For roads, these activities are exempt only if the traffic surface will be subject to an average daily traffic (ADT) volume of < 7,500 on an urban road or an ADT volume of < 15,000 vehicles on a rural road, freeway, or limited access control highway. If these thresholds are exceeded, these are considered new hard surfaces.
    - For parking areas, these activities are exempt only if the traffic surface will be subject to < 40 trip ends per 1,000 square feet of building area or 100 total trip ends. If either of these thresholds is exceeded, these are considered new hard surfaces.

The text in this box originates from one or more of the following Permits:
Appendix 1 of the Phase I / Phase II Municipal Stormwater Permits
Construction Stormwater General Permit

Underground Utility Activities

Underground utility activities include installing, maintaining, and/or upgrading an underground utility. The limits of the exempt surfaces include only the area disturbed by the trench work necessary for the underground utility work (including any over-excavating necessary for the utility trench).

In order for an underground utility activity to be exempt, it cannot be part of, directly related to, or caused by a new development or redevelopment project.

Underground utility activities must replace the ground surface with in-kind material or materials with similar runoff characteristics.

Underground utility activities are subject to only 2.4.2 CE2: Construction Stormwater Pollution Prevention Plan (SWPPP).

The text in this box originates from one or more of the following Permits:
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2.3 Applicability of the Core Elements

Core Element Thresholds

Follow the steps below to ensure the project complies with the applicable Core Elements:

1. First, determine if all runoff is infiltrating into a UIC well (i.e. calculations show that the 100-yr, 3-hr storm OR the 100-yr, 72-hr storm, whichever is larger, is fully infiltrated). If it is, refer to Chapter 5 - UIC Program Guidelines. If not, continue with the steps below.
2. Determine the Core Elements that apply to the entire project using the Project Thresholds for new development and redevelopment listed below.
3. If the Core Elements apply to the Project, review the additional thresholds within Core Elements 5, 6, and 8 to determine if Runoff Treatment and/or Flow Control BMPs are required for the Project to be in compliance with the Core Element.

Not all of the Core Elements apply to every new development or redevelopment project. The applicability varies depending on the project type and size. This section identifies thresholds that determine the applicability of the Core Elements to projects. Use the flow charts in Figure 2.1: Flow Chart for Determining Requirements for New Development and Figure 2.2: Flow Chart for Determining Requirements for Redevelopment to determine which of the Core Elements apply. The Core Elements themselves are presented in 2.4 Core Elements (CEs).

Use the thresholds in Figure 2.1: Flow Chart for Determining Requirements for New Development and Figure 2.2: Flow Chart for Determining Requirements for Redevelopment at the time of application for a subdivision, plat, short plat, building permit, or other construction permit. The plat or short plat approval shall identify all stormwater BMPs that are required for each lot. For projects involving only land disturbing activities, (e.g. clearing or grading), the thresholds apply at the time of application for the permit allowing or authorizing that activity. Note the exemption in 2.2 Exemptions for forest practices other than Class IV General.

For projects that are implemented in incremental stages or phases as part of a common plan of development or sale, the thresholds below must be considered for the complete project at full build-out.

The text in this box originates from one or more of the following Permits:
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Construction Stormwater General Permit

Figure 2.1: Flow Chart for Determining Requirements for New Development

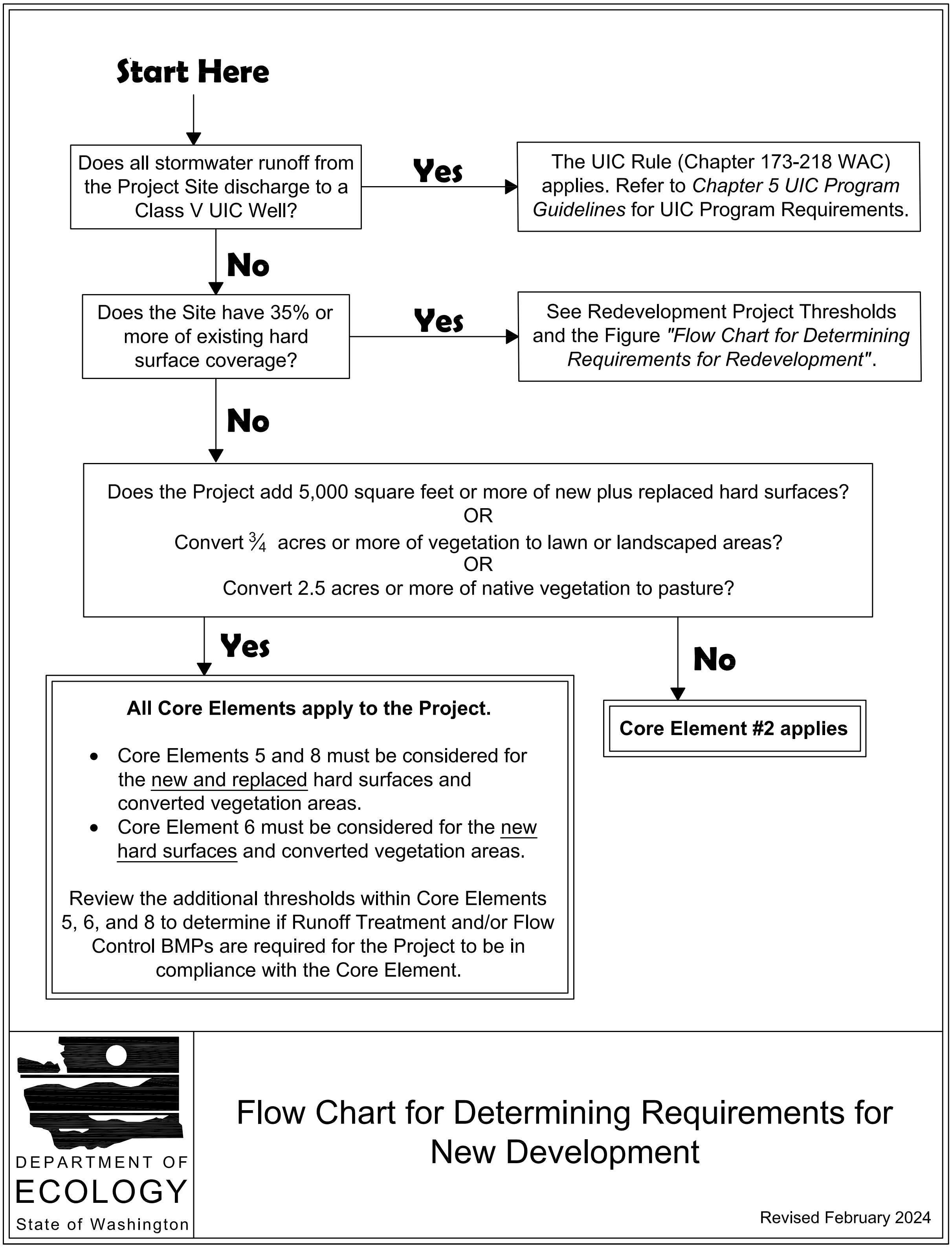
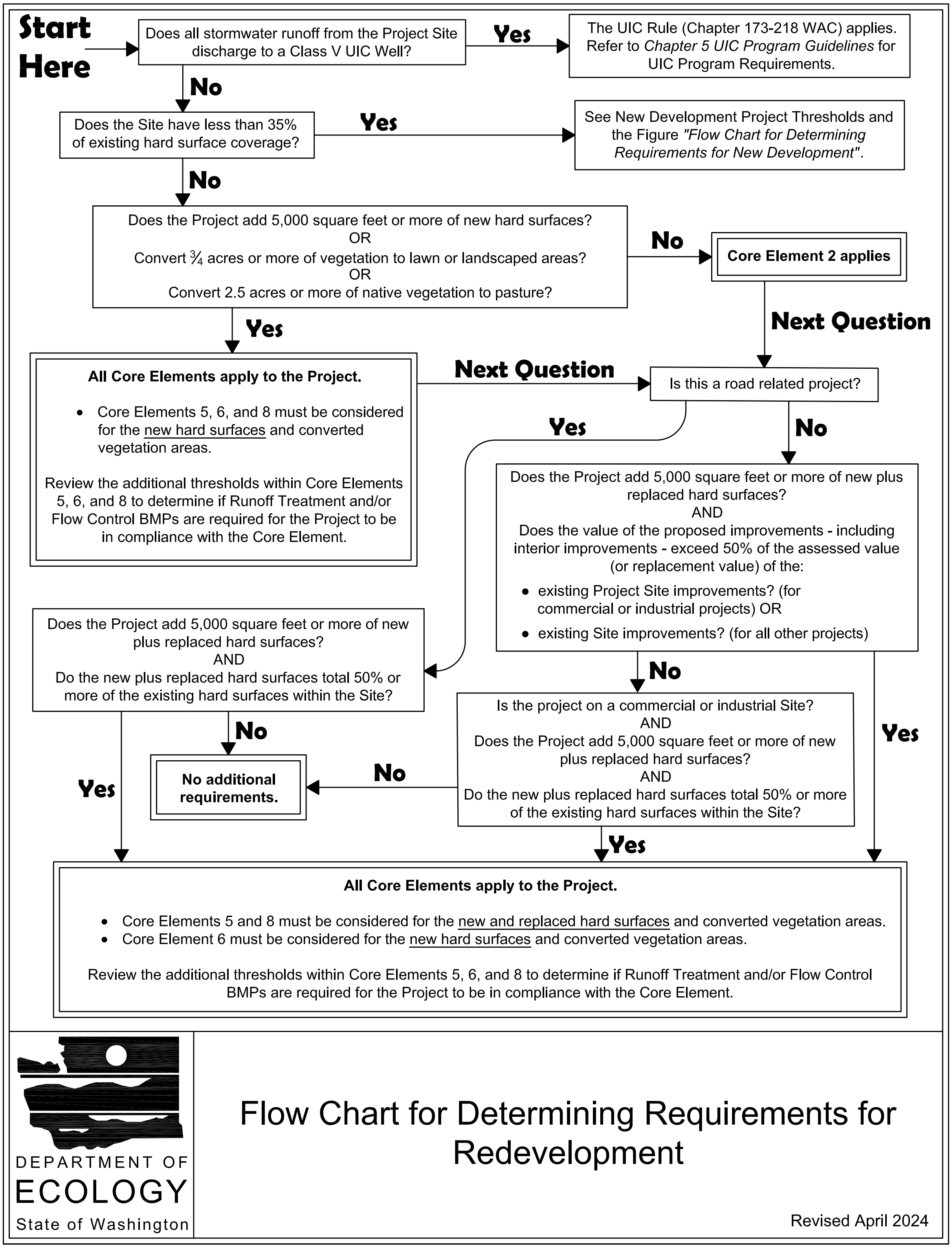


Figure 2.2: Flow Chart for Determining Requirements for Redevelopment



New Development Project Thresholds

All new development shall be required to comply with Core Element #2.

The following new development shall comply with all Core Elements. Core Elements 5 and 8 must be considered for (i.e. the Core Element Thresholds must be evaluated for) the new and replaced hard surfaces and converted vegetation areas. Core Element 6 must be considered for the new hard surfaces and converted vegetation areas.

- the Project adds 5,000 square feet, or more, of new plus replaced hard surface area, or
- Converts ¾ acres, or more, of vegetation to lawn or landscaped areas, or
- Converts 2.5 acres, or more, of native vegetation to pasture.

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Redevelopment Project Thresholds

The following redevelopment shall comply with all Core Elements. Core Elements 5, 6, and 8 must be considered for (i.e. the Core Element Thresholds must be evaluated for) the new hard surfaces and converted vegetation areas.

- Adds 5,000 square feet or more of new hard surfaces or,
- Converts ¾ acres, or more, of vegetation to lawn or landscaped areas, or
- Converts 2.5 acres, or more, of native vegetation to pasture.

Additional Requirements for Redevelopment

Road-related redevelopment projects shall comply with all Core Elements if they meet both of the following thresholds. If the following thresholds are met, Core Elements 5 and 8 must be considered for (i.e. the Core Element Thresholds must be evaluated for) the new and replaced hard surfaces and converted vegetation areas. Core Element 6 must be considered for the new hard surfaces and converted vegetation areas.

- the Project adds 5,000 square feet or more of new plus replaced hard surfaces, and
- the new plus replaced hard surfaces total 50% or more of the existing hard surfaces within the Site.

Other types of redevelopment projects shall comply with all Core Elements if they meet either of the following two thresholds. If either of the following thresholds are met, Core Elements 5 and 8 must be considered for (i.e. the Core Element Thresholds must be evaluated for) the new and replaced hard surfaces and converted vegetation areas. Core Element 6 must be considered for the new hard surfaces and converted vegetation areas.

- Threshold 1:
    - the Project adds 5,000 square feet or more of new plus replaced hard surfaces, and
        - For commercial or industrial projects: the valuation of the proposed improvements, including interior improvements, exceeds 50% of the assessed value of the existing Project Site improvements.
        - For all other projects: the valuation of the proposed improvements, including interior improvements, exceeds 50% of the assessed value of the existing Site improvements.
- Threshold 2 (for commercial or industrial sites only):
    - the Project adds 5,000 square feet or more of new plus replaced hard surfaces, and
    - the new plus replaced hard surfaces total 50% or more of the existing hard surfaces within the Site.

The local jurisdiction may exempt or institute a stop-loss provision for redevelopment projects from compliance with Core Elements #5, #6, and/or #8 as applied to the replaced hard surfaces if the local jurisdiction has adopted a plan and a schedule that fulfills those requirements in regional facilities.

The text in this box originates from one or more of the following Permits:
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Objective

Redevelopment projects have the same requirements as new development projects in order to minimize the impacts from new surfaces. To not discourage redevelopment projects, replaced surfaces aren't required to be brought up to new stormwater standards unless the cost or space thresholds identified above are exceeded. As long as the replaced surfaces have similar pollution-generating potential to the surfaces that they are replacing, the amount of pollutants discharged shouldn't be significantly different from the existing site conditions. However, if the redevelopment project scope is sufficiently large that the cost or space thresholds identified above are exceeded, it is reasonable to require the replaced surfaces to be brought up to current stormwater standards. This is consistent with other utility standards. When a structure or a property undergoes significant remodeling, local governments often require the site to be brought up to new building code requirements (e.g. on-site sewage disposal systems, fire systems).

Supplemental Guidelines

The local government may allow the Core Elements to be met for an equivalent (flow and pollution characteristics) area for new development projects as well as redevelopment projects. The equivalent area must drain to the same receiving water. For public road projects, the equivalent area does not have to be within the project limits, but must drain to the same water body segment and be located upstream from a confluence with another water body downstream from the project site.

The local jurisdiction should give the project proponent guidance on if their project (or Site) is considered a "commercial" or "industrial" project (or Site) for the purposes of the project thresholds described in this section. The determination may be based on zoning, activities proposed to take place at the completed Project Site, and/or other factors.

If new development or redevelopment is occurring on a surface that is already mitigated by a stormwater BMP (and that surface requires a stormwater BMP for the current new development or redevelopment project), then the design must determine if the existing BMP meets current standards.

- If the existing BMP meets current standards, then it may continue to be used to mitigate for the surface, so long as it is not part of an area transfer (i.e. equivalent area trade) - see bullet below.
- If the existing BMP does not meet current standards, then it must be either adjusted to meet current standards, or new BMP(s) must be installed as part of the project.
- If the existing BMP was installed as part of an area transfer (i.e. it is mitigating this project's area as an "equivalent area" in lieu of providing a stormwater BMP for a previous project at a different area), then BMP(s) must be provided to mitigate for the current project using a different equivalent area.

Recommendations for Local Governments

As part of the routine project approval and permitting process, local jurisdictions should review redevelopment project plans for intent and completeness in meeting the redevelopment guidelines. Where space is limited, staff may assist project proponents in modifying Best Management Practices (BMPs) and/or finding creative ways to meet the intent of the Core Elements. Optionally, local jurisdictions may conduct planning for regional Runoff Treatment BMPs in areas where meeting the on-site treatment objectives for individual redevelopment projects would be challenging.

Options for Local Governments

Local governments may select from various methods for identifying projects that must comply with all the Core Elements for the new and replaced hard surfaces and the converted vegetation areas on the project site (See Additional Requirements for Redevelopment, above). Examples of methods that may vary between jurisdictions include:

- Identifying the valuation of the proposed improvements by various methods such as:
  - The designer's estimate of the proposed project,
  - The anticipated future (post-project) assessed value for the improvements on the Site (not including the property value), minus the current year, pre-project assessor's data for the improvements on the Site (not including the property value),

    - The anticipated future (post-project) appraisal value for the improvements on the Site (not including the property value), minus the current (within a year or other predetermined period of time), pre-project appraisal value of the improvements on the Site (not including the property value),

- Identifying the assessed value of the existing Site improvements by various methods such as:

    - Current year, pre-project assessor's data for the improvements on the Site (not including the property value),

    - Current (within a year or other predetermined period of time), pre-project appraisal value of the improvements on the Site (not including the property value),

    - The estimated cost to replace the existing improvements on the Site, as determined by the Marshall Value System, or a similar valuation system.

- Providing an alternate method that does not rely on the direct comparison of existing and proposed Site improvements, such as:

    - Exceeding a certain dollar value of improvements, as determined by a predetermined method, such as the designer's estimate of the proposed project,

    - Exceeding a certain ratio of the new hard surfaces to the total of replaced plus new hard surfaces

A local government’s thresholds for the application of the Core Elements to replaced hard surfaces must be at least as stringent as Ecology’s thresholds. Local governments should be prepared to demonstrate that by comparing the number and types of historical projects that would have been regulated using Ecology's thresholds versus the local government’s thresholds.

Local jurisdictions may institute a stop-loss provision (an upper limit on the extent to which requirement is applied) on the application of stormwater requirements that apply to replaced impervious surfaces. A stop-loss provision may not, however, be instituted for the application of stormwater requirements for new impervious surfaces.

For instance, there could be a maximum percentage of the estimated total project costs that are dedicated to meeting stormwater requirements for replaced impervious surfaces. A project would not have to incur additional stormwater costs above that maximum though the standard redevelopment requirements would not be fully achieved.

Allowances may also be made for sites that would, by imposing the treatment requirement, become nonconforming to other requirements that apply to the site. Every effort should still be made to find creative ways to meet the intent of the Core Elements. The allowance for a stop-loss provision pertains to the extent that treatment, flow control and wetlands protection requirements are imposed on replaced impervious surfaces. It does not apply to meeting stormwater requirements for new impervious surfaces.

Local governments can also establish criteria for allowing redevelopment projects to pay a fee in lieu of constructing Runoff Treatment or Flow Control BMPs on a redeveloped site. At a minimum, the fee should be the equivalent of an engineering estimate of the cost of meeting all applicable Core Elements for the project. The local government should use such funds for the implementation of stormwater control projects that would have similar benefits to the same receiving water as if the project had constructed its required improvements. Expenditure of such funds is subject to other state statutory requirements.

Ecology cautions local governments about the potential long-term consequences of allowing a fee-in-lieu of stormwater facilities. Sites that are allowed to pay a fee continue to discharge stormwater without stormwater controls. If it is determined, through future basin planning for instance, that controls on such sites are necessary to achieve water quality goals or legal requirements, the public may bear the costs for providing those controls.

Local jurisdictions may require Runoff Treatment BMPs for redevelopment projects that discharge to a receiving water that has a documented water quality problem. This provision should focus on water quality problems for metals, oil and grease, bacteria, sediment, suspended solids, phosphorus, or any other water quality problem to which stormwater is considered a contributor.

Sites with 100% existing building coverage that are currently connected to a municipally owned storm sewer or combined sewer must be evaluated on a case-by-case basis to continue to be connected without treatment. Additional local requirements such as flow restrictors may also be required.

2.4 Core Elements (CEs)

2.4.1 CE1: Preparation of a Stormwater Site Plan

All projects meeting the Project Thresholds in 2.3 Applicability of the Core Elements shall prepare a Stormwater Site Plan for local jurisdiction review. Stormwater Site Plans shall use site-appropriate development principles, as required and encouraged by local development codes, to retain native vegetation and minimize impervious surfaces to the extent feasible. Stormwater Site Plans shall be prepared in accordance with Chapter 3 - Preparation of Stormwater Site Plans.

The text in this box originates from one or more of the following Permits:
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Construction Stormwater General Permit

Objective

Stormwater management is most successful when integrated into project planning and design. Projects are expected to demonstrate compliance with the applicable Core Elements through preparation of a Stormwater Site Plan (SSP).

Supplemental Guidelines

Projects proposed by departments and agencies within the local jurisdiction must comply with this requirement. The local jurisdiction shall determine the process for ensuring proper project review, inspection, and compliance by its own departments and agencies.

A simplified SSP may be developed by the local jurisdiction and made available for use by proponents of small projects.

Recommendations for Local Jurisdictions

As part of the routine project approval and permitting process, local jurisdictions should review SSPs for completeness and adequacy in fulfilling the objectives of the Core Elements. Plan review staff should be trained in the application of this manual or the approved local equivalent.

2.4.2 CE2: Construction Stormwater Pollution Prevention Plan (SWPPP)

All new development and redevelopment projects are responsible for preventing erosion and discharge of sediment and other pollutants into receiving waters.

The text in this box originates from one or more of the following Permits:
Appendix 1 of the Phase I / Phase II Municipal Stormwater Permits
Construction Stormwater General Permit

Core Element Thresholds

Compliance requirements for this Core Element are as follows:

- Projects that do not qualify for an Erosivity Waiver (as described below, if allowed by the local jurisdiction) that meet any of the following thresholds must prepare a Construction Stormwater Pollution Prevention Plan (SWPPP) for local jurisdiction review:
    - (for new development projects)
        - result in 5,000 square feet, or more, of new plus replaced hard surface area, or
        - converts ¾ acres, or more, of vegetation to lawn or landscaped areas, or
        - converts 2.5 acres, or more, of native vegetation to pasture.
    - (for redevelopment projects)
        - adds 5,000 square feet, or more, of new hard surface area, or
        - converts ¾ acres, or more, of vegetation to lawn or landscaped areas, or
        - converts 2.5 acres, or more, of native vegetation to pasture.
- Projects below those thresholds (listed directly above) are not required to prepare a Construction SWPPP, but must consider all of the Construction SWPPP Elements (listed in 7.2 13 Elements of Construction Stormwater Pollution Prevention) and develop controls for all Construction SWPPP Elements that pertain to the project site.

The text in this box originates from one or more of the following Permits:
Appendix 1 of the Phase I / Phase II Municipal Stormwater Permits
Construction Stormwater General Permit

General Requirements

The Construction SWPPP shall include a narrative and drawings. All BMPs shall be clearly referenced in the narrative and marked on the drawings. The Construction SWPPP narrative shall include documentation to explain and justify the pollution prevention decisions made for the project. Each of the 13 Construction SWPPP Elements (listed in 7.2 13 Elements of Construction Stormwater Pollution Prevention) must be considered and included in the Construction SWPPP unless site conditions render the Element unnecessary and the exemption from that Element is clearly justified in the narrative of the SWPPP.

Clearing and grading activities for developments shall be allowed only if conducted pursuant to an approved site development plan (e.g. subdivision approval) that establishes permitted areas of clearing, grading, cutting, and filling. These permitted clearing and grading areas and any other areas required to preserve critical or sensitive areas, buffers, native growth protection easements, or tree retention areas (as may be required by local jurisdictions), shall be delineated on the site plans and the development site.

The Construction SWPPP shall be implemented beginning with initial land disturbance and until final stabilization. Sediment and Erosion control BMPs shall be consistent with the BMPs contained in 7.4 Construction Stormwater BMPs.

Seasonal Work Limitations: From October 1 through June 30, land disturbing activities shall only be permitted if shown to the satisfaction of the local jurisdiction that turbid water will be prevented from leaving the site through a combination of the following:

1. Site conditions including existing vegetative coverage, slope, soil type and proximity to receiving waters; and
2. Limitations on activities and the extent of disturbed areas; and
3. Proposed erosion and sediment control measures.

Based on the information provided and/or local weather conditions, the local jurisdiction may expand or restrict the seasonal work limitations.

The following activities are exempt from the seasonal work limitations:

1. Routine maintenance and necessary repair of erosion and sediment control BMPs,
2. Routine maintenance of public facilities or existing utility structures that do not expose the soil or result in the removal of the vegetative cover to soil, and
3. Activities where there is one hundred percent infiltration of stormwater runoff within the site in approved and installed erosion and sediment control facilities.

If erosion and sediment control requirements are not being met (i.e. turbid water is leaving the site), then the local jurisdiction shall require that the contractor maintain the existing BMPs or implement other BMPs as appropriate.

The text in this box originates from one or more of the following Permits:
Appendix 1 of the Phase I / Phase II Municipal Stormwater Permits
Construction Stormwater General Permit

Erosivity Waiver

The local jurisdiction may allow construction site operators to qualify for a waiver from the requirement to submit a Construction SWPPP for local jurisdiction review if all of the following conditions are met:

1. The site will result in the disturbance of fewer than five (5) acres and the site is not a portion of a common plan of development or sale that will disturb five (5) acres or greater.
2. Calculation of Erosivity "R" Factor and Regional Timeframe:
    a. The project's calculated rainfall erosivity factor ("R" Factor) must be less than five (5) during the period of construction activity.

       See the CSWGP website at the following address for a link to the EPA's calculator and step by step instructions on computing the "R" Factor in the *EPA Erosivity Waiver Fact Sheet*:

       https://ecology.wa.gov/regulations-permits/permits-certifications/stormwater-general-permits/construction-stormwater-permit

       The period of construction activity starts when the land is first disturbed and ends with final stabilization. In addition:
    b. The entire period of construction activity must fall within the following timeframes:
        i. **For sites west of the Cascades Crest:** June 15 – September 15.
        ii. **For sites east of the Cascades Crest, excluding the Central Basin:** June 15 – October 15.
        iii. **For sites east of the Cascades Crest, within the Central Basin:** no timeframe restrictions apply.

            The Central Basin is defined as the portions of Eastern Washington with mean annual precipitation of less than 12 inches.
3. Construction site operators must submit a complete Erosivity Waiver certification form to the local jurisdiction at least one week before disturbing the land. Certification must include statements that the operator will:

a. Comply with applicable local stormwater requirements; and

b. Implement appropriate erosion and sediment control BMPs to prevent violations of water quality standards.

4. This waiver is not available for facilities declared significant contributors of pollutants or for any size construction activity that could reasonably expect to cause a violation of any water quality standard (see the *Construction Stormwater General Permit* (CSWGP) for details).

5. This waiver does not apply to construction activities which include non-stormwater discharges (see the CSWGP for details).

6. If construction activity extends beyond the certified waiver period for any reason, the operator must either:

   a. Recalculate the rainfall erosivity "R" factor using the original start date and a new projected ending date and, if the "R" factor is still under 5 and the entire project falls within the applicable regional timeframe in 2.b (above), complete and submit an amended waiver certification form before the original waiver expires; or

   b. Submit a complete permit application to Ecology before the end of the certified waiver period (see the CSWGP for details).

The text in this box originates from one or more of the following Permits:
Appendix 1 of the Phase I / Phase II Municipal Stormwater Permits
Construction Stormwater General Permit

Objective

Runoff from project sites during the construction phase can contribute quantities of sediment and other contaminants sufficient to result in water quality violations. Sediment-laden runoff can enter infiltration BMPs, reducing their infiltration capacity and lifetime of operation or increasing maintenance costs.

Controlling erosion and preventing sediment and other pollutants from leaving the project site during the construction phase is achievable through implementation of selected Best Management Practices (BMPs) that are appropriate both to the site and to the season during which construction activities take place. The Construction Stormwater Pollution Prevention Plan (SWPPP) identifies project-specific guidance for preventing pollution resulting from erosion and sediment runoff during the construction phase. A well-written SWPPP provides guidance that is neither over- nor underprotective of the project site. The Construction SWPPP should include seasonally appropriate guidance and anticipate adjustments that may be necessary in the event of delays in the construction schedule.

Supplemental Guidelines

Project proponents may be required to obtain a Construction Stormwater General Permit (CSWGP) from the Washington State Department of Ecology (Ecology) prior to beginning construction. See Ecology's website (https://ecology.wa.gov/) for details on when a CSWGP is required and how to obtain one when it is needed.

If a Construction SWPPP is found to be inadequate (with respect to erosion and sediment control requirements), then the local jurisdiction shall require that other Construction Stormwater BMPs be implemented, as appropriate.

The local jurisdiction may allow development of generic Construction SWPPPs that apply to commonly conducted public road activities, such as road surface replacement, that trigger this Core Element.

Based on the information provided and/or local weather conditions, the local jurisdiction may expand or restrict the Seasonal Work Limitation period on site disturbance. The local jurisdiction shall take enforcement action - such as a notice of violation, administrative order, penalty, or stop-work order under the following circumstances:

- If, during the course of any construction activity or soil disturbance during the Seasonal Work Limitation period, sediment leaves the construction site causing a violation of the surface water quality standard; or
- If clearing and grading limits or erosion and sediment control measures shown in the approved plan are not maintained.

The primary project proponent shall coordinate with utilities and other contractors. The primary project proponent shall evaluate, with input from utilities and other contractors, the stormwater management requirements for the entire project, including the utilities, when preparing the Construction SWPPP.

Construction SWPPP Elements

Project proponents are responsible for preventing erosion and discharge of sediment from the project site into surface waters of the State and must consider each of the 13 elements of pollution prevention to determine which controls are appropriate for the project site. The SWPPP elements listed in this section are from the latest version of Ecology's CSWGP.

The 13 Construction SWPPP elements are listed below. See 7.2 13 Elements of Construction Stormwater Pollution Prevention for a description of each of these elements and suggested BMPs for each element.

1. 7.2.1 Element 1: Preserve Vegetation / Mark Clearing Limits
2. 7.2.2 Element 2: Establish Construction Access
3. 7.2.3 Element 3: Control Flow Rates
4. 7.2.4 Element 4: Install Sediment Controls
5. 7.2.5 Element 5: Stabilize Soils
6. 7.2.6 Element 6: Protect Slopes
7. 7.2.7 Element 7: Protect Storm Drain Inlets
8. 7.2.8 Element 8: Stabilize Channels and Outlets
9. 7.2.9 Element 9: Control Pollutants

10. [7.2.10 Element 10: Control Dewatering]
11. [7.2.11 Element 11: Maintain BMPs]
12. [7.2.12 Element 12: Manage the Project]
13. [7.2.13 Element 13: Protect Infiltration BMPs]

Maintaining an Updated SWPPP

Contractors must maintain the Construction SWPPP on the construction site for reference and use by project personnel. The SWPPP, including the site map, must be amended whenever there is a change in design, construction, operation, or maintenance at the construction site that has or could have a significant effect on the discharge of pollutants to surface or groundwater that has not been previously addressed in the SWPPP. The SWPPP must be amended if during inspections or investigations by site staff, Ecology, or by the jurisdiction, it is determined that the SWPPP is ineffective in eliminating or significantly minimizing pollutants in stormwater discharges from the construction site. Based on the results of an inspection, the SWPPP must be modified as necessary to include additional or modified BMPs designed to correct problems identified. Revisions to the SWPPP must be completed within 7 calendar days following the inspection. Implementation of these additional or modified BMPs must be accomplished before the next storm event whenever practicable. Where implementation before the next storm event is impracticable, the situation must be documented in the SWPPP and alternative BMPs must be implemented as soon as possible.

Recommendations for Local Jurisdictions

Local jurisdictions should review SWPPPs for completeness and adequacy in meeting the objectives of Core Element #2. Train staff inspecting projects during construction in assessing the application of erosion and sediment control BMPs and how to address deficiencies.

2.4.3 CE3: Source Control of Pollution

Following construction, all new development and redevelopment projects meeting the Project Thresholds in 2.3 Applicability of the Core Elements shall apply all known, available, and reasonable Source Control BMPs.

Source Control BMPs shall be selected, designed, and maintained in accordance with this manual.

The text in this box originates from one or more of the following Permits:
Appendix 1 of the Phase I / Phase II Municipal Stormwater Permits
Construction Stormwater General Permit

Objective

The intent of Source Control BMPs is to prevent stormwater from coming in contact with pollutants. They are a cost-effective means of reducing pollutants in stormwater and should be a first consideration in all projects.

Supplemental Guidelines

Source Control BMPs identified for Core Element #3 are separate from those implemented for 2.4.2 CE2: Construction Stormwater Pollution Prevention Plan (SWPPP). Source Control BMPs installed to satisfy Core Element #3 require long-term maintenance to ensure successful operation.

Source Control BMPs include Operational BMPs and Structural Source Control BMPs. See Chapter 8 - Source Control for design details of these BMPs.

Structural Source Control BMPs should be identified in the stormwater site plan and should be shown on all applicable plans submitted for local government review and approval.

An adopted and implemented Basin Plan (see Appendix 2-A: Altering the CEs with Basin Plans) or Total Maximum Daily Load (see 1.2.15 Total Maximum Daily Loads (TMDLs)) may be used to develop more stringent source control requirements that are tailored to a specific basin.

Identifying Source Control Strategies in a Basin Plan

Basin Plans can identify potential sources of pollution within the basin and develop strategies to eliminate or control these sources to protect beneficial uses.

A Basin Plan can include the following Source Control strategies:

1. Detection and correction of illicit discharges to storm sewer systems, including the use of dry weather sampling and dye-tracing techniques;
2. Identification of existing businesses, industries, utilities, and other activities that may store materials susceptible to spillage or leakage of pollutants into the storm sewer system or to the ground via wells, drains, or sumps;
3. Elimination or control of pollutant sources identified in (2);
4. Identification and control of future businesses, industries, utilities, and other activities which may store materials susceptible to spillage or leakage of pollutants into the storm sewer system; and
5. Training and public education

A Basin Plan that incorporates the standard requirements from this section as well as more stringent requirements does not require Ecology approval.

Recommendations for Local Jurisdictions

During plan review, local jurisdictions should evaluate whether selected source control BMPs will meet the objectives of Core Element #3. Train staff conducting inspections of commercial and industrial facilities in assessing the proper selection and implementation of Source Control BMPs and how to address deficiencies.

2.4.4 CE4: Preservation of Natural Drainage Systems and Outfalls

All new development and redevelopment projects meeting the Project Thresholds in 2.3 Applicability of the Core Elements shall preserve and maintain natural drainage patterns to the maximum extent practicable at the site. Discharges from the Project Site shall occur at the natural location, to the maximum extent practicable.

The manner by which runoff is discharged from the Project Site must not cause a significant adverse impact to downstream receiving waters and down-gradient properties, and should be addressed as part of the off-site analysis described in the SWMMEW.

All concentrated discharge locations (i.e. discharges from pipe systems, culverts, and ditches) must address energy dissipation. A project proponent who believes that energy dissipation should not be required must provide justification in the project's stormwater site plan.

The text in this box originates from one or more of the following Permits:
Appendix 1 of the Phase I / Phase II Municipal Stormwater Permits
Construction Stormwater General Permit

Objective

To preserve and utilize natural drainage systems to the fullest extent because of the multiple stormwater benefits these systems provide; and to prevent erosion at and downstream of the discharge location.

Supplemental Guidelines

The intent is to continue the discharge at, or return the discharge to, the natural location. If the Site does not currently discharge at the natural location, and is such that it is impractical (as determined by the local jurisdiction) to return the discharge to the natural location, then the requirement is to keep the discharge at the existing location. An example of this case is a site in an ultra-urban environment, where fully built-out conveyance systems exist and are not in the natural (i.e. historic) locations.

Creating new drainage patterns results in more site disturbance and more potential for erosion and sedimentation during and after construction. Creating new discharge points can create significant stream channel erosion problems as the receiving water body typically must adjust to the new flows. Diversions can cause greater impacts than would otherwise occur by discharging runoff at the natural location.

Where no conveyance system exists at the adjacent downgradient property line and the discharge was previously unconcentrated flow or significantly lower concentrated flow, then measures must be taken to prevent downgradient impacts. Drainage easements from downstream property owners may be needed and should be obtained prior to approval of engineering plans.

Core Element #4 includes stormwater infiltration if that is the natural discharge method for the site. The designer shall investigate whether shallow groundwater, a sensitive aquifer, or other concerns will affect design choices for the project.

To the maximum extent practicable, discharge stormwater in the same manner, at the same location, and at the same flow rate and volume as under the conditions that existed prior to development. Because some change in natural flow patterns is unavoidable after development, the preferred options for discharge of excess stormwater, listed in order of preference to maintain natural drainage systems, are the following:

1. Maintain dispersed sheet flow to match natural conditions.
2. Infiltrate on-site.
3. Infiltrate off-site.
4. Discharge to existing ditch networks, canals, or other dispersal methods that allow for potential groundwater recharge.
5. Discharge to wetlands, if allowed.
6. Discharge to existing private or municipally owned stormwater systems, if allowed.
7. Evaporate on-site or off-site.
8. Create a new outfall for discharge to receiving waters.

Stormwater control or treatment structures should not be located within the expected 25-year water level elevations for salmonid-bearing waters. Such areas may provide off-channel habitat for juvenile salmonids and salmonid fry.

Designs for outfall systems to protect against adverse impacts from concentrated runoff are included in 6.1.10.3 Outfall Systems.

For projects with no identified discharge point, local jurisdictions may wish to adopt guidance for management of the collected water per the requirements of 2.4.6 CE6: Flow Control. The guidance is intended to protect downstream properties from flooding as a result of postconstruction concentrated runoff.

Recommendations for Local Jurisdictions

During plan review, local jurisdictions should consider whether the construction and stormwater management approaches meet the objectives of this Core Element. Local jurisdictions may also wish to provide project proponents with resources about appropriate low impact development (LID) techniques that can assist in meeting the objectives of this Core Element as part of 2.5.4 APM3: Local Requirements.

For more information: See Appendix 3-C: Additional Guidance on Low Impact Development Site Planning Principles and Design Strategies for LID site planning information.

2.4.5 CE5: Runoff Treatment

All new development and redevelopment projects meeting the Project Thresholds in 2.3 Applicability of the Core Elements shall apply Runoff Treatment BMPs in accordance with the following thresholds, standards, and requirements to remove pollutants from stormwater runoff.

The text in this box originates from one or more of the following Permits:
Appendix 1 of the Phase I / Phase II Municipal Stormwater Permits
Construction Stormwater General Permit

Core Element Thresholds

Each project that requires Core Element #5 (per the Project Thresholds in 2.3 Applicability of the Core Elements) must be reviewed to determine if Runoff Treatment BMPs are required for the project to be in compliance with Core Element #5.

Note that it is possible for a project that triggers the thresholds for Core Element #5 per the Project Thresholds in 2.3 Applicability of the Core Elements to not need Runoff Treatment BMP(s) to be in compliance with Core Element #5. If a project does not trigger either of the Core Element thresholds for Runoff Treatment BMPs, then the designer must document the areas within the project used to determine that neither of the Core Element thresholds are met. This documentation will demonstrate compliance with Core Element #5 for the project.

When assessing a project against the following thresholds, only consider the types of surfaces (e.g. new hard surfaces, replaced hard surfaces, converted vegetation areas) that are subject to Core Element #5, per the Project Thresholds in 2.3 Applicability of the Core Elements.

The following projects require construction of Runoff Treatment BMPs. If a project meets either of the following thresholds, Runoff Treatment BMPs are required. The project proponent must demonstrate that the project does not meet either of the following thresholds for Runoff Treatment BMPs to not be required for the project.

- Projects that have a total of 5,000 square feet or more of pollution-generating hard surface (PGHS), or
- Projects that have a total of 3/4 of an acre or more of pollution-generating pervious surfaces (PGPS) – not including permeable pavements, and from which there will be a surface discharge in a natural or man-made conveyance system from the site.

The text in this box originates from one or more of the following Permits:
Appendix 1 of the Phase I / Phase II Municipal Stormwater Permits
Construction Stormwater General Permit

Runoff Treatment BMP Sizing

Size Runoff Treatment BMPs to treat the Water Quality Design Volume or the Water Quality Design Flow Rate, as detailed in 6.1.5 Sizing Your Runoff Treatment BMPs.

The text in this box originates from one or more of the following Permits:
Appendix 1 of the Phase I / Phase II Municipal Stormwater Permits
Construction Stormwater General Permit

Runoff Treatment BMP Selection, Design, and Maintenance

Runoff Treatment BMPs shall be:

- Selected in accordance with the process identified in 6.1.2 Choosing Your Runoff Treatment BMPs,
- Designed in accordance with the design criteria in Chapter 6 - Runoff Treatment, Flow Control, and LID BMP Library, and
- Maintained in accordance with the maintenance criteria in Chapter 6 - Runoff Treatment, Flow Control, and LID BMP Library.

The text in this box originates from one or more of the following Permits:
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Bypass Requirements

A bypass must be provided for all Runoff Treatment BMPs unless the BMP is able to convey the 25-year short-duration storm without damaging the BMP or dislodging pollutants from within it. Extreme runoff events may produce high flow velocities through BMPs that can damage and or dislodge pollutants from within the facility. The designer must: check the maximum allowable velocity (typically less than 2 ft/s) or shear stress specified for the BMP; and implement a flow bypass as necessary to prevent exceeding these velocities. Bypass is not recommended for wet ponds, constructed wetlands, and similar volume-based Runoff Treatment BMPs; inlet structures for these BMPs should be designed to dampen velocities; the pond dimensions will further dissipate the energy.

The text in this box originates from one or more of the following Permits:
Appendix 1 of the Phase I / Phase II Municipal Stormwater Permits
Construction Stormwater General Permit

Objective

The purpose of Runoff Treatment is to reduce pollutant loads and concentrations in stormwater runoff using physical, biological, and chemical removal mechanisms so that beneficial uses of receiving waters are maintained and, where applicable, restored. When site conditions are appropriate, infiltration can potentially be the most effective BMP for Runoff Treatment.

Supplemental Guidelines

See 6.1.2 Choosing Your Runoff Treatment BMPs for determining the appropriate Runoff Treatment Performance Goal for the site, and a list of BMPs that may be used to meet that performance goal using the presumptive approach.

See Chapter 6 - Runoff Treatment, Flow Control, and LID BMP Library for detailed guidance on design and maintenance of Runoff Treatment BMPs.

An adopted and implemented basin plan, or a Total Maximum Daily Load (TMDL - also known as a Water Clean-up Plan) may be used to develop Runoff Treatment requirements that are tailored to a specific basin. However, Runoff Treatment requirements shall meet, at a minimum, the Basic Treatment Performance Goal (as detailed in 6.1.2 Choosing Your Runoff Treatment BMPs).

Runoff from surfaces that are not pollution-generating do not need to be treated and may bypass the Runoff Treatment BMP(s), if it is not mingled with runoff from pollution-generating surfaces.

Drainage from areas in native vegetation should not be mixed with untreated runoff from streets and driveways, if possible. It is best to infiltrate or disperse this relatively clean runoff to maximize recharge to shallow groundwater, wetlands, and streams.

Project designers are encouraged to consider site grading, conveyance, and other design specifications that separate NPGIS from PGIS runoff to avoid treating all of the runoff from the site. Designers are also encouraged to keep PGIS runoff from portions of the site that require oil control or metals treatment separate from PGIS areas that need only basic treatment where it might be possible to avoid treating all of the runoff from the site to the higher standard.

Revising Core Element #5 through a Basin Plan

Basin Plans (see Appendix 2-A: Altering the CEs with Basin Plans) can develop different requirements and performance standards than those detailed above to reduce pollutant concentrations or loads based on an evaluation of the beneficial uses to be protected within or downstream of the basin. Consideration must be given to the antidegradation provisions of the Clean Water Act and implementing state water quality standards. The evaluation should include an analysis of existing and future conditions. Basin specific requirements and performance standards can be developed based on an evaluation of pollutant loads and modeling of receiving water conditions.

Basic Treatment (as described in 6.1.2 Choosing Your Runoff Treatment BMPs) is a minimum standard that must be applied regardless of the quality of the receiving water(s). Additional levels of Runoff Treatment beyond Basic Treatment may be justified in order to control the impacts of future development.

Runoff Treatment requirements and performance standards developed from a Basin Plan should apply to individual development sites within the basin. Regional Runoff Treatment BMPs can be considered an acceptable substitute for on-site Runoff Treatment BMPs if they can meet the Runoff Treatment requirements and performance standards identified in the Basin Plan. A limitation to the use of regional Runoff Treatment BMPs is that the conveyances used to transport the stormwater to the Regional BMP must not include waters of the state that have existing or attainable beneficial uses other than drainage.

The above text describes how Basin Plans can influence Runoff Treatment requirements and performance standards for new and redevelopment. Basin Plans can also be used to identify structural retrofit Runoff Treatment requirements for reducing the effects of existing development on the aquatic resources.

Recommendations for Local Jurisdictions

During plan review, local jurisdictions should evaluate whether the objectives of Core Element #5 have been met. Staff should be aware of any current water cleanup plans (including TMDLs), sole-source aquifer protection measures, wellhead protection areas, or other requirements to protect or restore water quality.

Each local jurisdiction should identify a preferred method for calculating (1) runoff volumes and (2) flow rates to ensure consistent sizing of Runoff Treatment BMPs in their jurisdiction and to facilitate plan review. Local jurisdictions may choose to accept road projects designed per another approved equivalent manual. Projects using BMPs in the latest approved edition of the WSDOT *Highway Runoff Manual* should still apply the Core Elements for new development and redevelopment in this manual. Proponents of unique or complex projects may wish to use other methodologies, and staff should work with those designers to ensure that the objectives of Core Element #5 are met.

For more information: Local jurisdictions are encouraged to assist in development and testing of new treatment methodologies. See 6.11 Manufactured Treatment Devices as BMPs for more information.

2.4.6 CE6: Flow Control

All new development and redevelopment projects meeting the Project Thresholds in 2.3 Applicability of the Core Elements shall apply Flow Control BMPs in accordance with the following thresholds, standards, and requirements to reduce the impacts of stormwater runoff from hard surfaces and land cover conversions.

The text in this box originates from one or more of the following Permits:
Appendix 1 of the Phase I / Phase II Municipal Stormwater Permits
Construction Stormwater General Permit

Core Element Exemption

Flow Control is not required for projects that discharge directly to, or indirectly through an MS4 to a water listed in Appendix 2-C: Flow Control Exempt Receiving Waters, subject to all of the following restrictions:

- Stormwater runoff should not be diverted from the project area to an existing wetland, stream, or near-shore habitat sufficient in quantities large enough to result in significant adverse impact. Adverse impacts are expected from uncontrolled flows causing a significant increase or decrease in the 1.5- to 2-year peak flow rate.

- The project must be drained by a conveyance system that is comprised entirely of manmade conveyance elements (e.g. pipes, ditches, outfall protection).
- The conveyance system must extend to the ordinary high water mark of the exempt receiving water (or the mean higher high water mark for tidally influenced exempt receiving waters). To avoid construction activities in sensitive areas, an alternative to extending the conveyance system to the ordinary high water mark is to ensure that flows are properly dispersed (see 6.1.10.3 Outfall Systems) before reaching the buffer zone of the sensitive or critical area.
- The conveyance system between the project and the exempt receiving water shall have sufficient hydraulic capacity (per local jurisdiction conveyance sizing requirements) to convey discharges from future build-out conditions (under current zoning) from contributing areas of the Site, and the existing condition from contributing off-site areas.
- Any erodible elements of the manmade conveyance system must be adequately stabilized to prevent erosion under the conditions noted above.

Note that Ecology does not consider newly constructed or reconstructed stream channels to be manmade conveyance elements.

Additionally, the following projects do not need to provide additional Flow Control BMPs to comply with this Core Element:

- Any project able to disperse (i.e. by using BMP F6.42: Full Dispersion), without discharge to surface waters, the total 25-year runoff volume for the proposed development condition on property that is under the functional control of the project proponent.
- A road project able to disperse (i.e. by using BMP F6.42: Full Dispersion), without discharge to surface waters, the total 25-year runoff volume for the proposed development condition on land for which this use has been specifically authorized by the controlling entity.
- A project discharging to stream reaches consisting primarily of irrigation return flows and not providing habitat for fish spawning and rearing.
- A project located at a site with less than 10 inches of average annual rainfall that discharges to a seasonal stream that is not connected via surface flow to a nonexempt surface water by runoff generated by the 2-year Type IA design storm.
- A project that discharges to a stream that flows only during runoff-producing events. The runoff carried by the stream following the 2-year regional storm in Climate Regions 1 and 4, or the Type IA storm in Climate Regions 2 and 3, must not discharge via surface flow to a nonexempt surface water. The stream may carry runoff during an average annual snowmelt event but must not have a period of base flow during a year of normal precipitation.

> ***The text in this box originates from one or more of the following Permits:***
> *Appendix 1 of the Phase I / Phase II Municipal Stormwater Permits*
> *Construction Stormwater General Permit*

Any additional exemptions to and overriding of Core Element #6 are left to the local jurisdiction based on basin planning and studies. These plans and studies should consider: the total impervious area in the watershed under likely future development scenarios, other possible development impacts or contributions toward increasing future streamflow volumes and changing the stream channel morphology and/or increasing the potential for stream bank erosion, other potential cumulative downstream effects, and unique habitat characteristics.

Additional Exemption Options

Additional exemptions to Core Element #6 may be granted (by the local jurisdiction) to projects discharging to surface water where the long-term, projected total man-made impervious surface area in the contributing watershed is less than 10% of the total area, and at least 65% of the native vegetation is retained. This determination must be based on current and probable future zoning requirements and build-out conditions as determined through a basin analysis conducted by the local jurisdiction. This analysis could also be done for a road project in a rural area, although dispersion (i.e. BMP F6.42: Full Dispersion) would be preferable to conveyance of runoff to a nonexempt stream.

Local jurisdictions may also exempt a project discharging to a seasonal stream from Core Element #6 where a downstream analysis has concluded that the stream channel morphology was established by past glacial or catastrophic flooding events and the stream channel is capable of carrying a larger frequent streamflow without incision or widening. The stream must not discharge via surface flow to a nonexempt stream.

Suggested Approach for Additional Exemptions

In order for a jurisdiction to exempt other water bodies or reaches from flow control requirements, the local jurisdiction must provide scientific justification for the exemption. The exemption may apply only to restricted areas within a watershed. This means the jurisdiction must determine that under probable build-out conditions in the watershed, disregarding Core Element #6 will not adversely affect the receiving waters. Adverse impacts are expected from uncontrolled flows causing a significant increase in the 1.5- to 2-year recurrence interval peak instream flow rate. Documentation must be provided showing that significant increases in instream flow rates will not take place under the maximum projected development condition for the contributing watershed. The documentation should include at least the following elements:

- Analysis of available historical streamflow data for the water body and hydrologic modeling of the watershed under both undeveloped and projected future build-out conditions. For a lake, the outlet stream may be the primary water body of interest for flow control.
- Observation of downstream channel conditions, including: assessment of the geomorphic conditions, instream habitat, and resident benthic community.
- Maps or geographic analyses showing the following:

    - Current and probable future zoning with definitions for density of development in each category
    - The portion of watershed under the jurisdiction of the petitioner
    - Projected total impervious surface areas
    - Area of native vegetation preserved under probable future build-out conditions
- Description of the watershed planning efforts undertaken by the petitioning jurisdiction and cooperative planning efforts undertaken with other agencies and jurisdictions with authority in the watershed.

A local jurisdiction also should consider and use the information provided in this section when planning and designing a regional Flow Control BMP, and in particular for determining the appropriate capacity and operation requirements of the BMP.

Core Element Thresholds

Each project that requires Core Element #6 (per the Project Thresholds in 2.3 Applicability of the Core Elements) must be reviewed to determine if Flow Control BMPs are required for the project to be in compliance with Core Element #6.

Note that it is possible for a project that triggers the thresholds for Core Element #6 per the Project Thresholds in 2.3 Applicability of the Core Elements to not need Flow Control BMP(s) to be in compliance with Core Element #6. If a project does not trigger either of the Core Element thresholds for Flow Control BMPs, then the designer must document the areas within the project used to determine that neither of the Core Element thresholds are met. This documentation will demonstrate compliance with Core Element #6 for the project.

When assessing a project against the following thresholds, only consider the types of surfaces (e.g. new hard surfaces, replaced hard surfaces, converted vegetation areas) that are subject to Core Element #6, per the Project Thresholds in 2.3 Applicability of the Core Elements.

The following projects require construction of Flow Control BMPs to achieve the Flow Control Performance Standard. If a project meets any of the following thresholds, Flow Control BMPs are required. The project proponent must demonstrate that the project does not meet any of the following thresholds for Flow Control BMPs to not be required for the project.

- Projects that have a total of 10,000 square feet or more of effective impervious surfaces, or
- Projects that convert ¾ acres or more of native vegetation, pasture, scrub/shrub, or unmaintained non-native vegetation to lawn or landscape, or convert 2.5 acres or more of native vegetation to pasture, and from which there is a surface discharge in a natural or man-made conveyance system from the project, or

- Projects that through a combination of effective hard surfaces and converted vegetation areas cause a 0.15 cubic feet per second (cfs) or greater increase in the runoff for the 25-year, 24-hour, storm event (using a 15 minute time-step).

  The 0.15 cfs increase should be a comparison of the post project runoff to the existing condition runoff. For the purpose of applying this threshold, the existing condition is either the pre-project land cover, or the land cover that existed prior to the first issue date of the Municipal Stormwater Permit to the local jurisdiction.

The text in this box originates from one or more of the following Permits:
Appendix 1 of the Phase I / Phase II Municipal Stormwater Permits
Construction Stormwater General Permit

Flow Control Performance Standard

Projects must limit the peak release rate of the post-developed 2-year, 24-hour peak flow to 50% of the pre-developed 2-year, 24-hour peak flow and maintain the pre-developed 25-year, 24-hour peak runoff rate. Check the 100-year, 24-hour event for downstream flooding and property damage.

Additionally, the 10-year, 24-hour rainfall event must be retained on-site without any discharge to the MS4.

The above requirements must be demonstrated using a single-event model.

The pre-developed condition used for the analysis shall be the existing land cover.

The text in this box originates from one or more of the following Permits:
Appendix 1 of the Phase I / Phase II Municipal Stormwater Permits
Construction Stormwater General Permit

Alternative Flow Control Performance Standard

An alternative Flow Control Performance Standard may be established through application of watershed-scale hydrologic modeling and supporting field observations. Possible reasons for an alternative Flow Control Performance Standard include:

- Establishment of a stream–specific threshold of significant bedload movement other than the assumed 50% of the 2-year peak flow;
- Zoning and Land Clearing Ordinance restrictions that, in combination with an alternative Flow Control Performance Standard, maintain or reduce the naturally occurring erosive forces on the stream channel; or
- A duration control standard is not necessary for protection, maintenance, or restoration of designated and existing beneficial uses or Clean Water Act compliance.

The text in this box originates from one or more of the following Permits:
Appendix 1 of the Phase I / Phase II Municipal Stormwater Permits
Construction Stormwater General Permit

Additional Requirement

Flow Control BMPs shall be selected, designed, and maintained in accordance with this manual.

The text in this box originates from one or more of the following Permits:
Appendix 1 of the Phase I / Phase II Municipal Stormwater Permits
Construction Stormwater General Permit

Objective

The purpose of this Core Element is to mitigate, to the maximum extent practicable, the impacts of increased stormwater runoff volumes and flow rates on streams in eastern Washington. The intent of this Core Element is to prevent cumulative future impacts due to urban runoff and protect stream morphology. The impacts of prior development and/or flow modifications in eastern Washington are not addressed in this manual.

Wherever possible, infiltration is the preferred method of Flow Control for urban runoff. Some stream habitat problems in eastern Washington result from reduced instream flows during the hot summer months. Flow Control using detention BMPs will not address this issue and may exacerbate it. The cumulative effect of infiltrating urban runoff, where feasible, should have a neutral or possibly beneficial effect.

Core Element #6 is targeted to smaller water bodies, especially first to third order streams or water bodies with contributing watershed areas of less than 100 square miles. These smaller streams and water bodies are more susceptible than larger streams and water bodies to changes in runoff patterns caused by development.

Core Element #6 is also targeted to wetlands. Discharges to wetlands should maintain the hydrology (depth and duration of inundation) of the existing condition in order to protect the unique vegetation and other characteristics necessary to support existing and designated uses.

Note: Design specifications for conveyance and flood prevention are determined by local jurisdictions. This Core Element does not address those issues.

Supplemental Guidelines

Reduction of flows through infiltration decreases stream channel erosion and helps to maintain base flow throughout the summer months. Infiltration should follow the guidance in this manual to reduce the chance of threatening groundwater quality.

Using LID BMPs reduces the predicted runoff rates and volumes, and thus also reduces the size of required Flow Control BMPs.

Diversion of flow from perennial streams and from wetlands can be considered if significant existing (i.e. pre-project) flooding, stream stability, water quality, or aquatic habitat problems would be solved or significantly mitigated by bypassing stormwater runoff rather than providing stormwater detention and discharge to natural drainage features. Bypassing should not be considered as an alternative to applicable Flow Control or Runoff Treatment if the flooding, stream stability, water quality or habitat problem to be solved would be caused by the project. In addition, the proposal should not exacerbate other water quality/quantity problems such as inadequate low flows or inadequate wetland water elevations. The existing problems and their solution or mitigation as a result of the direct discharge should be documented by a stormwater engineer or scientist after review of any available drainage reports, basin plans, or other relevant literature. The restrictions in this Core Element on conveyance systems that transfer water to an exempt receiving water are also applicable in these situations. Approvals by all regulatory authorities with relevant permits applicable to the project are necessary.

To meet Core Element #6, designers may use infiltration BMPs that are also considered UIC wells. These BMPs must be designed to meet the Flow Control requirements for Core Element #6 and must be registered as a UIC well.

Use of Pumps While Meeting CE6

Ecology does not have guidance on pump design. If a pump is required (e.g. due to the topography of the project site), it must be designed to ensure that the discharge from the site meets the Flow Control Performance Standard within this CE.

- This most likely will mean that the pump is upstream of the Flow Control BMP, and the Flow Control BMP modeling must consider the flow from the pump into the storage area of the Flow Control BMP.
- If the pump is placed downstream of a Flow Control BMP (or no Flow Control BMP is used), then the flow from the pump would be considered the discharge from the site, and the design would need to show that the discharge from the pump meets the Flow Control Performance Standard.

Hydrologic Analysis

Estimate predevelopment or existing and proposed development condition runoff volumes and flow rates using the methods described in Chapter 4 - Hydrologic Analysis and Design or by an alternative method approved by the local jurisdiction.

Local jurisdictions may adopt a conservative, restricted set of curve numbers for estimating runoff volumes and flow rates from predevelopment or existing conditions. Ecology recommends that local jurisdictions consider applying native vegetation predevelopment conditions. Native vegetation generally reduces stormwater runoff during rain-on-snow events, and changes in cover should be a primary consideration in evaluating the change in runoff volumes caused by development in many areas of eastern Washington.

In order to reduce potential effects of increased water temperatures during the hot summer months, projects should consider withholding the total runoff volume for the proposed development condition from the 2-year short-duration storm in the detention BMP for infiltration (preferred) and/or evaporation.

Local jurisdictions may require detention basins to be designed to match the 10-year peak flow in addition to 50% of the 2-year peak flow and the full 25-year peak flow. The purpose of this design specification is to improve the function of the detention basin in matching predeveloped or existing peaks between 50% of the 2-year peak flow and the full 25-year peak flow and possibly reduce the size of the detention BMP.

How to Determine an Alternative Flow Control Performance Standard

The local jurisdiction or project proponent may evaluate the substrate of a stream to determine whether the requirement to release the 2-year peak volume for the proposed development condition at 50% of the 2-year peak flow rate for the predevelopment or existing can and should be adjusted. The release rate of 50% of the 2-year peak flow rate is a middle ground that should be protective for most streams and was chosen for its ease of application. However, for a highly erodible substrate such as sand or loess the target should be closer to 20% of the 2-year peak flow rate. For an erosion-resistant substrate such as clay, the target could be closer to 90% of the 2-year peak flow rate. The substrate should be evaluated for a minimum distance of one-half mile downstream of the proposed discharge. The focus of the study should be on evaluating the erodibility of the downstream substrate under the probable build-out conditions to at least the next significant natural inflow, and the results considered together with studies and findings by (Leopold et al., 1964), (Williams, 1978), (Harvey and Watson, 1986), (Hammer, 1972), (Bledsoe and Watson, 2001), (Booth, 1997), and (Cappuccitti and Page, 2000) in making the determination.

Revising CE6 through a Basin Plan

Basin Plans (see Appendix 2-A: Altering the CEs with Basin Plans) are well-suited to control stream channel erosion for both existing and future conditions. Flow Control standards developed from a Basin Plan may be used to alter the default standards described above, and can include a combination of on-site, regional, and stream protection and rehabilitation measures, and retrofitting opportunities.

- On-site standards are usually the primary mechanism to protect streams from the impacts of increased high flows in future conditions.
- Regional Flow Control facilities are used primarily to correct existing stream erosion problems.
- In-stream protection and rehabilitation measures may be applied where stream channel erosion problems exist that will not be corrected by on-site or regional facilities. However, caution is urged in the application of such measures. If the causes of the stream channel erosion problems still exist, repairs to the physical expression of those problems may be short-lived. In some instances, it may be prudent to apply in-stream measures to reduce impacts until the basin hydrology is improved. This does not alleviate the jurisdiction from needing to ensure that existing and beneficial uses are restored to the receiving water. In stream work cannot be used to satisfy the Core Elements under the permit.
- Retrofitting opportunities may include modified outlets for, and expansion of existing Detention BMPs.

Basin Plans may be used to:

- develop an Alternative Flow Control Performance Standard, as described above.
- identify additional receiving waters as Flow Control Exempt, as described in Appendix 2-C: Flow Control Exempt Receiving Waters.

Recommendations for Local Jurisdictions

During plan review, local jurisdictions should evaluate whether the objectives of Core Element #6 have been met. Local jurisdictions should establish design criteria for conveyance systems, flood protection, and drywells and other UIC wells.

In particular, local jurisdictions should determine whether the default design criterion of the 25-year runoff volume for detention/retention flow control BMPs is appropriate to meet local flood protection goals and, if it is not, establish a different upper boundary design criterion.

Local jurisdictions should also determine whether the default design criteria for BMP F6.20: Drywells are appropriate to meet local goals. In particular, knowledge of local geology and groundwater levels may lead to specific siting and infiltration capacity requirements, or to development of presumptive infiltration rates for certain areas in the local jurisdiction. These criteria and local information should be made readily available to designers.

2.4.7 CE7: Operation and Maintenance

All new development and redevelopment projects meeting the Project Thresholds in 2.3 Applicability of the Core Elements shall create an operation and maintenance (O&M) manual for all BMPs used to meet 2.4.5 CE5: Runoff Treatment, 2.4.6 CE6: Flow Control, and/or 2.4.8 CE8: Wetlands Protection.

The O&M manual shall identify:

- Maintenance requirements that are consistent with the provisions in Chapter 6 - Runoff Treatment, Flow Control, and LID BMP Library, and
- The party (or parties) responsible for the operation, maintenance, and long-term funding source(s).

At private facilities, a copy of the O&M manual shall be retained on site or within reasonable access to the site, and shall be transferred with the property to the new owner. For public facilities, a copy of the O&M manual shall be retained in the appropriate department.

A log of maintenance activity that indicates what actions were taken shall be kept and be available for inspection by the local government.

The text in this box originates from one or more of the following Permits:
Appendix 1 of the Phase I / Phase II Municipal Stormwater Permits
Construction Stormwater General Permit

Objective

The objective of this Core Element is to ensure that Stormwater Management BMPs are properly maintained and operated. Projects are required to plan for and perform appropriate preventive maintenance and performance checks at regular intervals.

Supplemental Guidelines

Inadequate maintenance is a common cause of failure for Stormwater Management BMPs. See the maintenance section within each BMP, as well as the tables in Appendix 6-A: BMP Maintenance Tables. Local governments should consider more detailed requirements for maintenance logs, such as a record of where wastes were disposed.

Local governments may develop generic O&M plans, including checklists of actions and procedures for the operators, for BMPs that are commonly used in public projects. Commercial and residential property developers may also develop generic O&M plans, including checklists of actions and procedures for the operators, for BMPs that are commonly used in their projects.

O&M information for conveyance systems should also be developed. Conveyance is not discussed in this manual, but proper operation of the conveyance system is integral to the successful operation of the Stormwater Management BMPs.

Recommendations for Local Jurisdictions

As part of plan review and approval, local jurisdictions should consider a performance bond for operation and maintenance of BMPs at the site. Staff can enforce proper operation and maintenance requirements during site inspections or in response to complaints about a site or BMP.

2.4.8 CE8: Wetlands Protection

All new development and redevelopment projects meeting the Project Thresholds in 2.3 Applicability of the Core Elements shall include Stormwater Management BMPs in accordance with the following thresholds, standards, and requirements to reduce the impacts of stormwater runoff to wetlands.

The text in this box originates from one or more of the following Permits:
Appendix 1 of the Phase I / Phase II Municipal Stormwater Permits
Construction Stormwater General Permit

Core Element Thresholds

This Core Element applies only to projects whose stormwater discharges into a wetland, either directly or indirectly through a conveyance system.

The text in this box originates from one or more of the following Permits:
Appendix 1 of the Phase I / Phase II Municipal Stormwater Permits
Construction Stormwater General Permit

Levels of Wetland Protection

The following Levels of Wetland Protection are further explained in Appendix 2-D: Wetland Protection Guidelines.

General Protection

General Protection includes general practices that benefit wetlands of all types. See 2.D.2 General Wetland Protection for details.

Protection from Pollutants

Protection from Pollutants includes measures to protect the wetland from pollutants in stormwater runoff. Measures of protection include Construction Stormwater BMPs, Source Control BMPs, LID practices and principles, and Runoff Treatment BMPs. See 2.D.3 Wetland Protection from Pollutants for details.

Wetland Hydroperiod Protection

Wetland Hydroperiod Protection includes measures to avoid excessive hydrologic alteration of existing wetlands from development.

See 2.D.4 Wetland Hydroperiod Protection for details.

The text in this box originates from one or more of the following Permits:
Appendix 1 of the Phase I / Phase II Municipal Stormwater Permits
Construction Stormwater General Permit

Additional Requirements

Stormwater Management BMPs shall not be built within a wetland or its buffer, except for:

- Necessary conveyance systems as approved by the local government; or
- As allowed in 2.D.6 Compensatory Mitigation of Wetlands.

The text in this box originates from one or more of the following Permits:
Appendix 1 of the Phase I / Phase II Municipal Stormwater Permits
Construction Stormwater General Permit

Objective

The objective of this Core Element is to ensure that wetlands receive the same level of protection as any other water of the state. Wetlands are complex and extremely important natural resources that provide important functions, including water quality improvement, groundwater recharge, flood control, stream channel erosion protection, and habitat for wildlife. They are easily impacted by development unless careful planning and management are conducted. Wetlands can be severely degraded by stormwater discharges from urban development due to pollutants in the runoff and disruption of the natural hydrologic pattern of the wetland.

Supplemental Guidelines

Appendix 2-D: Wetland Protection Guidelines shall be used for discharges to natural wetlands and mitigated wetlands.

How Do I Reconcile the Flow Control Performance Standard from CE6 with CE8?

In most cases, if Wetland Hydroperiod Protection is required per this Core Element, then the Flow Control Performance Standard is also required per 2.4.6 CE6: Flow Control. In these cases, the designer must attempt to meet the requirements for both CEs.

If the designer is unable to meet both requirements, then the requirement to maintain the hydroperiod of the wetland becomes the overriding concern and the designer must show compliance with this Core Element. If this is the case, the designer must also provide documentation detailing why they are unable to meet both requirements.

Revising CE8 through a Basin Plan

Basin Plans (see Appendix 2-A: Altering the CEs with Basin Plans) can be used to develop alternative protection standards for wetlands and other sensitive areas, such as landslide hazard areas, wellhead protection areas, and groundwater quality management areas. These standards can include Source Control, Runoff Treatment, Flow Control, stage levels, and frequency and duration of inundations.

2.5 Additional Protective Measures

2.5.1 What Are Additional Protective Measures (APMs)?

Additional Protective Measures (APMs) are measures above and beyond the Core Elements (CEs) that Ecology recommends for local governments to consider in their stormwater program. Ecology considers their use to be in the best interest of the general public and the environment, but will not make their implementation a requirement for manual equivalency or permit compliance.

Project proponents must check with the local jurisdiction to determine what local requirements apply beyond the Core Elements (CEs) (see 2.5.4 APM3: Local Requirements).

2.5.2 APM1: Financial Liability

Ecology recommends that local governments require performance bonding or other appropriate financial guarantees for all projects to ensure construction of Stormwater Management BMPs in compliance with these standards. In addition, Ecology recommends that local governments require a project applicant post a minimum two-year financial guarantee of the satisfactory performance and maintenance of any Stormwater Management BMPs that are scheduled to be assumed by the local government for operation and maintenance.

Local governments may choose to require longer performance bonds for certain project types, such as those that use the demonstrative approach (see 1.1.8 Presumptive versus Demonstrative Approaches to Protecting Water Quality).

Objective

The objective of this APM is to ensure that development projects have adequate financial resources to fully implement their stormwater management requirements and that liability is not unduly incurred by local governments.

Supplemental Guidelines

The type of financial instrument required is less important than ensuring that there are adequate funds available in the event that non-compliance occurs.

2.5.3 APM2: Off-Site Analysis Report

Ecology recommends that local governments require development projects that discharge stormwater off-site to submit an off-site analysis report that assesses the potential off-site water quality, erosion, slope stability, and drainage impacts associated with the project, and proposes appropriate mitigation for those impacts. The report should also assess the amount of off-site run-on from upstream off-site areas that may affect the site design.

The initial qualitative analysis shall extend along the flow path from the project site to the receiving water, for a distance up to one mile. If the receiving water is within one-quarter mile from the project site, the analysis shall extend within the receiving water to one-quarter mile from the project site. The analysis shall extend one-quarter mile beyond any improvements proposed as mitigation. The analysis must extend upstream from the project site to a point where there are no backwater effects created by the project, and the designer can determine all areas contributing run-on to the project.

The existing or potential impacts to be evaluated and mitigated should include:

- Conveyance system capacity problems;
- Localized flooding;
- Erosion, including landslide hazards and erosion along streambanks and at the outfall location;
- Violations of surface water quality standards as identified in a Basin Plan or a TMDL; or violations of groundwater quality standards in a wellhead protection area.

Objective

The objective of the off-site analysis report is to identify, evaluate, and determine measures to prevent off-site water quality, erosion, slope stability, and drainage impacts that may be caused or aggravated by a proposed project. "Aggravated" shall mean increasing the frequency of occurrence and/or severity of a problem.

Supplemental Guidelines

Some of the most common and potentially destructive impacts of land development are erosion of downgradient properties, localized flooding, and slope failures. These are caused by increased surface water volumes and changed runoff patterns. Because these problems frequently do not have a related water quality impact, Ecology is not listing off-site analysis as a Core Element.

However, taking the precautions of off-site analysis could prevent substantial property damage and public safety risks.

The existing or potential impacts to be evaluated and mitigated should include the following:

- Conveyance system capacity problems
- Localized flooding
- Upland erosion impacts, including landslide hazards
- Downstream impacts to protective designations, including special resource waters, sole source aquifers, and recharge areas
- Stream channel erosion at the outfall location
- Violations of surface water quality standards as identified in a basin plan or a Total Maximum Daily Load (water cleanup plan); or violations of groundwater standards in a wellhead protection area

Projects should be required to initially submit, with the permit application, a qualitative off-site analysis report of each downstream system leaving a site. Upon review of the qualitative analysis, the local project reviewer may require that a quantitative analysis be performed. A quantitative off-site analysis report should contain the following:

1. **Define and map the study area**

   The off-site analysis report should include a map of the study area to show:

   - the study area's boundaries;
   - the study area's topography (at a minimum a USGS 1:24000 Quadrangle Topographic map);
   - the site's property lines;
   - the boundaries of proposed land disturbance;
   - the downstream flow path(s);
   - the tributary drainage areas to the downstream flow path(s); and
   - existing and/or potential problems.

2. **Review all available information on the study area**

   The designer should review, and the off-site analysis report should summarize all available basin plans, groundwater management area plans, geotechnical reports, drainage studies, floodplain/floodway FEMA maps, wetlands inventory maps, Critical Areas maps, stream habitat reports, salmon distribution reports, etc. within the study area. Contact the local jurisdiction for assistance in locating these and other relevant or historical data.

3. **Field inspect the study area**

The designer should physically inspect the existing on- and off-site drainage systems within the study area for existing or potential problems and drainage features. An initial inspection and investigation should include:

- Investigate problems reported or observed during the resource review;
- Locate existing/potential constrictions or capacity deficiencies in the drainage system;
- Identify existing/potential flooding problems;
- Identify existing/potential overtopping, scouring, bank sloughing, or sedimentation;
- Identify significant destruction of aquatic habitat (e.g. siltation, stream incision);
- Collect qualitative data on features such as land use, impervious surface, topography, geological hazards, soils, and presence of streams and/or wetlands;
- Collect information on pipe sizes, channel characteristics, and drainage structures;
- Verify contributing drainage areas identified in the mapped study area;
- Contact the local government office with drainage review authority, neighboring property owners, and residents about drainage problems;
- Note date and weather at time of inspection.

The results of this inspection should be detailed in the off-site analysis report.

4. **Describe the drainage system, and its existing and predicted problems**

For each drainage system component (e.g. pipe, culvert, bridges, outfalls, ponds, vaults) the following should be covered in the off-site analysis report: location, physical description, problems, and field observations.

All existing or potential problems (e.g. ponding water, erosion) identified from the field inspection and information review should be described. The descriptions should be used to determine whether adequate mitigation can be identified, or whether a more detailed quantitative analysis is necessary. The following information should be provided for each existing or potential problem:

- Magnitude of or damage caused by the problem
- General frequency and duration
- Return frequency of storm or flow when the problem occurs (may require quantitative analysis)
- Water elevation when the problem occurs
- Names and concerns of parties involved
- Current mitigation of the problem

- Possible cause of the problem
- Whether the project is likely to aggravate the problem or create a new one.

Upon review of this analysis, the local jurisdiction may require mitigation measures to address the problems, or a quantitative analysis, depending on the presence of existing or predicted flooding, erosion, or water quality problems, and on the proposed design of the Stormwater Management BMPs.

If required, the quantitative analysis should repeat Tasks 3 and 4 (above), using quantitative field data including profiles and cross sections. The quantitative analysis should provide information on the severity and frequency of an existing problem or the likelihood of creating a new problem. It should also evaluate proposed mitigation intended to avoid aggravation of the existing problem and to avoid creation of a new problem.

2.5.4 APM3: Local Requirements

Objective

This manual describes the minimum Core Elements for stormwater management at project sites in eastern Washington. Due to the variety in hydrology, climate, topography, soils, and priorities for protection of water resources in some areas of eastern Washington, discretion is provided to local jurisdictions in expanding and implementing stormwater requirements.

Guidelines

All projects, regardless of size, shall meet additional local requirements for flood control, discharges to wetlands, protection of sensitive areas, basin plans, aquifer protections, special water quality requirements based on a TMDL or water cleanup plan, or for any other purpose. Check with the local jurisdiction for the local requirements that are applicable to your project. See also Chapter 8 - Source Control, which provides guidance for selecting BMPs to meet 2.4.3 CE3: Source Control of Pollution. Chapter 8 - Source Control can help local jurisdictions and businesses to control urban sources of conventional and toxic pollutants in stormwater and add them in meeting state water quality standards to protect beneficial uses of receiving waters.

Recommendations for Local Jurisdictions

The following list provides examples of local standards, requirements, preferences, and tools to simplify implementation of this manual that may be considered or developed at the local jurisdiction level:

- Simplified or templated SSPs or Construction Stormwater Pollution Prevention Plans (SWPPPs) to ease the designer’s process of developing those documents for specific types of projects
- Clear, jurisdiction-specific submittal requirements for SSPs and SWPPPs
- Actions required under current water cleanup plans (such as TMDLs) or other measures necessary to protect or restore water quality
- Sole-source aquifer protection requirements and/or wellhead protection area requirements

- Preferred design storm and hydrologic analysis methods for calculating runoff volumes and flow rates to ensure consistent sizing of Runoff Treatment BMPs within the jurisdiction (based on the guidance included in Chapter 4 - Hydrologic Analysis and Design)
- A determination of whether a downstream jurisdiction's requirements may apply when jurisdictions have interconnected storm sewer systems (neighboring jurisdictions should work together to establish consistent design criteria for stormwater BMPs since hydrologic conditions are likely to be similar)
- Information on LID standards, requirements, or technical guidance for preserving native vegetation and reducing the amount of impervious surface area
- Preferred field and laboratory testing procedures for infiltration testing (based on the guidance included in 6.5.4 Determining the Design Infiltration Rate of the Native Soils)
- Design criteria for conveyance systems and flood prevention
- Design criteria for drywells, particularly infiltration capacity requirements and related local geologic information
- Design requirements for snowmelt, particularly BMP sizing requirements that factor snowmelt or rain-on-snow in determining appropriate design flows
- Plant requirements or recommended planting lists or methods
- Any alternative impervious area or other threshold below which projects are not required to provide Flow Control BMPs
- Retrofit requirements (if applicable)
- Additional exemptions (or exceptions) to the list of exempt surface waters
- Detailed operation and maintenance requirements
- Any other adjustments to the Core Elements or to the new and redevelopment requirements

2.6 Adjustments and Exceptions to the CEs

2.6.1 Adjustments to the CEs

Adjustments to the Core Elements may be granted by the jurisdiction provided that written findings of fact are prepared that address the following:

- The adjustment provides substantially equivalent environmental protection.
- Based on sound Engineering practices, the objectives of safety, function, environmental protection, and facility maintenance are met.

The text in this box originates from one or more of the following Permits:
Appendix 1 of the Phase I / Phase II Municipal Stormwater Permits
Construction Stormwater General Permit

Supplemental Guidelines

If an adjustment is requested by the project proponent, the jurisdiction must approve or deny the request prior to the development permit approval and construction beginning.

Adjustments may be used to alter the performance standards of one or more Core Elements (CEs). Adjustments may not be used to alter the design criteria of the BMPs used to comply with the CEs. If a project proponent wants to alter the design criteria of a BMP, they must follow the Demonstrative Approach for that BMP (see 1.1.8 Presumptive versus Demonstrative Approaches to Protecting Water Quality).

Adjustments are site specific requests between the project proponent and the jurisdiction. Ecology does not have a role in reviewing or approving adjustments. If either a project proponent or a jurisdiction wants to seek approval to alter the performance standards of one or more CEs for an area larger than a single site, a Basin Plan must be submitted for Ecology review and approval (see Appendix 2-A: Altering the CEs with Basin Plans).

The adjustment provisions are an important element of the plan review and enforcement programs. They are intended to maintain a necessary flexible working relationship between local officials and applicants. Plan Approval Authorities should consider these requests judiciously, keeping in mind both the need of the applicant to maximize cost-effectiveness and the need to protect off-site properties and resources from damage.

2.6.2 Exceptions to the CEs

Exceptions to the Core Elements may be granted by the jurisdiction following legal public notice of an application for an exception, legal public notice of the jurisdiction’s decision on the application, and written findings of fact that document the jurisdiction’s determination to grant an exception.

The jurisdiction may grant an exception to the Core Elements if such application imposes a severe and unexpected economic hardship. To determine whether the application imposes a severe and unexpected economic hardship on the project applicant, the jurisdiction must consider and document, with written findings of fact, the following:

- The current (pre-project) use of the Site, and
- How the application of the Core Element(s) restricts the proposed use of the Site compared to the restrictions that existed prior to the adoption of the Core Elements; and
- The possible remaining uses of the Site if the exception were not granted; and

- The uses of the Site that would have been allowed prior to the adoption of the Core Elements; and
- A comparison of the estimated amount and percentage of value loss as a result of the Core Elements versus the estimated amount and percentage of value loss as a result of requirements that existed prior to adoption of the Core Elements; and
- The feasibility for the owner to alter the project to apply the Core Elements.

In addition, any exception must meet the following criteria:

- The exception will not increase risk to the public health and welfare, nor be injurious to other properties in the vicinity and/or downstream, and to the quality of waters of the state; and
- The exception is the least possible exception that could be granted to comply with the intent of the Core Elements.

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Appendix 1 of the Phase I / Phase II Municipal Stormwater Permits
Construction Stormwater General Permit

Supplemental Guidelines

If an exception is requested by the project proponent, the jurisdiction must approve or deny the request prior to the development permit approval and construction beginning.

Exceptions are site specific requests between the project proponent and the jurisdiction. Ecology does not have a role in reviewing or approving exceptions. If either a project proponent or a jurisdiction wants to seek approval for relief from one or more of the Core Elements for an area larger than a single site, a Basin Plan must be submitted for Ecology review and approval (see Appendix 2-A: Altering the CEs with Basin Plans).

The exception provisions are an important element of the plan review and enforcement programs. They are intended to maintain a necessary flexible working relationship between local officials and applicants. Plan Approval Authorities should consider these requests judiciously, keeping in mind both the need of the applicant to maximize cost-effectiveness and the need to protect off-site properties and resources from damage.

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Appendix 2-A: Altering the CEs with Basin Plans

Ecology promotes Basin Plans as a means to develop and implement comprehensive water quality protection measures. Primary objectives of Basin Plans are to reduce pollutant loads and hydrologic impacts to surface and groundwaters in order to protect beneficial uses within a basin.

Although the Core Elements establish general standards for individual sites, a Basin Plan is needed to evaluate the overall pollution impacts and protection opportunities that could exist at the watershed level.

Basin Plans provide a mechanism by which the performance standards in the Core Elements can be evaluated and refined based on an analysis of an entire basin or watershed. Basin Plans are especially well suited to develop control strategies to address impacts from future development, and to correct specific problems whose sources are known or suspected. Basin Plans can be effective at addressing both long-term cumulative impacts of pollutant loads and short-term acute impacts of pollutant concentrations, as well as hydrologic impacts to streams, wetlands, and groundwater resources.

Ecology has not published definitive guidance regarding the scope of work for Basin Plans. Ecology hopes to have such guidance available for urbanized basins in the future after assessing the procedures and experiences of some test cases. We encourage you to contact your regional permit specialist if you are interested in conducting a Basin Plan.

What Are Basin Plans?

A Basin Plan is a plan that assesses, evaluates, and proposes solutions to existing and potential future impacts to the beneficial uses of, and the physical, chemical, and biological properties of waters of the state within a basin. Basins typically range in size from 1 to 50 square miles. A plan should include but not be limited to recommendations for:

- Stormwater requirements for new development and redevelopment;
- Capital improvement projects;
- Land Use management through identification and protection of critical areas, comprehensive land use and transportation plans, zoning regulations, site development standards, and conservation areas;
- Source control activities including public education and involvement, and business programs;
- Other targeted stormwater programs and activities, such as maintenance, inspections and enforcement;
- Monitoring; and
- An implementation schedule and funding strategy.

A plan that is “adopted and implemented” must have the following characteristics:

- It must be adopted by legislative or regulatory action of jurisdictions with responsibilities under the plan;
- Ordinances, regulations, programs, and procedures recommended by the plan should be in effect or on schedule to be in effect; and,
- An implementation schedule and funding strategy that are in progress.

Revising Core Element Default Standards through Basin Plans

Basin Plans provide a mechanism by which the performance standards in the Core Elements can be evaluated and refined based on an analysis of a basin or watershed. Basin Plans may be used to develop control strategies to address impacts from future development and to correct specific problems whose sources are known or suspected. Basin Plans can be effective at addressing both long-term cumulative impacts of pollutant loads and short-term acute impacts of pollutant concentrations, as well as hydrologic impacts to streams, wetlands, and groundwater resources.

Basin Plans may be used by the local jurisdiction to revise the default standards of the following Core Elements:

- 2.4.5 CE5: Runoff Treatment,
- 2.4.6 CE6: Flow Control, and/or
- 2.4.8 CE8: Wetlands Protection.

In order for a Basin Plan to serve as a means of revising the standards of one or more of the Core Elements listed above, the following conditions must be met:

- The Basin Plan must be formally adopted by all jurisdictions with responsibilities under the plan; and
- All ordinances or regulations called for by the Basin Plan must be in effect; and
- The Basin Plan must be reviewed and approved by Ecology.

Further guidance, if available, specific to revising the default standards of individual Core Elements through a Basin Plan is provided in the supplemental guidelines of the Core Element.

The text in this box originates from one or more of the following Permits:
Appendix 1 of the Phase I / Phase II Municipal Stormwater Permits
Construction Stormwater General Permit

Basin Plans That Have Been Approved by Ecology

The following Basin Plans have been approved by Ecology for incorporation into local codes:

- Alternative Flow Control Requirement in Central Sub-Area, Issaquah, WA
- Mill Creek Alternative Flow Control, Clark County, WA

- Des Moines Creek Regional Detention Facility, King County, WA

This list will be updated with each manual release and may not reflect all approved plans at the time of reading.

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Appendix 2-B: Basic Treatment Receiving Waters

Table 2.1: Basic Treatment Receiving Waters

Waterbody Type	Waterbody Name	Details
1. Rivers	**River Name**	**Basic Treatment Applies Downstream of This Location**
	Columbia	Canadian Border
	Grande Ronde	(Basic Treatment applies to entire river)
	Kettle	(Basic Treatment applies to entire river)
	Klickitat	(Basic Treatment applies to entire river)
	Methow	(Basic Treatment applies to entire river)
	Naches	(Basic Treatment applies to entire river)
	Okanogan	(Basic Treatment applies to entire river)
	Pend Oreille	(Basic Treatment applies to entire river)
	Similkameen	(Basic Treatment applies to entire river)
	Snake	(Basic Treatment applies to entire river)
	Wenatchee	(Basic Treatment applies to entire river)
	Yakima	(Basic Treatment applies to entire river)
2. Lakes	**Lake Name**	**County**
	Banks	Grant / Douglas
	Chelan	Chelan
	Moses	Grant
	Potholes (Reservoir)	Grant
Note: Local governments may petition for the addition of more waters to this list. The initial criteria for this list are rivers whose mean annual flow exceeds 1,000 cfs, and lakes whose surface area exceeds 300		

Table 2.1: Basic Treatment Receiving Waters (continued)

Waterbody Type	Waterbody Name	Details
acres. Additional waters do not have to meet these criteria, but should have sufficient background dilution capacity to accommodate dissolved metals additions from build-out conditions in the watershed under the latest Comprehensive Land Use Plan and zoning regulations.		

Appendix 2-C: Flow Control Exempt Receiving Waters

See 2.4.6 CE6: Flow Control for the criteria required for a project to be exempt from the Flow Control requirement.

Table 2.2: Flow Control Exempt Receiving Waters

Water Body	Upstream Point/Reach for Exemption (if applicable)
Exempt Surface Waters (Rivers and Lakes)	
Asotin Creek	Downstream of confluence with George Creek
Banks Lake	
Bumping River	Downstream of confluence with American River
Cle Elum River	Downstream of Cle Elum Lake
Columbia River	Downstream of Canadian border
Colville River	Downstream of confluence with Chewelah Creek
Grande Ronde River	
Kettle River	Downstream of confluence with Boulder Creek
Klickitat River	Downstream of confluence with West Fork
Lake Chelan	
Latah Creek (formerly called Hangman Creek)	Downstream of confluence with Rock Creek (in Spokane County)
Little Spokane River	Downstream of confluence with Deadman Creek
Lower Crab Creek	
Methow River	Downstream of confluence with Early Winters Creek
Moses Lake	
Naches River	Downstream of confluence with Bumping River
Okanogan River	
Palouse River	Downstream of confluence with South Fork Palouse River

Table 2.2: Flow Control Exempt Receiving Waters (continued)

Water Body	Upstream Point/Reach for Exemption (if applicable)
Pend Oreille River	
Potholes Reservoir	
Rock Creek	Downstream of confluence with Cottonwood Creek (in Whitman County)
Similkameen River	
Snake River	
Spokane River	
Teanaway River	Downstream of confluence of north and west forks
Tieton River	Downstream of Rimrock Lake
Toppenish Creek	Downstream of confluence with Wanity Slough
Touchet River	Downstream of confluence with Patit Creek
Tucannon River	Downstream of confluence with Pataha Creek
Walla Walla River	Downstream of confluence with Mill Creek
Wenatchee River	Downstream of confluence with Icicle Creek
Yakima River	Downstream of Lake Easton
Exempt Reservoirs	
Reservoirs on the Columbia, Snake, Pend Oreille, or Spokane Rivers	
Other reservoirs with outlet controls that are operated for varying discharges to the downstream reaches as for hydropower, flood control, irrigation, or drinking water supplies. Uncontrolled, flow-through impoundments are not exempt.	
Note: This list of exempt water bodies generally consists of fifth or greater order stream channels (determined from a 1:150,000-scale map) and lakes with watershed areas much > 100 square miles. The list is subject to change as more information is gathered. See the additional guidance below for additional receiving waters that may be considered Flow Control Exempt.	

Additional Guidance

The following receiving waters may be considered Flow Control Exempt:

1. Any river or stream that is:
    - Fifth order or greater as determined from a 1:24,000 scale map; or
    - Fourth order or greater as determined from a 1:100,000 or larger scale map.

    The maps should be standard USGS maps or GIS data sets derived from USGS base maps.
2. Any lake or reservoir with a contributing watershed area greater than 100 square miles.
3. Reservoirs with outlet controls that are operated for varying discharges to the downstream reaches as for hydropower, flood control, irrigation, or drinking water supplies. Uncontrolled, flow-through impoundments are not exempt.
4. Streams that flow only during runoff-producing events. The runoff carried by the stream following the 2-year, Type IA rainfall event must not discharge via surface flow to a non-exempt surface water. To be exempt, the stream may carry runoff during an average annual snowmelt event but must not have a period of baseflow during a year of normal precip-itation.

The other provisions of the Core Element Exemption must still be applied, and consideration should also be given to other information about the stream bed material and downstream channel conditions.

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Appendix 2-D: Wetland Protection Guidelines

2.D.1 Scope and Principles for Wetland Protection

Purpose

These guidelines are intended to prevent diminishment of the functions and values of wetlands by avoiding alterations to the structural, hydrologic, and water quality characteristics of existing wetlands to the extent feasible during new development, redevelopment, and stormwater management projects.

New development, redevelopment, and stormwater management projects may decrease the function and value of a wetland by:

- Increasing the amount of water flow discharged to a wetland.
- Decreasing the amount of water flow discharged to a wetland.
- Increasing the amount of pollutants discharged to a wetland.

This can happen even if the wetland is not physically altered for development or stormwater management purposes.

Regulatory Authority

Wetlands are Waters of the State as defined under Chapter 90.48 RCW, Surface Waters of the State under Chapter 173-201A WAC, and may be Waters of the U.S. according to the 2023 "Revised Definition of 'Waters of the United States'" rule and regulated under the Clean Water Act.

Every development project should follow the requirements of the State Environmental Policy Act. Proponents should contact the local permitting authority and any other agency that deals with wetland protection. Other state and federal agencies may also have jurisdiction over projects affecting wetlands such as the Washington State Departments of Ecology, Natural Resources, and Fish & Wildlife; the U.S. Environmental Protection Agency; and the U.S. Army Corps of Engineers.

Wetland Rating System

A wetland identified as a receiving water of a project needs to be rated using the *Washington State Wetland Rating System for Eastern Washington: 2014 Update* (Hruby, 2014) to determine its category and habitat score.

Wetlands in Washington State differ widely in their functions and values. The Washington State Wetland Rating System categorizes wetlands into four categories (I, II, III and IV) based on their sensitivity to disturbance, their rarity, our ability to replace them, and the functions they provide. Category I is the highest rated wetland and the most sensitive to disturbance and Category IV wetlands are the lowest rated, based on relatively low functions and values.

This Appendix uses categories and habitat scores for wetlands to determine the level of protection necessary to reduce the risk of loss of wetland functions and values.

The rating system does not replace a full assessment of wetland functions that may be necessary if wetlands are impacted and mitigation permits are required.

For more information on the wetland rating system refer to the following webpage:

https://ecology.wa.gov/Water-Shorelines/Wetlands/Tools-resources/Rating-systems

Wetland Protection Levels

The level of protection required for existing wetlands is based on the wetland category, habitat score, and the wetland characteristics.

The levels of wetland protection outlined in this Appendix include:

- 2.D.2 General Wetland Protection
- 2.D.3 Wetland Protection from Pollutants
- 2.D.4 Wetland Hydroperiod Protection

Information needs

The following information is needed to assess the impacts and risks to wetlands, and to determine the necessary protection level.

1. Size, boundary, and characteristics of the proposed project site, wetland contributing drainage area, and the wetland and its buffer.
2. Following Ecology's *Wetland Rating System for Eastern Washington: 2014 Update* (Hruby, 2014) determine:
    a. Wetland type (i.e. hydrogeomorphic class).
    b. Wetland category.
    c. Wetland habitat score.
3. Presence of rare, endangered, threatened, or sensitive species.
4. Presence of breeding populations of native amphibian species.

2.D.2 General Wetland Protection

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

1. Consult regulations issued under federal and state laws that regulate the discharge of pollutants to surface waters, including the Construction Stormwater General NPDES Permit.
2. Maintain the wetland buffer required by local and/or state regulations.

3. Retain areas of native vegetation connecting the wetland and its buffer with nearby wetlands and other contiguous areas of native vegetation.

4. Avoid compaction of soil and introduction of invasive plant or animal species in the wetland and its buffer.

5. Take measures to avoid general physical impacts (e.g. littering and vegetation destruction). Examples are protecting existing buffer zones, discouraging access - especially by vehicles, planting outside the wetland, and encouragement of stewardship and signage by landowners.

6. Any stormwater management practices, such as Runoff Treatment or Flow Control BMP implementation, must be done outside of the wetland buffer boundary, except limited circumstances where the wetland and/or buffer may be used for additional Runoff Treatment and/or Flow Control of stormwater (see 2.D.6 Compensatory Mitigation of Wetlands).

7. Discharge from a BMP or project site should be dispersed using a method to diffuse the flow before entering the wetland buffer.

8. Consider fences to restrict human access, but make sure it doesn't interfere with wildlife movement. They should be used when wildlife passage is not a major issue and the potential for intrusive impacts is high. When wildlife movement and intrusion are both issues, the circumstances will have to be weighed to make a decision about fencing. Check with the local and/or state agencies to determine if fencing would be allowed.

2.D.3 Wetland Protection from Pollutants

All wetlands (Categories I, II, III and IV) must receive the following protection from pollutants:

1. Provide Construction Stormwater BMPs as directed in 2.4.2 CE2: Construction Stormwater Pollution Prevention Plan (SWPPP) to prevent sediment and other pollutants from entering the wetland.

2. Provide Source Control BMPs as directed in 2.4.3 CE3: Source Control of Pollution. Refer to Chapter 8 - Source Control and local jurisdiction requirements.

   Note: Source Control BMPs may not be sufficient to protect wetlands from areas that use salts and other anti-icing and/or deicing chemicals. These chemicals can accumulate and impact the biological functions of a wetland. Separation and routing of runoff to an alternative discharge location may be necessary to protect the wetland from runoff from areas that use these chemicals .

   If the option to route runoff to an alternative discharge location is considered, there is potential for a conflict with the wetland hydroperiod requirements (see 2.D.4 Wetland Hydroperiod Protection) and 2.4.4 CE4: Preservation of Natural Drainage Systems and Outfalls. The Stormwater Site Plan (see 2.4.1 CE1: Preparation of a Stormwater Site Plan) must detail the efforts made to comply with both this requirement (protecting the wetland from pollutants) and the other applicable requirements. If all requirements cannot be met, a site-specific report from a wetland professional must be included to document that the design options chosen have the least amount of impact to both the wetland and the receiving water for the re-routed runoff .

3. Provide On-Site Stormwater Management and use LID principles as much as practicable for the site. LID principles and practices will help meet other wetland hydroperiod protection criteria and provide additional habitat.

4. Provide Runoff Treatment BMPs as directed in 2.4.5 CE5: Runoff Treatment to treat runoff prior to entering the wetland and its buffer.

   Note: If the thresholds for 2.4.5 CE5: Runoff Treatment are not met for a project, then it is not required to provide Runoff Treatment BMPs for that project to comply with 2.4.8 CE8: Wetlands Protection.

If the wetland is a special characteristic wetland (such as forested wetlands, bogs or calcareous fens, alkali wetlands, vernal pools, or wetlands of high conservation value), implement Runoff Treatment BMPs with the most advanced ability to control nutrient loads. Consider using Runoff Treatment BMPs with infiltration and active biological filtration.

2.D.4 Wetland Hydroperiod Protection

Protection of many wetland functions and values depends on maintaining the existing wetland's hydroperiod. This means maintaining the hydrology (depth and duration) of the existing condition in order to protect the unique vegetation and other characteristics to support existing and designated uses. The natural variability in Eastern Washington climates creates a broad range of hydrologic conditions that wetlands experience through time. Ecology is focused on preventing activities that greatly alter the hydroperiod with added emphasis given to activities that dry out wetlands.

General Criteria

Hydrologic modification shall not be allowed if the wetland is classified as Category 1 or Category 2 according to the Washington State Wetland Rating System for Eastern Washington (Ecology, 2014) unless the project proponent demonstrates that preferred methods of excess stormwater disposal (e.g. infiltration) are not possible at the site and that other options (e.g. evaporation) would result in more damage to the wetland by limiting inflow.

A wetland receiving stormwater from a new development or redevelopment project can be considered for hydrologic modification if it is a Category 3 or 4 wetland according to the Washington State Wetland Rating System for Eastern Washington (Ecology, 2014), and the following criteria are met:

- There is good evidence that the natural hydrologic regime of the wetland can be restored by augmenting its water supply with excess treated stormwater runoff, or the wetland is under imminent threat exclusive of stormwater management and could receive greater protection if acquired for a stormwater management project rather than left in existing ownership.
- The runoff is from the same natural drainage basin; the wetland lies in the natural routing of the runoff, and the site plan allows runoff discharge at the natural location. Exceptions may be made for regional facilities planned by the local jurisdiction, but the wetland should receive water from sites in the same watershed.

Stormwater runoff should not be diverted from the project area to an existing wetland in quantities large enough to result in significant adverse impact. Adverse impacts are expected from uncontrolled flows causing a significant increase or decrease in the 1.5- to 2-year peak flow rate.

Mitigation shall be required for the impact of hydrologic modification on a wetland.

Guidance to Avoid Drying Out Wetlands

Consider the following strategies and guidance to minimize impacts to the wetland hydroperiod and to avoid drying out the wetland:

- Implement BMPs that maintain the total discharge volumes from pre-development to post-development from the site.
- Do not infiltrate the total stormwater discharge volume from the site if that discharge has previously been contributing to a wetland.
- Do not bypass flows around a wetland.
- Increase or maintain larger wetland buffer zones.

2.D.5 Wetland Hydroperiod Protection Strategies

Consider the following strategies to minimize impacts on the wetland hydroperiod and to meet the criteria. The list is in order of preference:

- Increasing the retention of natural pervious cover.
- Reducing the level of development.
- Reducing the total amount of impervious surfaces.
- Increasing infiltration using on-site LID techniques.
- Increasing or maintaining larger wetland buffer zones.
- Increasing infiltration and/or storage capacity of Flow Control BMPs.

2.D.6 Compensatory Mitigation of Wetlands

When a Runoff Treatment BMP is required for the project (e.g. to comply with 2.4.5 CE5: Runoff Treatment and/or 2.4.8 CE8: Wetlands Protection), the treatment must be provided prior to discharge to a wetland or its buffer. Any required Runoff Treatment BMPs, up to and including the outlet structure of the BMP, must be provided outside of the wetland and its buffer boundaries. If outflow from a BMP or project site is concentrated, flow should be diffused prior to discharge into the wetland buffer.

Compensatory Mitigation Required

When project proponents alter a wetland(s) as part of a Runoff Treatment and/or Flow Control BMP system, they must demonstrate that they have done everything possible to avoid and minimize impacts. Remaining impacts to wetland area and/or functions must be compensated according to local, state, and federal regulations and guidelines. Check with the agencies responsible for issuing permits.

Compensatory Mitigation Not Required

Treated stormwater may be beneficial to wetlands that have been heavily disturbed by human activities and can improve wetland hydrologic functions. In these limited cases when all of the solid bullets below are met, hydrologic alteration of the wetland to meet the requirements of a Flow Control BMP/facility is allowed without compensatory mitigation. This alteration will be considered a hydrologic functional restoration activity.

- The wetland is rated Category III or IV.
- The wetland has a habitat score of 5 or less.
- The wetland does not provide habitat for rare, threatened or endangered species.
- The wetland does not contain a breeding population of any native amphibians.
- The hydrologic functions of the wetland can be improved by modification. Generally, this means that constraints exist within the wetland (or surrounding area) that have altered natural hydrologic processes. The constraints are described in Charts 4 & 5 in *Selecting Wetland Mitigation Sites Using a Watershed Approach (Eastern Washington)* (Ecology, 2010b).

  Proponents must identify and address at least one of the following common constraints to document improvement of hydrologic functions:

  - Surface water flows have been diverted away from the wetland by prior development. Surface/subsurface water flows could be directed to the site to augment hydrologic inputs.
  - Ditches that artificially drain water from the wetland could be filled or plugged to retain water.
  - Drain tiles that artificially drain water from the wetland could be broken or removed to retain water.
  - Artificially placed fill that decreases surface water storage capacity could be removed to increase surface water storage capacity.
  - Dikes, dams, water control structures, or berms that prevent overbank flooding could be breached or removed.
  - Outlet culvert that is lower than the surrounding topographic depression could have its invert elevation raised to increase surface water storage

    OR

  - The wetland is part of a priority restoration plan that achieves restoration goals identified in a Shoreline Master Program or other local or regional watershed plan.
- The wetland lies in the natural route of water and the discharge follows the natural routing.

- Successful demonstration that no net loss of wetland function and value occurs as a result of the structural or hydrologic modifications.
  - This includes the impacts from the machinery used for the construction. Heavy equipment can damage the soil structure of a wetland.
  - When the functions and values of a degraded wetland are improved by project alterations, the project proponent must specify which project activities would thus be self-mitigating.
  - Check with the agency(ies) issuing the permits for the modification(s) to determine which method(s) and/or analyses to use to determine no net loss of wetland functions and values.
  - Functions and values that are not replaced on site will have to be compensated for elsewhere.

2.D.7 Jurisdictional Planning for Wetland Protection from Stormwater

Ecology recommends that local jurisdictions plan and manage their resources to protect overall wetland functions and values, including their role in stormwater management.

Wetlands protection planning can help local jurisdictions to take advantage of the most options for managing stormwater from development projects. Policies for the protection of wetlands should aim to prevent or minimize impacts at their point of origin and be self-perpetuating, that is they do not require periodic infusions of capital or labor.

The Department of Ecology and other agencies are actively developing new tools for watershed planning that will address many of the steps outlined below. We suggest you review information that has already been developed for your region or jurisdiction. This may significantly reduce your efforts.

Information for Wetlands Protection Planning

1. A map of the contributing watershed to the wetlands, or other appropriate landscape unit (see 2.D.8 Wetland Protection Definitions), and an estimate of its area.
2. Approximate or precise wetland boundaries. Wetland boundaries may have been previously delineated by the jurisdiction or by a project proponent working in the vicinity. Boundaries should be delineated using the latest approved Federal Manuals. Refer to https://ecology.wa.gov/Water-Shorelines/Wetlands/Tools-resources/Delineation-resources for details. Use the best information available.
3. A definition of environmental and development goals for the landscape unit subject to planning and management.
4. Existing management and monitoring plans.
5. Existing and projected land uses in the landscape unit in the following categories, expressed as percentages of the total watershed area:

- commercial,
- industrial,
- multi-family residential,
- single-family residential,
- agricultural,
- various categories of undeveloped, and
- areas subject to active logging or construction.

6. Hydrologic network throughout the landscape unit.
7. Soil conditions, including soil types, infiltration rates, and elevation of water table as it changes seasonally, and the presence of any restrictive layers.
8. Groundwater recharge and discharge points.

Typical Steps in Wetlands Protection Planning

1. Define the landscape unit you will be using for your planning effort. See the definition of landscape unit in 2.D.8 Wetland Protection Definitions.
2. Begin the plan for the landscape unit with attention to the following general principles:
   a. Formulate the plan based on clearly articulated community goals. Carefully identify conflicts and choices between retaining and protecting desired resources and community growth.
   b. Map and assess the suitability of different areas for urban uses.

      There are several tools available for identifying such areas. For more information visit the following website:

      https://ecology.wa.gov/Water-Shorelines/Puget-Sound/Watershed-characterization-project/Watershed-characterization

      When appropriate, the assessment can also highlight outstanding local or regional resources that the community determines should be protected. Examples include fish spawning and rearing areas, scenic areas, recreational areas, threatened or endangered species habitat, and farmland.
3. Maximize natural water storage and infiltration opportunities within the landscape unit and outside of existing wetlands, especially:
   a. Promote the conservation of forest cover. Develop on deforested land. This affects the water flows in a basin less than building on land that requires removing forest cover. Loss of forest cover increases peak runoff requiring expensive structural solutions.

b. Maintain natural storage reservoirs and drainage corridors, including depressions, areas of permeable soils, swales, and intermittent streams. Implement policies and regulations to discourage the clearing, filling, and channelization of these features. Use existing drainage networks in preference to pipes, culverts, and engineered ditches as long as the flows and volumes of water in them are not increased.

4. Establish and maintain buffers surrounding wetlands and in riparian zones as required by the Critical Area Ordinance for the local jurisdiction. Also, maintain interconnections among wetlands and other natural habitats to allow for wildlife movements (see *Update on Wetland Buffers: The State of the Science, Final Report*, (Ecology, 2013d)).

5. Implement measures to avoid general impacts on wetlands and other water bodies (e.g. littering, vegetation destruction, and human and pet intrusion harmful to wildlife).

6. In wetlands that are relatively unaffected by human activities, plan so the quantity of stormwater flows match the pre-project hydroperiod and hydrodynamics. In wetlands where water flows have been disturbed, consider ways of reducing the existing changes to flows. This involves not only management of high volumes and rates of flow during the wet season, but also preventing water supply depletion during the dry season. The latter may require augmenting flows if urbanization reduces existing surface or groundwater inflows. Refer to 2.D.5 Wetland Hydroperiod Protection Strategies for details on implementing these guidelines.

7. Assess alternatives for controlling the quantities of runoff as follows:

   a. Analyze proposed development actions in terms of changes to quantity of runoff.

   b. For existing development or redevelopment, assess possible alternative solutions to adding flow controls by:

      - Protecting health, safety, and property from flooding by removing buildings from floodplains.

      - Preventing stream channel erosion by stabilizing the eroding bed and/or bank area with bioengineering techniques, preferably, by using structural reinforcements that are consistent with the protection of aquatic habitats and beneficial uses of the stream (refer to Chapter 173-201A WAC for the definition of beneficial uses).

   c. For new development or redevelopment, assess different regulatory alternatives or incentives for changing common practices in land use including: density controls, clearing limits, impervious surface limits, transfer of development rights, purchase of conservation areas, etc.

   d. If the alternatives considered in Steps (a-c) above cannot solve an existing or potential problem, perform an analysis of the contributing drainage catchment to assess possible alternative solutions that can be applied on-site or on a regional scale. The most appropriate solution or combination of alternatives should be selected with regard to the specific opportunities and constraints existing in the drainage catchment.

For new development or redevelopment, on-site scale solutions that should be assessed include, in approximate order of preference:

- LID BMPs and LID principles.
- Infiltration basins or trenches.
- Detention ponds.
- Below-ground vault or tank storage.
- Parking lot detention.

Regional scale solutions that should be assessed for solving problems associated with new development, redevelopment or existing development include:

- LID BMPs and LID principles
- Infiltration basins or trenches.
- Detention ponds.
- Constructed wetlands.

e. Consider altering an existing wetland for controlling water quantities only if upland alternatives are inadequate to solve the existing or potential problem. Refer to the criteria in 2.D.6 Compensatory Mitigation of Wetlands to evaluate if wetlands can be altered.

8. Place strong emphasis on water resource protection during construction of new development. Establish effective erosion control programs to reduce the sediment loading to receiving waters. No existing wetland or other water body should ever be used for the sedimentation of solids in construction-phase runoff.

9. Stimulate public awareness of and interest in wetlands and other water resources in order to encourage protective attitudes in the community. This program should include:

   a. Education regarding the use of fertilizers and pesticides, automobile maintenance, the care of animals and the importance of retaining buffers to prevent water pollution. Refer to *Homeowners' Guide to Wetlands and Buffers* (Ecology, 2018).

   b. Descriptive signboards adjacent to wetlands informing residents of the wetland type, its functions, the protective measures taken, etc.

   c. If beavers are present in a wetland, educate residents about their ecological role and value and take steps to avoid human interference with beavers.

10. If long term water quality impacts are a concern, the monitoring program should include the following tasks:

   a. Perform pre-project baseline sampling by collecting water quality grab samples in an open water pool of the wetland for at least one year, allocated through the year as follows:

- November 1 - March 31: 4 samples
- April 1 - May 31: 1 sample
- June 1 - August 31: 2 samples
- September 1 - October 31: 1 sample

If the wetland is dry during any period, reallocate the sample(s) scheduled then to another time when the wetland is no longer dry.

The monitoring program should use the analytical methods approved by the U.S. Environmental Protection Agency and listed at 40 CFR part 136 or approved by Department of Ecology with similar reporting limits.

b. Considering the baseline results, set water quality goals to be maintained in the post-project period. Example goals are:

   - No increase in violations of the Water Quality Standards for Surface Waters of the State of Washington (Chapter 173-201A WAC). Repeat the sampling on the same schedule for at least once year after all development is complete. Compare the results to the set goals.

2.D.8 Wetland Protection Definitions

The following terms are applicable only to this Appendix.

Buffer

The area (either upland, open water, or another wetland) that surrounds a wetland or watercourse and that reduces adverse impacts to the ecosystem functions and values from adjacent development.

Compensatory mitigation

The stage of the mitigation sequence where impacts to wetland functions are offset (i.e. compensated for) through creation (establishment), restoration (re-establishment, rehabilitation), or enhancement of other wetlands. Because regulatory requirements and policies tend to focus on compensatory mitigation, the term “mitigation” is often used to refer to compensation, which is just one part of the overall mitigation sequence.

Constructed wetland

A wetland intentionally created from a non-wetland site for the purpose of water treatment.

Hydrodynamics

The science involving the energy and forces acting on water or other liquids and the resulting impact on the motion of the liquid.

Hydrogeomorphic (HGM) classification

Classification of wetlands based upon landscape position (geomorphic setting), water source, and the flow and fluctuation of water in the wetland (hydrodynamics).

Hydroperiod

The seasonal occurrence of flooding and/or soil saturation; it encompasses the depth, frequency, duration, and seasonal pattern of inundation.

Invasive species

Nonnative organisms whose introduction causes or is likely to cause economic or environmental harm or harm to human, animal or plant health.

Landscape unit

An area of land that has a specified boundary used for planning purposes that defines an area of interrelated physical, chemical, and biological processes. A watershed or drainage basin is a common type of landscape unit. A groundwater aquifer is another type of landscape unit.

Modification, Modified (wetland)

A wetland whose physical, hydrological, or water quality characteristics have been purposefully altered for a management purpose, such as by dredging, filling, forebay construction, and inlet or outlet control.

Rare, threatened, endangered, or sensitive species

Plant or animal species that are relatively uncommon regionally, are nearing endangered status, or whose existence is in jeopardy and is usually restricted to highly specific habitats. Threatened, endangered or sensitive species are listed by federal or state authorities, whereas rare species are unofficial species of concern that fit the above definitions.

Regional

An action (here, for stormwater management purposes) that involves more than one discrete property.

Seasonal wetland

A wetland that has water above the soil surface for a period of time (usually between two months to less than one year) during and/or after the wettest season but in typical years dries to or below the soil surface in warmer, drier weather.

Slope Wetlands

Slope wetlands occur on slopes where groundwater surfaces and begins running along the surface, or immediately below the surface. Water in these wetlands flows only in one direction (down the slope) and the gradient is steep enough that the water is not impounded. The downhill side of the wetland is always the point of lowest elevation in the wetland.

Stage excursion

A post-project departure, either higher or lower, from the water depth existing under a given set of conditions in the pre-development state.

Water Level Fluctuation (WLF)

This is a defining characteristic of a wetland. Water level fluctuation (WLF) during a monitoring interval is as follows:

Average base stage = (Instantaneous stage at beginning of interval + Instantaneous stage at end of interval)/2

Wetland functions

The ecological (physical, chemical, and biological) processes or attributes of a wetland. Functions are often defined in terms of the processes that provide value to society, but they can also be defined based on processes that are not value based. Wetland functions include food chain support, provision of ecosystem diversity and fish and wildlife habitat, flood flow alteration, groundwater recharge and discharge, water quality improvement, and soil stabilization.

Wetland structure

The physical components of a wetland, both the abiotic (physical and chemical) and biotic (living).

Wetland values

Wetland processes or attributes that are valuable or beneficial to society (also see Wetland functions). Wetland values include support of commercial and sport fish and wildlife species, protection of life and property from flooding, recreation, education, and aesthetic enhancement of human communities.

Wetlands

Those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas. Wetlands do not include those artificial wetlands intentionally created from nonwetland sites, including, but not limited to, irrigation and drainage ditches, grass-lined swales, canals, detention BMPs, wastewater treatment facilities, farm ponds, and landscape amenities, or those wetlands created after July 1, 1990, that were unintentionally created as a result of the construction of a road, street, or highway. Wetlands may include those artificial wetlands intentionally created from nonwetland areas to mitigate the conversion of wetlands. (Waterbodies not included in the definition of wetlands as well as those mentioned in the definition are still waters of the state.)

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Chapter 3 - Preparation of Stormwater Site Plans

3.1 Introduction

The Stormwater Site Plan (SSP) is a comprehensive report containing all of the technical information and analysis necessary for regulatory agencies to evaluate a proposed new development or redevelopment project for compliance with stormwater requirements. Preparation of an SSP constitutes 2.4.1 CE1: Preparation of a Stormwater Site Plan. Contents of the SSP will vary with the type and size of the project, individual site characteristics, and special requirements of the local jurisdiction.

The scope of the SSP will also vary depending on the applicability of Core Elements (see Chapter 2 - Core Elements for New Development and Redevelopment).

This chapter describes the contents of the SSP and provides a general procedure for how to prepare the plan. The specific Best Management Practices (BMPs) and design methods and standards to be used are contained in Chapter 4 - Hydrologic Analysis and Design through Chapter 8 - Source Control. Guidelines for selecting runoff treatment and flow control BMPs are provided in Chapter 4 - Hydrologic Analysis and Design and Chapter 6 - Runoff Treatment, Flow Control, and LID BMP Library. The content of, and the procedures for preparing a Construction Stormwater Pollution Prevention Plan (SWPPP) are covered in detail in Chapter 7 - Construction Stormwater Pollution Prevention. Guidelines for selecting source control BMPs are provided in Chapter 8 - Source Control.

The goal of this chapter is to provide a framework for uniformity in plan preparation. Such uniformity will promote predictability throughout the region and help secure prompt governmental review and approval. Properly drafted engineering plans and supporting documents will also facilitate the operation and maintenance of the proposed system long after its review and approval.

State law requires that engineering work be performed by or under the direction of a licensed engineer in the state of Washington. Plans involving construction of runoff treatment BMPs, flow control BMPs, structural source control BMPs, or drainage systems generally involve engineering principles and shall be prepared by or under the direction of a licensed engineer in the state of Washington. Construction SWPPPs that involve engineering calculations must also be prepared by or under the direction of a licensed engineer in the state of Washington.

3.2 Stormwater Site Plans: Step by Step

3.2.1 Introduction

The development of a Stormwater Site Plan (SSP) consists of eight steps:

- 3.2.2 Step 1: Site Analysis: Collect and Analyze Information on Existing Conditions
- 3.2.3 Step 2: Prepare Preliminary Development Layout

- [3.2.4 Step 3: Perform Off-Site Analysis](#)
- [3.2.5 Step 4: Determine Applicable Core Elements](#)
- [3.2.6 Step 5: Prepare a Permanent Stormwater Control Plan](#)
- [3.2.7 Step 6: Select Construction Stormwater Pollution Prevention BMPs](#)
- [3.2.8 Step 7: Complete the Stormwater Site Plan](#)
- [3.2.9 Step 8: Check Compliance With All Applicable Core Elements](#)

The level of detail needed for each step depends on the project size, as explained in the individual steps. A narrative description of each of these steps follows.

3.2.2 Step 1: Site Analysis: Collect and Analyze Information on Existing Conditions

Collect and review information on the existing site conditions including topography, drainage patterns, soils, ground cover, presence of critical areas, adjacent areas, existing development, existing stormwater BMPs, adjacent on- and off-site utilities, and prior disturbance of the site. Disturbance may cause changes in soil profiles, permeability, water holding capacity and transmissivity, tilth, native vegetation, and fertility. Analyze the data to determine the site limitations, including the following:

- Areas with high potential for erosion and sediment deposition (based on soil properties, slope, etc.)
- Locations of sensitive and critical areas (e.g., vegetative buffers, wetlands, steep slopes, floodplains, geologic hazard areas, streams, etc.)
- Observation of potential runoff contribution from off-site basins
- Adjacent properties and/or projects that have a history of stormwater problems, noting whether the cause of the problem(s) has been determined
- Adjacent properties and/or projects where geotechnical investigations have identified shallow bedrock, high groundwater, seasonally perched groundwater, or clay lenses in the substrata

Delineate these areas on the site map required as part of Step 3, Prepare a Permanent Stormwater Control Plan. Prepare an existing conditions summary that will be submitted as part of the SSP. Part of the information collected in this step should be used to help prepare the Construction Stormwater Pollution Prevention Plan (SWPPP).

3.2.3 Step 2: Prepare Preliminary Development Layout

Based on the analysis of existing site conditions, locate the buildings, roads, parking lots, landscaping features, and preliminary locations of stormwater BMPs for the proposed development. Consider the following points when laying out the site:

- Fit development to the terrain to minimize land disturbance; confine construction activities to the least area necessary, and away from critical areas.
- Preserve areas with native vegetation (especially forested areas) as much as possible.
- On sites with a mix of soil types, locate impervious areas over less permeable soil, try to restrict development over more porous soils or take advantage of them by locating infiltration BMPs over them.
- Cluster buildings together.
- Minimize impervious areas.
- Maintain and utilize natural drainage patterns.
- Identify existing utilities and proposed utility corridors.

See Appendix 3-C: Additional Guidance on Low Impact Development Site Planning Principles and Design Strategies for additional guidance on site planning principles and design strategies.

3.2.4 Step 3: Perform Off-Site Analysis

An off-site analysis is required as part of 2.4.4 CE4: Preservation of Natural Drainage Systems and Outfalls. Development projects that propose to discharge stormwater off-site are required to submit an off-site analysis report that assesses the potential off-site water quality, erosion, slope stability, and drainage impacts associated with the project and that proposes appropriate mitigation of those impacts. An initial qualitative analysis should extend downstream for the entire flow path from the project site to the receiving water, or up to 1 mile or to a point where the impact on receiving waters are minimal or nonexistent, as determined by the local jurisdiction. If a receiving water is within 0.25 miles, the analysis should extend within the receiving water to 0.25 miles from the project site. The analysis should extend 0.25 miles beyond any improvements proposed as mitigation. The analysis should extend upstream to a point where backwater effects created by the project cease. Upon review of the qualitative analysis, the local jurisdiction may require that a quantitative analysis be performed. A full description of a typical off-site analysis procedure, along with a sample checklist to aid in the preparation and review of an off-site analysis, are included in 2.5.3 APM2: Off-Site Analysis Report.

3.2.5 Step 4: Determine Applicable Core Elements

The Phase II Municipal Stormwater National Pollutant Discharge Elimination System (NPDES) Permit for eastern Washington or local jurisdiction establishes project size thresholds for the application of Core Elements (in Chapter 2 - Core Elements for New Development and Redevelopment), to new development and redevelopment projects. The designer of the SSP should meet with local officials to agree on the applicable Core Elements, prior to proceeding to the next step.

3.2.6 Step 5: Prepare a Permanent Stormwater Control Plan

Select stormwater BMPs (all projects) and Runoff Treatment and Flow Control BMPs (projects subject to 2.4.5 CE5: Runoff Treatment and/or 2.4.6 CE6: Flow Control) that will serve the project site in its developed condition. The selection process for Runoff Treatment and Flow Control BMPs is presented in detail in Chapter 6 - Runoff Treatment, Flow Control, and LID BMP Library.

A preliminary design of the BMPs is necessary to determine how they will fit within and serve the entire preliminary development layout. After a preliminary design is developed, the designer may want to reconsider the site layout to reduce the need for construction of BMPs, or the size of the BMPs by reducing the amount of impervious surfaces created and increasing the areas to be left undisturbed. After the designer is satisfied with the BMP selection, the information must be presented in a Permanent Stormwater Control Plan, which typically consists of a drainage report and a set of construction plans.

Drainage Report

The drainage report is to be inclusive, clear, legible, and reproducible, with a complete set of drainage computations and stamped by a licensed engineer in the state of Washington. The computations are to be presented in a rational format with information included so as to allow a reviewer to be able to reproduce the same results. The computations should provide sufficient information for an unbiased third party to be able to review the report and determine that all applicable standards have been met. All assumptions and computer input and output data, and variables listed in the computer printouts, should be clearly identified. Computer printouts should clearly show which subbasin(s) they apply to and the design storm event identified thereon if multiple storm events are addressed in the design. Copies of design charts, nomographs, or other design aids used in the analysis should be included in the calculations.

All relevant geotechnical information related to the project and all site-specific soil logs and subsurface testing information should be included in the drainage report or provided in a separate report prepared and stamped by the geotechnical engineer or licensed engineering hydrogeologist.

The drainage report should also include a basin map. Under most conditions both a predevelopment basin map and a postdevelopment basin map should be provided, unless deemed unnecessary by the local jurisdiction. See Appendix 3-A: Basin Maps for a checklist of items to be included on the basin map.

The drainage report is to identify existing drainage BMPs which are clearly inadequate or need repair, such as collapsed culverts or culverts with a substantial amount of debris. The condition and capacity of existing drainage BMPs located on-site, which are proposed for use by the development, should be evaluated and disclosed in the drainage report.

Calculations for detention and infiltration ponds sized to meet 2.4.5 CE5: Runoff Treatment and/or 2.4.6 CE6: Flow Control may include the following: inflow and outflow hydrographs, level-pool routing calculations, a listing of the maximum water surface elevation, a pond volume rating table (e.g., stage vs. storage), and discharge rating table (e.g., stage versus discharge). Each hydrograph and level-pool routing calculation sheet is to have clearly marked: the design storm event, the applicable subbasin(s), and the pond identification name, which corresponds with the basin map and plans.

The drainage submittal should incorporate all calculations for the determination of the required size of the systems. Typical calculations include the following:

- Hydrologic computations:
    - Drainage basin (and subbasin) delineation
    - Model output reports summarizing input parameters and results
- Hydraulic computations:
    - Inlet capacities
    - Detention/retention storage capacities
    - Culvert and pipe system capacities and outlet velocities
    - Ditch capacities and velocities
- Map with the project plotted thereon

A copy of applicable floodplain maps, or studies within the project area should be included in the drainage report.

Construction Plans

Construction plans should be prepared for all open and closed drainage systems. This information should be presented in a clear, concise manner that can be easily followed, checked, and verified. All pipes, culverts, catch basins, channels, swales, and other stormwater conveyance appurtenances must be clearly labeled. The plans should call out sufficient hydraulic and physical data for construction of the system and future evaluation of the design. An example checklist describing many of the items typically shown on construction plans is included in Appendix 3-B: Stormwater Construction Plans. Designers should consult local jurisdiction requirements for specific information to include on construction plans.

3.2.7 Step 6: Select Construction Stormwater Pollution Prevention BMPs

A Construction SWPPP may be required as part of 2.4.2 CE2: Construction Stormwater Pollution Prevention Plan (SWPPP). Guidance is also provided for construction stormwater pollution prevention for small projects.

Large-Project Construction SWPPP

The Construction SWPPP must contain sufficient information to satisfy the local jurisdiction that the potential pollution problems have been adequately addressed for the proposed project. An adequate Construction SWPPP includes a narrative and drawings. The narrative is a written statement that explains the pollution prevention decisions made for a particular project. The narrative contains concise information concerning existing site conditions, construction schedules, and other pertinent items that are not contained on the drawings. The drawings and notes describe where and when the various BMPs should be installed, the performance the BMPs are expected to achieve, and actions to be taken if the performance goals are not achieved.

The 13 Elements listed in 2.4.2 CE2: Construction Stormwater Pollution Prevention Plan (SWPPP) must be considered in the development of the Construction SWPPP unless site conditions render the element unnecessary and the exemption from that element is clearly justified in the narrative of the Construction SWPPP. These elements are described in detail in Chapter 7 - Construction Stormwater Pollution Prevention. They cover the general water quality protection strategies of limiting site impacts, preventing erosion and sedimentation, and managing activities and sources.

On construction sites that discharge to receiving water, the primary consideration in the preparation of the Construction SWPPP is compliance with the State Water Quality Standards. The step-by-step procedure outlined in Chapter 7 - Construction Stormwater Pollution Prevention is recommended for the development of these Construction SWPPPs. A checklist is contained in Chapter 7 - Construction Stormwater Pollution Prevention that may be helpful in preparing and reviewing the Construction SWPPP.

On construction sites that infiltrate all stormwater runoff, the primary consideration in the preparation of the Construction SWPPP is the protection of the infiltration BMPs from fine sediments during the construction phase and protection of groundwater from other pollutants. Several of the other elements are very important at these sites as well, such as marking the clearing limits, establishing the construction access, and managing the project.

Under current federal regulations, if a project disturbs > 1 acre and discharges to receiving water, the local jurisdiction may require review and approval of the Construction SWPPP prior to construction.

Small-Project Construction Stormwater Pollution Prevention

This guidance is recommended for small construction projects adding or replacing < 2,000 square feet (sf) of impervious surface or clearing < 7,000 sf to prevent the discharge of sediment and other pollutants to the maximum extent practicable. The following should be evaluated for small construction projects:

- Plan and implement proper clearing and grading of the site. It is most important only to clear the areas needed, thus keeping exposed areas to a minimum. Phase clearing so that only those areas that are actively being worked are uncovered. Note: Clearing limits should be flagged in the lot or area prior to initiating clearing.

- Soil should be managed in a manner that does not permanently compact or deteriorate the final soil and landscape system. If disturbance and/or compaction occur the impact must be corrected at the end of the construction activity. This should include restoration of soil depth, soil quality, permeability, and percentage of organic matter. Construction practices must not cause damage to or compromise the design of permanent landscape or infiltration areas.

- Locate excavated soil a reasonable distance behind the curb, such as in the backyard or side yard area. This will increase the distance eroded soil must travel to reach the drainage system. Soil piles should be covered until the soil is either used or removed. Piles should be situated so that sediment does not run into the street or adjoining yards.

- Backfill foundation walls as soon as possible and rough grade the lot. This will eliminate large soil mounds, which are highly erodible, and prepares the lot for temporary cover, which will further reduce erosion potential.
- Remove excess soil from the site as soon as possible after backfilling. This will eliminate any sediment loss from surplus fill.
- If a lot has a soil bank higher than the curb, a trench or berm should be installed moving the bank several feet behind the curb. This will reduce the occurrence of gully and rill erosion, while providing a storage and settling area for stormwater.
- The construction entrance should be stabilized where traffic will be leaving the construction site and traveling on paved roads or other paved areas within 1,000 feet of the site.
- Provide for periodic street cleaning to remove any sediment that may have been tracked out. Sediment should be removed by shoveling or sweeping and carefully removed to a suitable disposal area where it will not be eroded again.
- Utility trenches that run up and down slopes should be backfilled within 7 days. Cross-slope trenches may remain open throughout construction to provide runoff interception and sediment trapping, provided that they do not convey turbid runoff off-site.

3.2.8 Step 7: Complete the Stormwater Site Plan

The SSP encompasses the entire submittal to the local jurisdiction with drainage review authority. The SSP should address the following:

- **Project overview:** The project overview must provide a general description of the project, predeveloped and developed conditions of the site, site area and size of the improvements, and the pre- and postdevelopment stormwater runoff conditions. The overview should summarize difficult site parameters, the natural drainage system, and drainage to and from adjacent properties, including bypass flows.
- **Vicinity map:** This map should clearly locate the property, identify all roads bordering the site, show the route of stormwater off-site to the local natural receiving water, and show significant geographic features and sensitive/critical areas (streams, wetlands, lakes, steep slopes, etc.).
- **Site map:** This map should use at a minimum a U.S. Geological Survey 1:2,400-scale topographic map as a base and display the following:
    - Acreage and outlines of all drainage basins
    - Existing stormwater drainage to and from the site
    - Routes of existing, construction, and future flows at all discharge points
    - The length of travel from the farthest upstream end of a proposed drainage system to any proposed flow control and runoff treatment BMP
- **Soils map:** This map should show the soils within the project site as verified by field testing. It is the designer’s responsibility to ensure that the soil types of the site are properly

identified and correctly used in the hydrologic analysis.

- **Existing conditions summary:** This is the summary described in Step 1. If the local jurisdiction does not require a detailed off-site analysis, this summary should also describe the following:
  - The natural receiving waters that the stormwater runoff either directly or eventually (after flowing through the downstream conveyance system) discharges to
  - Any area-specific requirements established in local plans, ordinances, or regulations or in water cleanup plans approved by the Washington State Department of Ecology
- **Off-site analysis report:** This is the report described in Step 3.
- **Permanent stormwater control plan:** This is the plan described in Step 5.
- **Construction SWPPP:** This is the plan described in Step 6.
- **Special reports and studies:** Include any special reports and studies conducted to prepare the SSP (e.g., a soils report that could include the results of soil sampling and testing, infiltration tests and/or soil gradation analyses, depth to groundwater; wetlands delineation).
- **Other permits:** List conditions from other permits and regulatory agency approvals that affect the drainage plan or contain more restrictive drainage-related requirements.
- **Operation and maintenance (O&M) manual:** Submit an O&M manual for each flow control and runoff treatment BMP based on the guidelines included in 2.4.7 CE7: Operation and Maintenance.
- **Declaration of covenant for privately maitained flow control and treatment BMPs:** A declaration of covenant and grant of easement may be required by the local jurisdiction for privately maintained flow control and runoff treatment BMPs to ensure future maintenance and allow access for inspection by the local jurisdiction.
- **Bond quantities worksheet:** If the local jurisdiction adopts a requirement for a performance bond (or other financial guarantee) for proper construction and operation of construction site BMPs, and proper construction of permanent drainage BMPs, the designer shall provide documentation to establish the appropriate bond amount.

3.2.9 Step 8: Check Compliance With All Applicable Core Elements

The SSP as designed and implemented should specifically fulfill all Core Elements applicable to the project. Review the completed SSP to check that these requirements are satisfied.

3.3 Plans Required After Stormwater Site Plan Approval

3.3.1 Introduction

This section includes the specifications and contents required of those plans submitted after the local jurisdiction has approved the original Stormwater Site Plan (SSP).

3.3.2 Stormwater Site Plan Changes

If the designer wishes to make changes or revisions to the originally approved SSP, the proposed revisions should be submitted to the local jurisdiction or agency with review authority prior to construction. The submittals should include the following:

- Substitute pages of the originally approved SSP that include the proposed changes
- Revised drawings showing structural changes
- Other supporting information that explains and supports the reason for the change

3.3.3 Record Drawings

If the project included construction of conveyance systems, runoff treatment Best Management Practices (BMPs), flow control BMPs, or structural source control BMPs, the applicant should submit record drawings to the local jurisdiction when the project is completed. These should be engineering drawings that accurately represent the stormwater infrastructure of the project as constructed. These corrected drawings must be professionally drafted revisions that are stamped, signed, and dated by a licensed engineer in the state of Washington.

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Appendix 3-A: Basin Maps

Site Planning — Basin Maps Checklist

The following items should be included on predeveloped and postdeveloped basin maps:

- Site boundary
- Basin limits, both on-site and off-site areas which contribute or receive stormwater runoff onto or from the project, field verified by a licensed engineer in the state of Washington
- Drainage subbasins. All subbasins should be clearly labeled and correlated with the calculations.
- Topographic contours, which should extend beyond the project or drainage basin boundaries to the extent necessary to confirm basin limits used in the calculations; or, in the absence of topographic mapping being available, a licensed engineer in the state of Washington may field verify the basin limits, including contributing off-site areas, and should describe how the basin limits were determined.
- Significant drainage features, natural or man-made, such as creeks, seasonal drainage channels, culverts, closed depressions, maintenance holes
- Time of concentration routes, clearly labeled and correlated with the calculations
- Footprint of proposed drainage features, such as ponds, vegetated or other infiltration Best Management Practices (BMPs), pipe routes, ditches
- Indications of floodplain limits, as defined by Federal Emergency Management Agency (FEMA) or other studies
- North arrow and scale bar
- Wetlands
- Existing easements

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Appendix 3-B: Stormwater Construction Plans

Site Planning — Stormwater Construction Plans Checklist

The following items should be included on stormwater construction plans, as applicable:

- A plan profile of all key drainage systems including: streets, roads, and drainage Best Management Practices (BMPs).
- Elevation datum
- North arrow and scale bar
- Right-of-way details
- Outfall details
- Ditch details
- Invert elevations, slopes, and lengths of ditches
- Cross sections of all open ditches
- Elevations of all inlet grates
- Size, types, invert elevations, and lengths of all culverts and pipe systems
- Invert elevations of the existing or other proposed drainage system to which the drainage plan proposes to connect
- Stationing of all inlets, culverts and pipe systems angle points
- Invert elevations of pipes at all structures such as catch basins or maintenance holes
- Construction details for inlets, drywells, detention BMPs, etc. (notes referring to standard plans may suffice where applicable)
- Drainage easements shown, with key dimensions for depicting location, width, and length
- The location of existing underground and aboveground utilities
- Lot grading elevations where appropriate
- Grading plan for detention ponds. The grading plan should include:
    - existing contours
    - proposed contours
    - catch points

  A typical cross section of the pond should be provided in the plans, showing:

  - bottom of pond elevation
  - maximum water surface elevation for the design storm(s)
  - inlet and outlet elevations
  - berm elevation and slopes
  - keyway location and dimensions

- Detention ponds, pipe inlets and outlets, ditches, and drainage structures, which are serving public roads or are in single-family residential neighborhoods, should be horizontally defined with respect to property corners, street stationing, or a coordinate system.
- Drainage ditches should have their longitudinal grades defined with either a profile or elevation grades at intervals of 50 feet. Ditch centerlines and flow directions should be also be illustrated.
- Summary of short- and long-term operation and maintenance requirements

Appendix 3-C: Additional Guidance on Low Impact Development Site Planning Principles and Design Strategies

3.C.1 Introduction

This appendix includes additional guidance on low impact development (LID) site planning principles and design strategies that have been integrated with minor revisions from Chapters 2 and 3 of the *Eastern Washington Low Impact Development Guidance Manual*.

3.C.2 LID Site Planning

Introduction

Performing a comprehensive inventory and analysis is an essential first step preceding low impact development (LID) design. The inventory and analysis should include on- and off-site natural and built conditions that would affect the project design. Policies, land use controls, and legally enforceable restrictions should also be evaluated and documented.

The process of planning for LID includes an in-depth analysis of the natural conditions of the site (e.g., soils, topography, hydrology, etc.), as well as the built and regulatory elements (e.g., access, utilities, easements, zoning, etc.) that will influence development and the use of LID practices. This appendix provides an overview of LID planning principles and presents guidelines for performing a site analysis and developing a composite site map that can be used as the basis for LID site design.

LID Planning Principles

The following key principles of LID planning provide a foundation for LID site design, construction, and long- term maintenance:

- Preserving native vegetation
- Protecting critical areas
- Minimizing impervious surfaces
- Minimizing grading and compaction of site soils
- Preserving existing flow paths
- Infiltrating stormwater runoff
- Dispersing stormwater to vegetated Best Management Practices (BMPs)
- Utilizing naturalistic surface conveyance BMPs
- Utilizing small-scale, distributed LID BMPs

These principles should be evaluated at the beginning of the project and should be revisited during design iterations to provide for a comprehensive approach to LID site planning and design. Design of LID BMPs as described in Chapter 6 - Runoff Treatment, Flow Control, and LID BMP Library should integrate with and not replace application of these key principles.

Site Analysis

Site analysis is the evaluation and documentation of natural and built elements on the site, culminating in development of a composite site map that can be used as the basis for LID site design. The scope of the site analysis may vary with the type and size of the project, individual site characteristics, and requirements of the local jurisdiction.

The remainder of this section provides details related to site analysis and documentation of the following project site elements:

- Topography
- Hydrologic patterns and features
- Soil and subsurface hydrologic characterization
- Native vegetation and soil protection areas
- Wetlands
- Riparian management areas
- Streams
- Floodplains
- Access
- Utilities
- Land use controls

Topography

Understanding the existing site topography is important to implementing LID principles, such as minimizing grading and preserving existing flow paths, as well as planning for siting LID BMPs on-site. Relatively large projects may require a topographic survey prepared by a registered land surveyor, with the following recommended contour resolutions based on site slope:

- Up to 10% slopes, 2-foot contours
- Over 10% to < 20% slopes, 5-foot contours
- 20% or greater slopes, 10-foot contours

Hydrologic Patterns and Features

Understanding and preserving existing hydrologic patterns and features is paramount to achieving many of the key LID planning principles, and begins by identifying and maintaining on-site hydrologic processes, patterns and the physical features (streams, wetlands, native soils and vegetation, etc.) that influence those patterns.

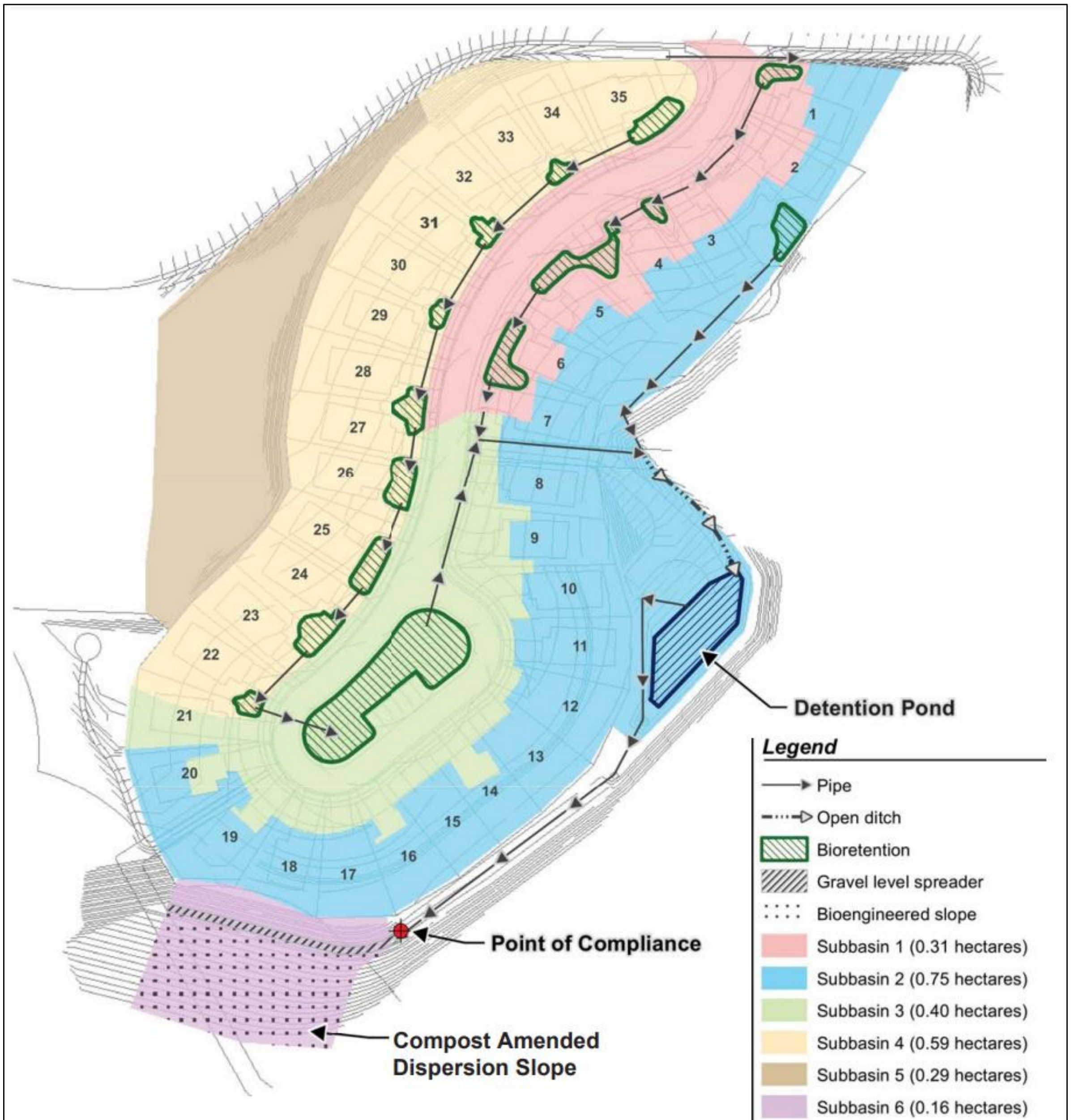
The documentation of hydrologic patterns and features will require locating and mapping prominent hydrologic features but should also include the following actions:

- Identifying and mapping minor hydrologic features including seeps, springs, closed depression areas, and drainage swales
- Identifying and mapping surface flow patterns during wet periods, and identify signs of duration and energy of storm flows including vegetation composition, and erosion and deposition patterns

It may be necessary to divide the site into subbasins in order to preserve existing flow paths and properly locate and size small-scale, distributed LID BMPs, as are key LID planning principles, it may be necessary to divide the site into subbasins (see Figure 3.1: Subbasin Delineation for Designing Distributed LID Practices). This detailed approach provides several advantages:

- Individual practices receive smaller hydraulic and pollutant loads.
- Small-scale practices can be arranged in the project efficiently and save space for other amenities.
- Individual LID BMPs can be accurately sized based on the appropriate tributary contributing areas and their cumulative performance across the site can be evaluated.

Figure 3.1: Subbasin Delineation for Designing Distributed LID Practices



Source: Low Impact Development Technical Guidance Manual for Puget Sound (WSU-PSP, 2012)

DEPARTMENT OF ECOLOGY State of Washington

Subbasin Delineation for Designing Distributed LID Practices

Revised June 2013

The following text provides additional discussion of the planning practices associated with protecting wetlands, streams, riparian areas, and floodplains. Mapping and planning for each of these types of hydrologic features should be conducted at the subbasin scale. Check with your local jurisdiction for related ordinances and planning documents.

Wetlands

On- and off-site wetlands should be delineated and assessed in accordance with local critical areas regulations. Delineating the wetland to determine its edge is accomplished by using the U.S. Army Corps of Engineers' *Wetland Delineation Manual* (USACE, 1987).

After determining the limits or edge of the wetland, it must be rated or assessed. The rating or assessment of the wetland is performed so that appropriate protective mechanisms, typically buffers, can be applied. The *Washington State Wetland Rating System for Eastern Washington* (Ecology, 2014) is the resource used to rate the ecological and hydrological value of the wetland. Buffer standards are typically found in locally adopted critical areas regulations.

Core assessment and management objectives for a project located in a drainage basin with a wetland designated as high quality and sensitive and not used as flow control or treatment should include the following:

- Protect native riparian vegetation and soils.
- Protect diverse native wetland habitat characteristics to support the native assemblage of wetland biota.
- Match the preproject surface and groundwater inputs that drive wetland water surface elevations.

The following steps should be used as a starting point to adequately inventory and provide an assessment of wetlands, where applicable:

- Delineate and assess the wetland category using the *Wetland Delineation Manual* (USACE, 1987) and the *Washington State Wetland Rating System for Eastern Washington* (Ecology, 2014). Protective buffers will be found in the critical areas regulations for the local jurisdiction.
- Determine if the wetland meets the criteria for "Hydrologic Modification of a Wetland" in 2.4.6 CE6: Flow Control.

Streams

Determining appropriate assessment and management protocols for stream channel corridors will be found in locally adopted critical areas regulations. If the project is within a watershed with streams designated as high quality and sensitive, objectives for assessment and management strategies should include the following:

- Protect mature native riparian vegetation and soils.
- Protect diverse native stream habitat characteristics to support the native assemblage of stream life.
- Maintain predevelopment hydrology.

The following steps should be used to adequately inventory and analyze creeks, streams, or rivers, where applicable:

- Identify stream category by using the Washington State Department of Natural Resources water typing classification system (WAC 222-16-030).
- Identify riparian area and fish and wildlife habitat in locally adopted critical areas regulations. See the Riparian Areas subsection for additional discussion of riparian areas.
- Assess general stream corridor condition and determine if there is a need for more detailed assessment and specific management strategies. Specific management strategies, typically including the application of protective buffers, are found in locally adopted critical areas regulations.

Riparian Areas

Riparian areas are those areas adjacent to streams, lakes, and ponds that support native vegetation adapted to saturated or moderately saturated soil conditions. Riparian areas with adequate mature vegetation, land form, and large woody debris can:

- Dissipate stream energy and erosion associated with high-flow events;
- Filter sediment, capture bedload, and aid in floodplain development;
- Improve floodwater retention and groundwater recharge;
- Develop diverse ponding and channel characteristics that provide habitat necessary for fish and other aquatic life to spawn, feed and find refuge from flood events;
- Provide vegetation litter and nutrients to the aquatic food web;
- Provide habitat for a high diversity of terrestrial and aquatic biota;
- Provide shade and temperature regulation; and
- Provide adequate soil structure, vegetation and surface roughness to slow and infiltrate stormwater delivered as precipitation or low-velocity sheet flow from adjacent areas (Prichard et al., 1998)

The objective for riparian area assessment and management is to protect, maintain and restore mature native vegetation cover that provides the functions and structures listed in this section. Consult the critical areas regulations for the local jurisdiction for inventory, assessment, and management standards. Also consult the local regulations to determine whether or not construction of LID BMPs would be allowed in riparian area buffers.

Floodplains

The objective for floodplain area assessment and management is to maintain or restore the following:

- Connection between the stream channel, floodplain and off channel habitat
- Mature native vegetation cover and soils

- Predevelopment hydrology that supports the above functions, structures, and flood storage

The following steps should be used to inventory and assess floodplain areas, where applicable:

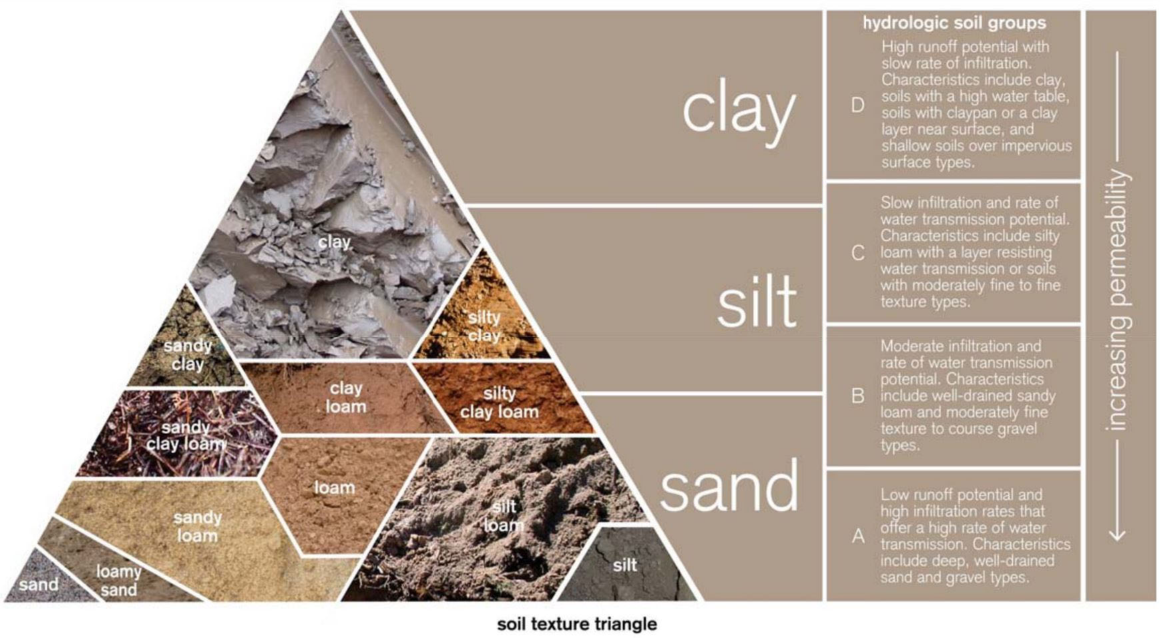
- Identify, survey, and map the 100-year floodplain and channel migration zone.
- Inventory, survey, and map the composition and structure of vegetation within the floodplain area.
- Identify, survey, and map the active channel.

Where possible, development within the 100-year floodplain should be avoided to best protect people and property and help maintain critical floodplain functions, such as storage and conveyance of floodwaters.

Soil and Subsurface Hydrology Characterization

In-depth characterization of soil and subsurface hydrology is vital to LID planning and design. Typically, the goals of this task are to evaluate the site's feasibility for infiltration and, where appropriate, determine long-term native soil design infiltration rates. Soil characterization is also important to help specify materials to be used in design. For example, geotextile layers for separation may not be needed on the sides or bottom of excavations for bioretention or permeable pavement if the native site soils are not expected to migrate into the various BMP layers based on grain size distributions (see Figure 3.2: Soil Texture Triangle).

Figure 3.2: Soil Texture Triangle



Source: Low Impact Development: A Design Manual for Urban Areas (University of Arkansas Community Design Center, 2010)

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Soil Texture Triangle

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This section documents well-accepted practices that may be used to characterize the soils and subsurface hydrologic conditions and evaluate long-term native soil infiltration rates to be used for design of infiltration-based BMPs. Designers should consult local jurisdiction requirements to determine the soil and subsurface hydrology characterization method that will be required to support the design.

Soil and subsurface characterization relies to a large extent on infiltration test pits, soil test pits, or soil borings. The type and number of these tests for initial site assessment is variable and site specific; however, some general guidelines are appropriate. A few strategically placed tests are generally adequate for initial soil and infiltration assessment. Test locations are determined by topography, estimated soil type, hydrologic characteristics, and other site features. Consult a certified soil scientist, engineer, geologist, hydrogeologist or engineering geologist licensed in the state of Washington for the infiltration test pit, soil test pit, and soil boring recommendations for initial assessment. A more detailed soil and infiltration capacity assessment may be necessary after the preliminary site layout with location of LID stormwater controls is established.

The methods described in this section are used to determine the measured saturated hydraulic conductivity rate for existing subgrade soils for overall site assessment and beneath bioretention areas and permeable pavement. The measured saturated hydraulic conductivity with no correction factor may be used as the design infiltration rate if the licensed professional deems the infiltration testing described in this section (and perhaps additional tests) are conducted in locations and at appropriate distribution capable of producing a soil profile characterization that fully represents the infiltration capability where the bioretention or permeable pavement areas are located (e.g., if the small-scale pilot infiltration tests (PITs) are performed for all bioretention areas and the site soils are adequately homogeneous).

If deemed necessary by a licensed professional, a correction factor may be applied to the measured saturated hydraulic conductivity to determine the long- term design native soil infiltration rate. Whether or not a correction factor is applied and the specific number used will depend on heterogeneity of the site soils and number of infiltration tests in relation to the number and type of infiltration areas. For bioretention, the overlying bioretention soil mix provides excellent protection for the underlying native soil from sedimentation; accordingly, the measured native soil infiltration rate for bioretention does not require a correction factor for influent control and potential clogging over time.

For recommendations on test frequency and correction factors specific to bioretention, see BMP F6.23: Bioretention. For recommendations on test frequency and correction factors specific to permeable pavement, see 6.5 Infiltration BMPs.

The depth and number of test holes or test pits and samples should be increased if, in the judgment of a licensed professional, conditions are highly variable and such increases are necessary to accurately estimate the performance of the infiltration system. Licensed professionals for this type of evaluation include certified soil scientists, licensed engineers in the state of Washington, geologists, hydrogeologists or licensed engineering geologists in the state of Washington. The exploration program may also be decreased if, in the opinion of the licensed professional, the conditions are relatively uniform and omitting the test pits or borings will not influence the design or successful operation of the BMP. At sites with a high water table, the subsurface exploration sampling need not be conducted deeper than 2 feet below the groundwater table.

Prepare detailed logs for each test pit or test hole and a map showing the location of the test pits or test holes. Logs should include, at a minimum: depth of pit or hole, soil descriptions, depth to water, and presence of stratification. Logs should substantiate whether stratification does or does not exist. The certified soils professional may consider additional methods of analysis to substantiate the presence of stratification that may influence the design or successful operation of the LID practice.

Soil stratigraphy should also be assessed for low-permeability layers, highly permeable sand/gravel layers, depth to groundwater, and other soil structure variability necessary to assess subsurface flow patterns. Soil characterization for each soil unit (soil strata with the same texture, color, density, compaction, consolidation, and permeability) should include the following:

- Grain size distribution
- Textural class
- Percentage of clay content
- Cation exchange capacity
- Color/mottling
- Variations and nature of stratification

If the groundwater in the area is known to be < 5 feet below the proposed LID BMP, the groundwater regime should be assessed. At a minimum, groundwater monitoring wells should be installed to determine groundwater depth and seasonal variations, considering both confined and unconfined aquifers. Monitoring through at least one high groundwater period is necessary, unless site historical data regarding groundwater levels are available.

If on-site infiltration may result in shallow lateral flow (interflow), the conveyance and possible locations where that interflow may reemerge should be assessed by a certified soil scientist, licensed engineer in the state of Washington, geologist, hydrogeologist or licensed engineering geologist in the state of Washington (or suitably trained persons working under the supervision of the above professionals or by a locally licensed on-site sewage designer). In general, a minimum of three wells associated with three hydraulically connected surface or groundwater features are necessary to determine the direction of flow and gradient. Alternative means of establishing the groundwater levels may be considered. If the groundwater in the area is known to be > 5 feet below the proposed LID BMP, detailed investigation of the groundwater regime is not necessary.

Special considerations are necessary for highly permeable gravel areas. Signs of high groundwater will likely not be present in gravel lacking finer grain material such as sand and silt. Test pit and monitoring wells may not show high groundwater levels during low precipitation years. Accordingly, sound professional judgment, considering these factors and water quality treatment needs, is required to design multiple and dispersed infiltration BMPs on sites with gravel deposits.

A groundwater mounding analysis should be considered if the minimum depth to bedrock, water table, or other impermeable layer is < 5 feet. Groundwater mounding analysis may also warrant consideration if the contributing area drains to a LID BMP is large relative to the BMP footprint area.

See 6.5.4 Determining the Design Infiltration Rate of the Native Soils for detailed discussion of the following methods for evaluating native soil infiltration rates:

- In situ small-scale PIT method
- In situ large-scale PIT method
- Soil grain size analysis method

Generally, the small-scale and large-scale PITs are similar; however, the small-scale PIT reduces cost and test time and is appropriate for LID BMPs that have relatively low hydraulic loadings. The large-scale PIT is preferred for large-scale permeable pavement installations where stormwater from adjacent impervious surfaces is directed to the pavement surface, resulting in higher hydraulic loads. The soil grain size analysis method can be used if the site has soils unconsolidated by glacial advance. Consult local jurisdiction for soil testing and reporting requirements that pertain to the project site.

Native Vegetation and Soil Protection Areas

The conservation and use of on-site native vegetation and soil for stormwater management is a central tenet of LID design. Protecting these features helps reduce runoff, increase evapotranspiration, and reduce erosion from the site.

Vegetation surveys may be needed to determine baseline conditions, establish long-term management strategies, and determine appropriate application of dispersion techniques if stormwater is directed to the protection area. The following are steps to conduct a basic inventory and assessment of the function and value of on-site native vegetation:

- Identify vegetated areas on the site, including species and condition of ground cover and shrub layer.
- Identify underlying soils using soil pits and soil grain analysis to assess infiltration capability (6.5 Infiltration BMPs for site-specific analysis procedures).

Access

Vehicle and pedestrian access, circulation, and parking are elements of the built environment that should be identified as part of the site inventory and analysis. Access can often represent a controlling element for the design of a site. The designer should consult local requirements for site access. These requirements will establish the number of allowed access points, the width of the access, the spacing of access points between sites on the same or opposite side of the adjacent street right-of-way, and pedestrian circulation requirements along and through the site to the proposed use.

The following steps should be used to inventory and assess access:

- Map the location of roads, driveways, and other points of ingress and egress within 50 feet of the site.
- Consult the local jurisdiction to identify the classification of the street that will be providing access to the site. Knowing the classification of the abutting street will allow the designer to

understand frontage improvements, sight distance requirements, allowed driveway widths, and other geometric design requirements.

- Consult with the local jurisdiction to understand any motorized or nonmotorized plans that may influence the design of the project.

Land Use Controls

It is important to consult the local jurisdiction's planning department and review land use regulations in order to determine the allowable land uses and development standards. Review of the local planning standards will reveal if there are limitations on impervious surface coverage (lot coverage), minimum landscaping requirements, minimum lot area, setback requirements, parking requirements, and site design standards associated with building placement and orientation.

The following steps should be used to analyze and document land use controls:

- Review applicable comprehensive plan designation, zoning classifications, and overlay districts that may apply to the site. Overlay districts may include requirements for special design review or historic district overlays.
- Determine whether a locally adopted Shoreline Master Program applies to the site and comply with applicable guidelines and requirements.
- Consult with the local jurisdiction to identify other land use regulations that may allow clustering or other practices intended to minimize impervious surfaces. Examples include planned use district chapters and performance zoning chapters.

Utility Availability and Contacts

The location of wet (e.g., water, sewer, stormwater, etc.) and dry (e.g., power, phone, cable, etc.) utilities must be identified and the adequacy or concurrency of these utilities should be confirmed. Where utilities already exist on the site, easements or other covenants that may stipulate on-site restrictions should be identified and mapped by a surveyor. The county auditor or recorder's office or a title company is often a good source of finding restrictions and easements that may be recorded against the title of the property. Also consider directly contacting the utility purveyors for this information.

If new utilities need to be extended to the site, the designer will need to understand where the utility will come from, and potentially extend to, and the impact that easements and restrictions may have on the site design.

The following steps should be used to assess utilities:

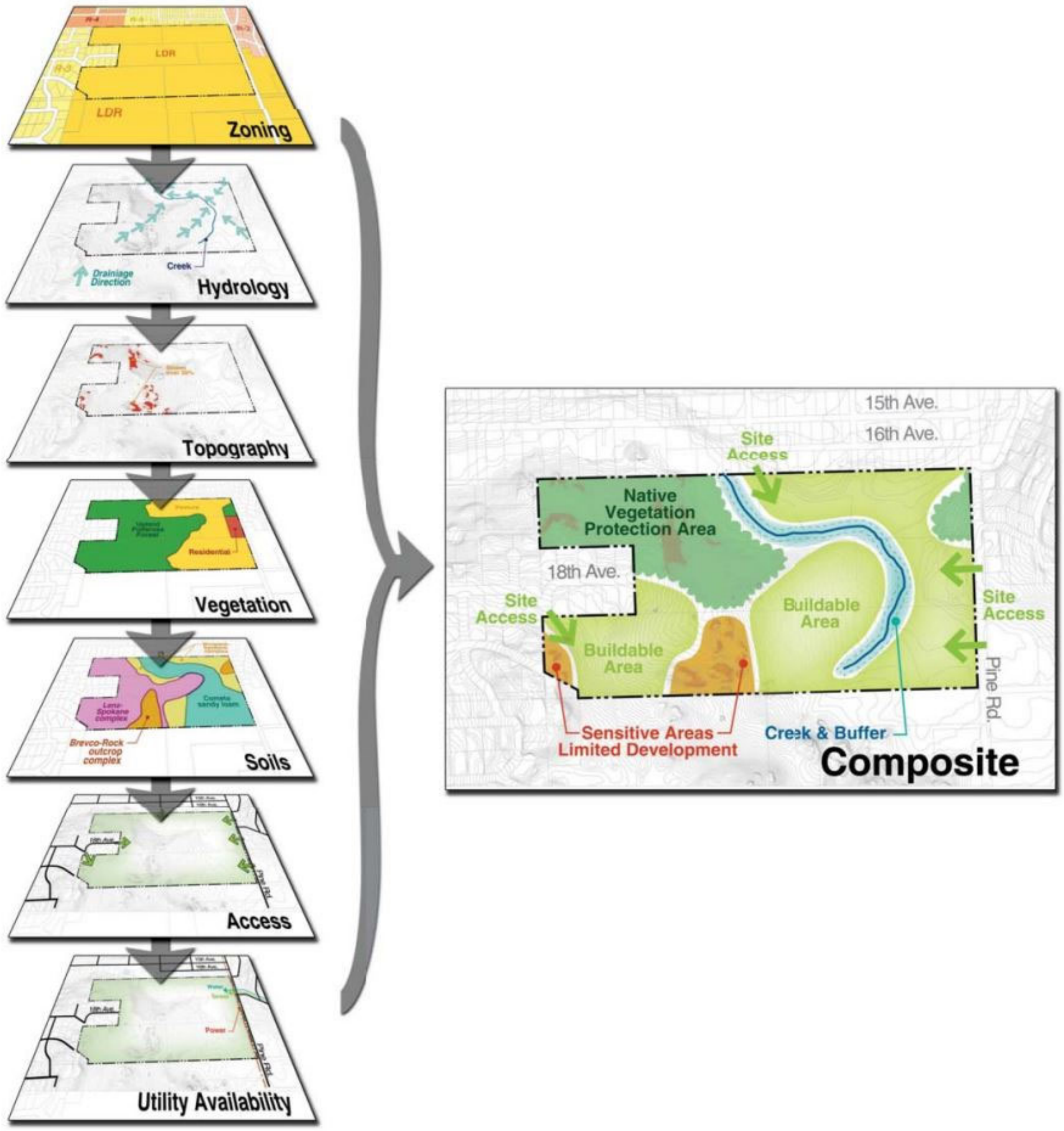
- Consult with the utility purveyor(s) to determine the location of wet (e.g., water, sewer, stormwater, etc.) and dry (e.g., power, phone, cable, etc.) utilities and discuss the proposed plans. This consultation should be initiated during the planning phase of the project and extended through final design.
- Map existing utilities and utility easements on the site plan. Note the setbacks from the easements that may be required.

- Map existing utilities that may need to be moved and new utilities to be extended to the site.
- Design appropriate measures to move or protect utilities, as needed.

Site Mapping Process

Through the assessment process, discussed in the Site Analysis portion of this appendix, map layers are produced to delineate important site features. These map layers are combined to provide a composite site map that guides the layout of streets, structures, and other site features and the overall location of the development envelope(s) (see Figure 3.3: Composite Site Map). This composite site map should be used for all development types and will form the basis for the site design, discussed in detail in 3.C.3 Designing for LID.

Figure 3.3: Composite Site Map



Source: Low Impact Development Technical Guidance Manual for Puget Sound (WSU-PSP, 2012)

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Composite Site Map

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3.C.3 Designing for LID

Design Process Overview

The low impact development (LID) design process builds on the planning process and the resulting composite site map of LID opportunities and constraints (3.C.2 LID Site Planning). The topography, hydrology, soils, vegetation, and other natural site features that are identified and analyzed through the site analysis will guide the layout of roads, buildings, parking, and other physical infrastructure, as well as LID Best Management Practices (BMPs).

The following text provides an overview of the design process, including clearly defining site goals, identifying applicable design standards and requirements, developing solutions that match the project goals with site opportunities and constraints, preparing a preliminary layout, and finalizing the design. This general design process works for many types of design, including standard urban stormwater management practices and LID. Following the general design process overview, more detailed guidance is provided for design of infiltration-based LID BMPs.

Define Site Goals

As described in 3.C.2 LID Site Planning, LID is versatile and may be successfully applied to meet a broad range of site goals. Possible site goals may include the following:

- Meeting core element requirements for runoff treatment and/or flow control
- Retrofitting existing developments for water quality improvement
- Reducing site water and energy demands
- Improving neighborhood aesthetics and mobility
- Controlling combined sewer overflows (CSOs)

The design process begins by clearly establishing the goals for the project, as these will ultimately drive the site layout and selection, sizing, and design of LID BMPs. LID projects commonly have multiple goals. By understanding all of the goals and their relative importance at the start of design, the team can develop plans that best accommodate all objectives or effectively prioritize what can be accomplished.

Identify Applicable Design Standards and Requirements

The next step is identifying and reviewing the local jurisdiction’s stormwater, roadway, utilities, and other engineering standards that will influence the design. This step typically involves meeting with local jurisdiction staff to discuss the proposed project and approach to meeting the standards and requirements. This meeting, often in the form of a preapplication meeting, should occur concurrent with the site inventory and assessment (3.C.2 LID Site Planning), and prior to the initiation of detailed site design. Local standards and requirements that may influence LID site design include the following:

- Stormwater regulations and design standards
- Setback requirements for infiltration BMPs

- Setback requirements for structures (e.g., cisterns may require setbacks from property lines)
- Soil and subsurface hydrology evaluation and reporting requirements
- Sizing methodologies to be used to demonstrate compliance with applicable stormwater requirements
- Street network design standards

During this review of design standards and requirements, the design team should also confirm local jurisdiction requirements for design submittal preparation, so the submittal requirements are understood prior to preparing the design package.

Every opportunity to optimize the LID design should be considered. Locally adopted design standards for street networks, generally derived by the American Association of State Highway and Transportation Officials (AASHTO), often require wider improvements than are necessary to facilitate the multimodal circulation objectives for the street classification. LID design practices, such as the use of flush curbs, can be used to satisfy International Fire Code (IFC) and AASHTO requirements for minimum travel widths. Municipal staff and project designers should review locally adopted standards for street improvements and parking requirements to consider design solutions where LID practices can maintain the use and function of the street network while concurrently achieving a stormwater benefit.

Selecting LID Solutions to Match Site Conditions and Goals

The selection of the LID solutions that match site conditions and goals should equally consider nonstructural and structural practices. Factors that affect selection of LID solutions include the following:

- Ability to meet site goals (summarized in the Define Site Goals section of this appendix). For example, bioretention can help meet flow control and treatment stormwater requirements, improve transportation safety and mobility, and provide aesthetic neighborhood enhancement. Minimal excavation foundations can help maintain site hydrology and significantly improve constructability on challenging sites. Vegetated roofs can reduce impervious surface area and improve building insulation, reducing energy demands for the site. Understanding the site goals and priorities is key to selecting the best LID solutions to be included in the designs.
- Soils and subsurface hydrology (3.C.2 LID Site Planning), which dictate infiltration feasibility. Infiltration-based BMPs should be prioritized for meeting flow control and treatment requirements where feasible.
- Available space for siting BMPs.
- Constructability.
- Ease of maintenance.
- Public acceptance (for public projects).

Streets and parking lots contribute significant impervious surface coverage, so site strategies to minimize this cover should be considered before stormwater storage and runoff treatment options. The residential design strategies and commercial and industrial design strategies presented in the Residential Design Strategies and Commercial and Industrial Design Strategies subsections include analysis of opportunities to minimize impervious surface coverage through thoughtful design of streets, access, parking, and other site infrastructure.

Develop Preliminary Site Layout

The preliminary site layout is an iterative process intended to balance and optimize the proposed project, avoid site constraints, conserve vegetation, and exploit infiltration opportunities. The site plan will show the location of proposed buildings, roadways, parking, utilities, and LID BMPs. The preliminary site layout should reflect required sizing of LID BMPs to meet applicable stormwater requirements. The preliminary site layout should also be drawn to a scale to show the feasibility of locating BMPs in the available space, considering local setback and other applicable requirements.

During development of the preliminary site layout, strategies to minimize impervious cover should be explored. These may include reducing roadway widths and parking (as allowed by local ordinances), paving with permeable paving, clustering buildings, and reducing the land coverage of buildings by constructing taller and narrower footprints. All of these strategies make more land available for infiltration, open space, and landscape amenities. In addition, reducing impervious surfaces should result in smaller-sized stormwater BMPs, yielding significant savings in development and maintenance costs.

Finalize Designs

After LID BMPs have been properly sized, the design team can begin preparing final site designs. This final design step entails updating the preliminary site plan (see previous section: Develop Preliminary Site Layout) to represent final sizing and BMP layout and confirming that the site goals are met. If the goals established for the project are not met, some iteration may be needed to reach the final design.

Review local engineering standards to determine the design package submittal requirements that pertain to each phase of design. A thorough understanding of the local engineering standards, submittal requirements, and review process will save significant time, money, and staff resources during design and permitting.

Steps for Design of Infiltration BMPs

This section provides a step-by-step process for designing infiltration-based LID BMPs, including bioretention and permeable pavement. The seven-step process is adapted from the *Stormwater Management Manual for Western Washington*, with updates as needed for eastern Washington.

Step 1. Select a Location

Identifying a location for the infiltration-based BMP based on the ability to convey flow to the location and the expected soil conditions and locations based on preliminary soils and subsurface hydrology evaluation (3.C.2 LID Site Planning). Conduct a preliminary check of local jurisdiction infiltration feasibility criteria and Site Suitability Criteria (SSC) in 6.5 Infiltration BMPs.

Step 2. Perform Preliminary BMP Sizing

Estimate the geometry of the infiltration BMP using an approved modeling method listed in Chapter 4 - Hydrologic Analysis and Design. For infiltration BMPs sized to meet treatment requirements, the BMP must successfully infiltrate the 6-month, 24-hour design storm. Flows in excess of this level can bypass the infiltration BMPs.

For infiltration BMPs sized to meet the flow control standard, the BMP must infiltrate a sufficient amount of the influent stormwater runoff such that any overflow/bypass meets the allowed peak flow discharge rate.

Step 3. Develop Trial Infiltration BMP Geometry

Use the preliminary infiltration rate developed from the soils and subsurface hydrology evaluation (3.C.2 LID Site Planning) to develop the trial BMP geometry. If infiltration rates are not available during this step, use a default infiltration rate of 0.5 inches per hour. Use this trial BMP geometry to help locate the BMP and for planning purposes in developing the geotechnical subsurface investigation plan.

Step 4. Complete More Detailed Site Characterization Study and Consider Site Suitability Criteria

Information gathered during initial soils and subsurface hydrology investigations is necessary to know whether infiltration is feasible. More detailed evaluation may be needed during the design phase to evaluate the suitability of the site for infiltration, establish the infiltration rate for design, and evaluate slope stability, foundation capacity, and other geotechnical design information needed to design and assess constructability of the BMP. See 3.C.2 LID Site Planning, for more detailed discussion of soils and subsurface hydrology evaluation.

Step 5. Determine the Design Infiltration Rate

Estimate the design (long-term) infiltration rate as follows:

- Use the large-scale or small-scale PIT method (or other local-approved method) as described in 6.5.4 Determining the Design Infiltration Rate of the Native Soils to estimate a measured (initial) saturated hydraulic conductivity (Ksat). Alternatively, for sites underlain with soils not consolidated by glacial advance (e.g., recessional outwash soils), the measured Ksat may be estimated using grain size distribution analysis.
- Assume that the Ksat is the measured (initial) infiltration rate for the BMP.
- Adjust this rate using the appropriate correction factors, as described in 3.C.2 LID Site Planning.

Step 6. Size Stormwater BMPs

Use an approved modeling method from Chapter 4 - Hydrologic Analysis and Design to evaluate whether the BMP can infiltrate the 6-month, 24-hour design storm if sizing a runoff treatment BMP. If sizing a BMP to meet the flow control requirement, use an approved modeling method to document that the total of any bypass and overflow meets the applicable flow control standard. Size conveyance BMPs in accordance with local jurisdiction requirements.

Step 7. Complete Final Design

After LID BMPs have been sized, the design team can complete the site design. This step entails updating the preliminary site plan to represent final sizing and BMP layout and confirming that the site goals are met. In many instances, the sizing of the BMPs and the completion of the site plan will involve several iterations.

Optional Step: Integrate Performance Monitoring Into Design

Performance monitoring allows for measurement and direct understanding of how the LID BMPs are performing and compare that with design expectations. These findings can provide valuable feedback and lessons learned to help continually improve future design guidelines and standards, as well as construction practices.

If performance monitoring is desired, then the design of LID BMPs and associated hydraulic structures should consider proposed locations for monitoring equipment early in the design process. For example, locations of flow monitoring gauges may influence design of stormwater pipes (material type, size, and slope), as well as conveyance structures and access for maintenance.

The monitoring data can be used to validate design assumptions, inform future design standards updates, and evaluate the LID site performance based on physical, on-site measurements. If the observed site performance was not meeting goals, adaptive management strategies could be implemented. For example, level spreaders could be installed or fixed to maintain disperse flows, curb cut inlets could be modified if needed to improve capture of stormwater flows, orifice controls could be added or adjusted, etc.

Residential Design Strategies

Low-Density Site Planning Strategies

Overall site planning concepts in low-density residential settings should include the following:

- Minimizing driveway lengths
- Using permeable driveway surfacing
- Preserving open space and native vegetation
- Conserving native soil

LID site planning strategies for low-density residential sites should focus on locating buildings as close to primary access roads as practical. Reducing access road lengths will reduce total impervious surface. Regardless of access roadway length, roads should use permeable pavement where feasible. On roads paved with conventional impervious concrete or asphalt surfaces, stormwater runoff should be routed to bioretention BMPs where feasible.

Every effort should be made to minimize storm flow velocities and maximize dispersion to avoid concentrated flows. Slopes with vegetation and nonhardpan soils downhill from proposed buildings and roadways may provide areas for the dispersal of storm flows. Supplemental plantings, soil amendments, and erosion control hydroseeding may also aid in this effort.

Soil conservation is an important site planning strategy. The Natural Resources Conservation Service (NRCS) and the Washington State University Extension offer excellent resources for assessing on-site soil conditions and recommending strategies for soil conservation. Understanding existing soil conditions is fundamental to design and subsequent construction phases.

Medium- and High-Density Site Planning Strategies

Street Layout and Alignment

"Complete streets" is an increasingly popular urban planning approach that promotes planning, designing, operating, and maintaining streets for safe and convenient use by users of all modes of transportation. In addition to improving safety and convenience of use, complete streets also provide extensive opportunities for LID planning and design within the right-of-way, providing additional benefits of flow control, treatment, and neighborhood amenities as integral features.

The overall objectives for LID, whether part of a complete street or not, are the following:

- Reduce total impervious area (TIA) by reducing the total area of street network (e.g., encourage narrow streets).
- Minimize or eliminate effective impervious area (EIA) and concentrated surface flows on impervious surfaces by reducing or eliminating hardened conveyance structures (e.g., gutters, catch basins, pipes, etc.).
- Infiltrate and slowly convey storm flows in street-side bioretention cells and swales, and through permeable pavements and aggregate storage systems under the pavement.
- Design street networks to minimize site disturbance, avoid sensitive areas, and promote open space connections.
- Promote connectivity in neighborhood street patterns and utilize open space areas to promote walking, biking and access to transit and services.
- Provide safe and efficient fire and emergency vehicle access.

Although reducing TIA and minimizing EIA are overall objectives for LID street design, opportunities to integrate bioretention and permeable pavement should also be explored. There may be a tension between trying to reduce TIA and EIA and providing adequate emergency vehicle access. The number of vehicle access points is usually dictated by the size and intensity of land use and is a function of emergency vehicle requirements.

Emergency vehicle access requirements will dictate the width of streets and the length and dimensions of cul-de-sacs. Balancing safe and adequate access with the desire to limit TIA and EIA through narrower streets may require negotiation. Many jurisdictions have successfully reconciled these two often competing objectives, in the form of a deviation, in a manner consistent with IFC, Section 503.2, which stipulates a minimum width of 20 feet (ICC, 2012).

The designer should look for ways of integrating bioretention and permeable pavement into the roadway where feasible. Opportunities abound for retrofitting existing or required buffer strips with bioretention features, and repurposing center medians. The designs should consider that, in eastern Washington, winter snow storage must be accommodated. Storing plowed snow in bioretention BMPs within street right-of-way can be an effective and appropriate strategy for cold climates (see Figure 3.4: Bioretention Snow Storage). Maintenance plans should include provisions to manage the sediment generated from road sanding.

Note: Where existing street standards become a barrier to the implementation of useful LID strategies, it may become necessary to explore adoption of alternative street standard details.

Figure 3.4: Bioretention Snow Storage

Source: Yakima Regional Low Impact Development Stormwater Design Manual
(Yakima County, 2011)

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Bioretention Snow Storage

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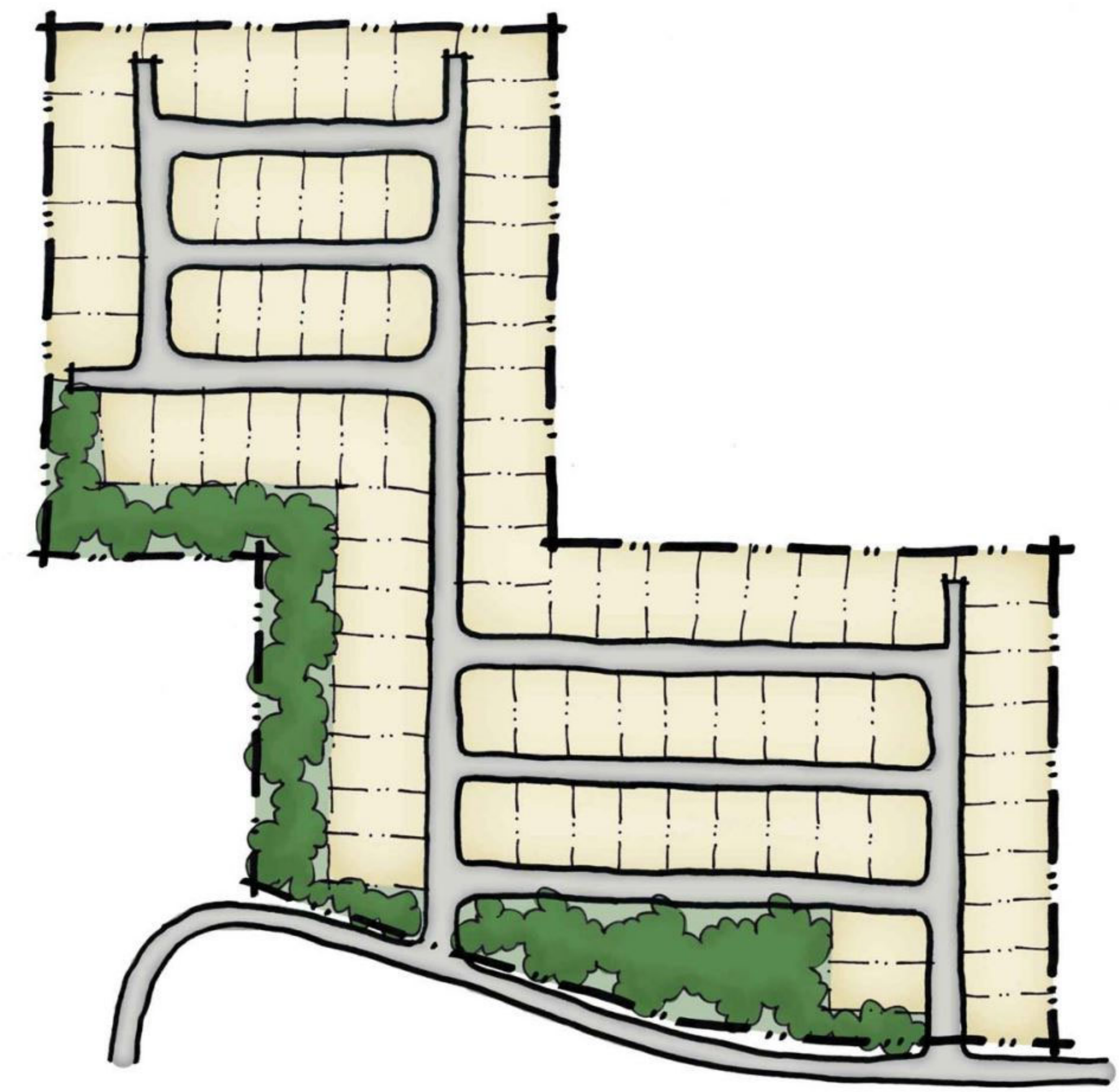
Street Types and Strategies

Residential street designs generally fall into three categories: grid, curvilinear, or hybrid. Figure 3.5: Grid Street Network and Figure 3.6: Curvilinear Street Network illustrate the grid and curvilinear road layouts, and Table 3.1: Grid and Curvilinear Street Network Comparison from the *Low Impact Development Technical Guidance Manual for Puget Sound* provides a concise summary of the strengths and weaknesses of grid and curvilinear street networks (WSU and PSP, 2012).

Figure 3.5: Grid Street Network



Source: Low Impact Development Technical Guidance Manual for Puget Sound (WSU-PSP, 2012)

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Grid Street Network

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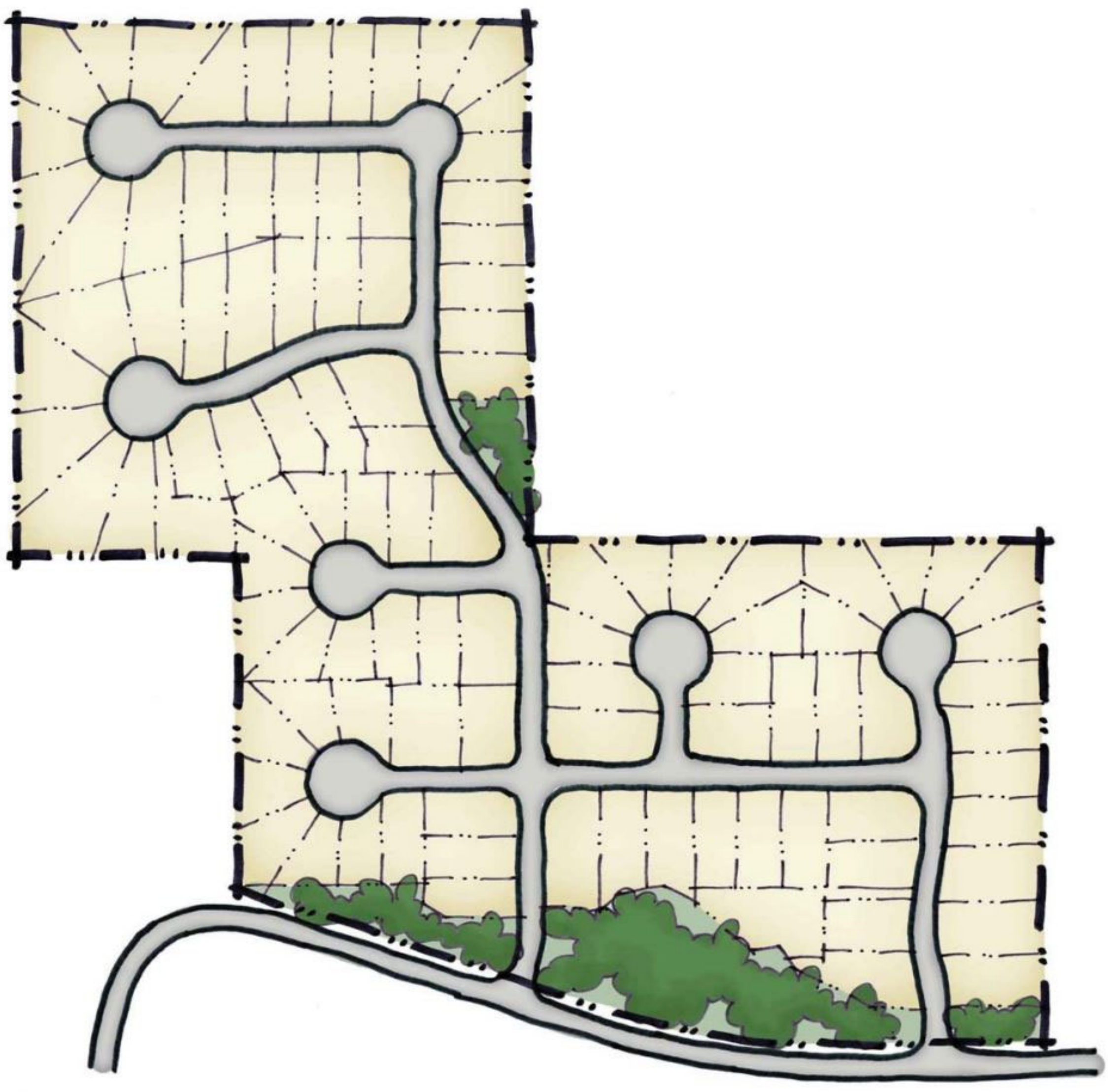
Figure 3.6: Curvilinear Street Network



Source: Low Impact Development Technical Guidance Manual for Puget Sound (WSU-PSP, 2012)

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Curvilinear Street Network

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Table 3.1: Grid and Curvilinear Street Network Comparison

Street Network	Impervious Coverage	Site Disturbance	Biking, Walking, Transit[a]	Safety	Auto Efficiency
Grid	27% to 36% (CMHC, 2007)	Less adaptive to site features and topography	Promotes by more direct access to services and transit	May decrease by increasing traffic throughout residential area	More efficient – disperses traffic through multiple access points
Curvilinear	15% to 29% (CMHC, 2007)	More adaptive for avoiding natural features, and reducing cut and fill	Generally, discourages through longer, more confusing, and less connected system	May increase by reducing through traffic in dead end streets	Less efficient – concentrates traffic through fewer access points and intersections
Looped	Not included in analysis by (CMHC, 2007)	Moderately adaptive to site topography	Promotes efficient access to services and transit	May decrease by increasing traffic throughout residential area	Moderately efficient distri-bution of traffic
[a]Biking, walking, and transit are included for livability issues and to reduce auto trips and associated pollutant contribution to receiving waters.					

Grid and curvilinear street networks have both advantages and disadvantages. Grid street networks provide access and circulation that allow for enhanced traffic flow for all transportation modes. Grid networks, however, typically include approximately 20 to 30% more street length than a similar width curvilinear street network (CWP, 1998). Curvilinear street networks trade minimized impervious surface coverage with poor connectivity that can affect local quality of life. Transportation planners have integrated the two prevalent models into hybrid designs that incorporate the strengths of both (see Figure 3.7: Loop and Grid Hybrid Street Network).

Figure 3.7: Loop and Grid Hybrid Street Network

Source: Low Impact Development Technical Guidance Manual for Puget Sound (WSU-PSP, 2012)

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Loop and Grid Hybrid Street Network

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The following are specific strategies used to create street layouts in medium- to high-density residential developments to minimize impervious surface coverage:

- Cluster structures to reduce overall development footprints and street lengths.
- Allow flexibility in lot width and frontage requirements to reduce overall street lengths.
- Increase block lengths for grid and modified-grid street layouts.
- Reduce cul-de-sac dimensions and integrate landscaping into a center island.
- Allow smaller front yard setbacks to reduce driveway lengths.

Loop streets offer multifunctional street design layouts supporting vehicle and pedestrian needs. A loop street alignment (see Figure 3.7: Loop and Grid Hybrid Street Network):

- Minimizes impervious road coverage per dwelling unit;
- Provides adequate turning radius for fire and safety vehicles;
- Provides through-flow of traffic with two or more points of access; and
- Provides sufficient area for bioretention in the center of the loop and a visual landscape break for homes facing the street.

Open-space pathways between homes, also called "green streets," offer open space and pedestrian amenities that can be combined with areas for wet and dry utilities. A green street design provides:

- A connected pedestrian system that takes advantage of open space amenities; and
- Additional stormwater conveyance and infiltration for infrequent, large storm events.

Smaller infill projects can be designed with one access to the development. Ample traffic flow through the project is provided by the loop and along home frontages, allowing for easier movement of fire and safety vehicles. Open space in the center of the loop can provide stormwater storage, a visual landscape break for homes facing the street, and a creative example of integrating a regulatory requirement with a site amenity.

Street Width

Residential street widths and associated impervious surface cover have increased by over 50% since the mid-1900s (Schueler, 1995). Total and effective impervious area can be significantly reduced by designing BMPs with the narrowest width necessary to meet operational requirements. In addition to the stormwater benefits associated with the reduced impervious surface cover, studies indicate that narrower streets have fewer accidents and are safer (Kulash, 2001), (Schueler, 1995).

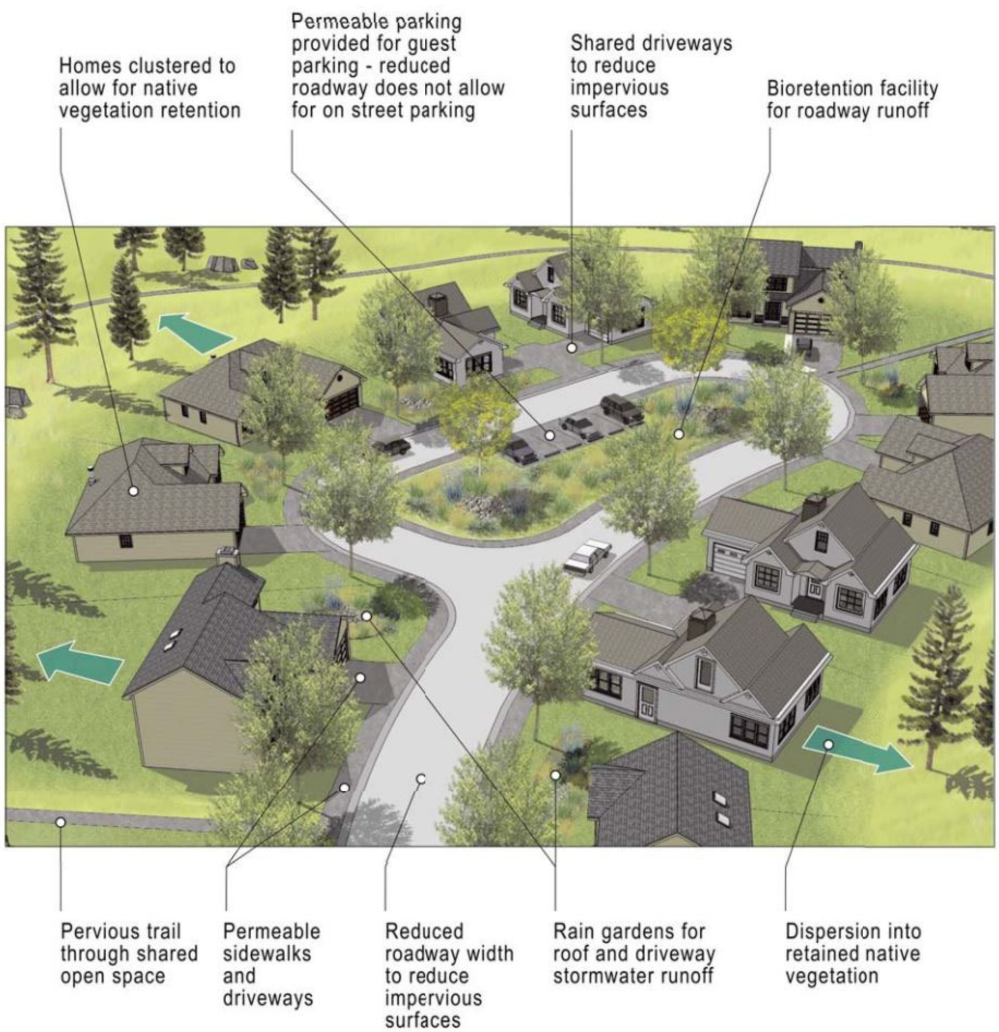
Turnarounds

Dead-end streets, particularly cul-de-sacs, can result in excessive impervious surface coverage. In general, dead-end or cul-de-sac streets should be discouraged because they contribute excessive impervious surface coverage and disrupt vehicle and pedestrian circulation. Where site conditions urge the use of a cul-de-sac or other turnarounds, the design should include elements such as landscaped center areas that minimize impervious surface while accommodating emergency vehicle service and other vehicle needs. A 40-foot radius with a landscaped center should accommodate most service and safety vehicle needs, while maintaining a minimum 20-foot inside turning radius (Schueler, 1995).

Islands in cul-de-sacs should be designed as retention BMPs where feasible.

The loop street configuration is an alternative to the dead-end street and provides multiple access points for emergency vehicles and residents. For similar impervious surface coverage, the loop street has the additional advantage of increasing available storm flow storage within the loop compared to the cul-de-sac design. Figure 3.8: Application of LID illustrates the application of an LID loop street configuration in a residential setting.

Figure 3.8: Application of LID



Source: AHBL and CleanWater Services

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Application of LID

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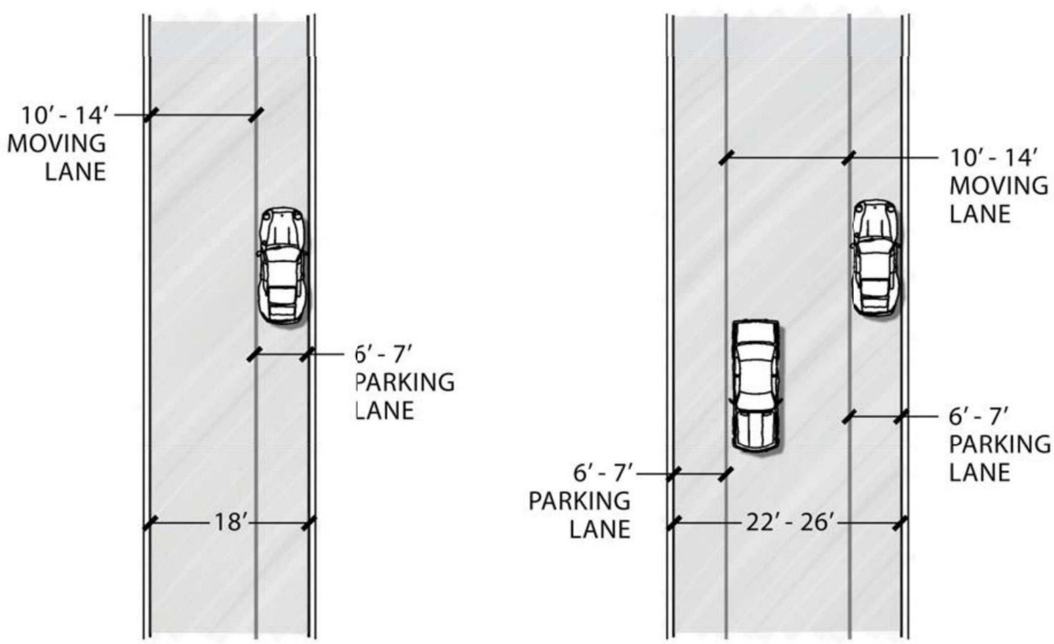
Parking

Most zoning ordinances require between 1.5 and 2.5 off-street parking spaces per dwelling unit. Driveways and garages provide the “off-site” element of the requirement for most projects. Consequently, local street classifications that require parking on both sides of the street in addition to two travel lanes result in excessive impervious surface coverage. Parking needs and traffic movement can be met on narrowed streets where one or two on-street parking lanes serve as a traffic lane (CWP, 1998). Figure 3.9: Parking and Queuing provides two examples of queuing for local residential streets.

Figure 3.9: Parking and Queuing



Source: Low Impact Development Technical Guidance Manual for Puget Sound (WSU-PSP, 2012)

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Parking and Queuing

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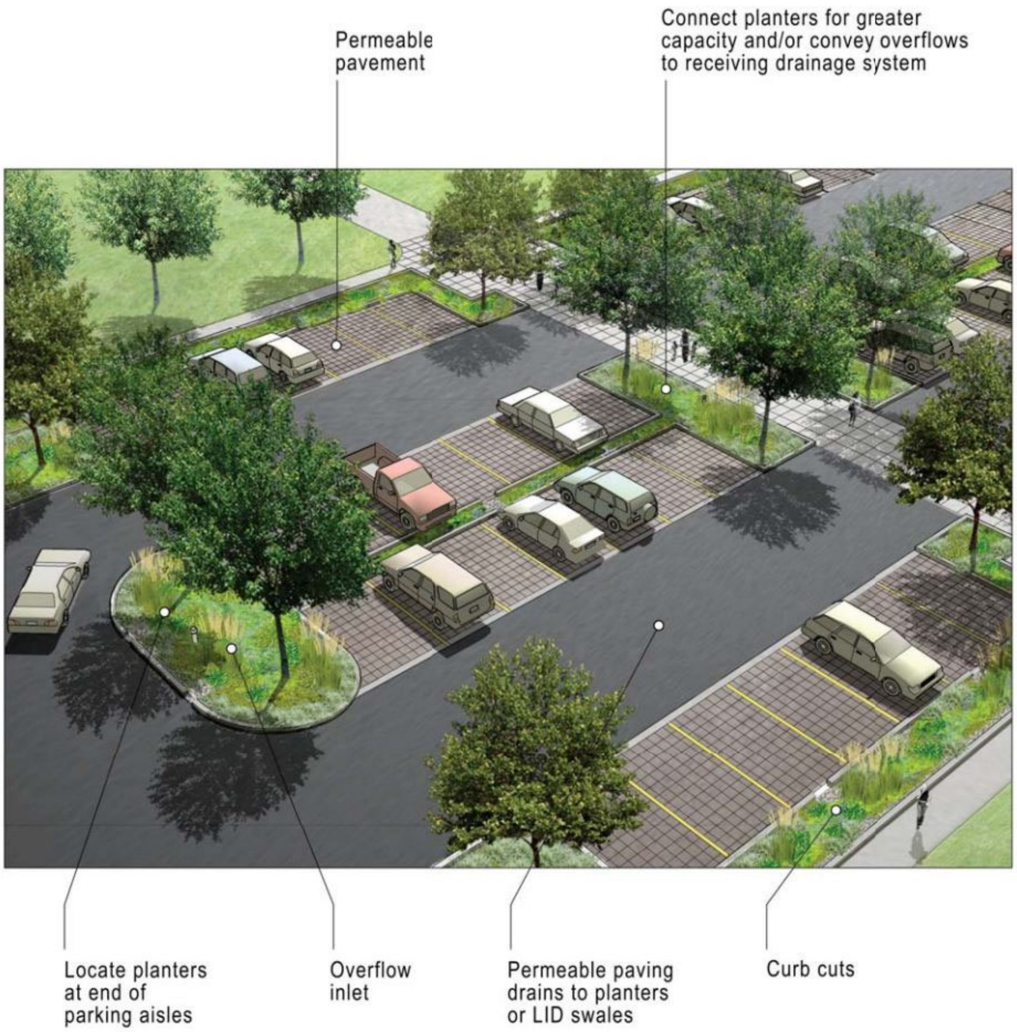
In higher density residential neighborhoods, pull-out parking can be used. Pull-outs (often designed in clusters of two to four stalls) should be strategically distributed throughout the area to minimize walking distances to residences. Depending on the street design, the parking areas may be more easily isolated and the impervious surface disconnected from other areas by slightly sloping the pavement to adjacent bioretention BMPs.

All or part of pull-out parking areas, queuing lanes or dedicated on-street parking lanes can be designed using permeable paving. Porous asphalt, pervious concrete, permeable pavers, and grid systems can support the load requirements for residential use, reduce or eliminate storm flows from the surface, and possibly be more readily acceptable for use on parking areas with lower loads by jurisdictions hesitant to use permeable pavements in the travel way. Snow management is particularly important in eastern Washington, and the site's long-term snow management plans must be considered early in the planning and design phase. Properly designed, constructed, and maintained permeable pavement can increase snowmelt rates and reduce freezing by allowing air and water to flow through the BMP via infiltration and/or underdrains. Figure 3.10: Parking Lot Applications illustrates a range of parking lot LID strategies.

Figure 3.10: Parking Lot Applications



Source: Low Impact Development Approaches Handbook (CleanWater Services, 2009)

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Parking Lot Applications

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Traffic-Calming Strategies

Several types of traffic-calming strategies can be used on residential streets to reduce vehicle speeds and increase safety. These design features also offer an opportunity for storm flow infilt-ration and/or slow conveyance to additional LID BMPs downstream. These features, coupled with narrower street widths are effective LID management strategies. Traffic-calming strategies include the following:

- Traffic circles
- Center planting medians
- Curb extensions or “bulb-outs”
- Curved streets or chicanes

In each case the dimensions of the right-of-way must be adequate to accommodate the calming feature and the feature must be of dimension sufficient to effectively slow traffic. Generally, these traffic-calming strategies should have a minimum dimension of 8 feet. Figure 3.11: Streetscape Applications illustrates a range of street applications of LID.

Figure 3.11: Streetscape Applications

Source: Low Impact Development Approaches Handbook (CleanWater Services, 2009)

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Streetscape Applications

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Alleys

Alleys often provide the primary vehicle access for homes in traditional grid street layouts. Alleys should be the minimum width required to allow: automobile access to garages, snow storage, and adequate area for service vehicles such as refuse trucks.

Strategies to reduce TIA associated with alleys include the following:

- Reducing alley widths from 16 to 20 feet wide to 12 to 16 feet wide
- Inverting crowned alley sections and directing the drainage to a center-line trench draining to bioretention areas
- Using permeable paving materials products such as the following:
  - Pervious concrete
  - Porous asphalt
  - Permeable paver systems
  - Gravel-pave systems
  - Systems integrating multiple types of permeable paving materials

Driveways

As much as 20% of the impervious cover in a residential subdivision can be attributed to driveways (CWP, 1998). Several techniques can be used to reduce impervious coverage associated with driveways including the following:

- Use shared driveways to provide access to multiple homes. Recommended widths range from 9 to 16 feet serving three to six homes (Kulash, 2001). A hammerhead or other configuration generating minimal impervious surface may be desirable for turnaround and parking areas.
- Minimize front yard setbacks to reduce driveway length.
- Reduce driveway widths by:
  - Allowing end-to-end garage layouts (widths 10 to 12 feet);
  - Encouraging single car garages (10 to 12 feet);
  - Using permeable pavements; and
  - Limiting pavement to tire travel paths (Hollywood strips or two-track driveways).

Sidewalks and Walkable Communities

Sidewalks are a key element of a walkable community. The elements of a good pedestrian circulation system include the continuity of the network, separation from vehicle traffic, and a width adequate to allow two adults to walk side by side.

In medium-density residential areas, walkways need not be wide, except near schools or libraries. In most cases, pervious surfacing options can be used. The following strategies should be considered in the design of pedestrian circulation systems:

- Reduce sidewalk to a minimum of 48 inches (36 CFR 1191).
- For low-speed local access streets, provide sidewalks on one side of the street.
- Design a bioretention swale or bioretention cell between the sidewalk and the street to provide a visual break and increase the distance of the sidewalk from the street for safety (Kulash, 2001). This design will also provide easier navigation by wheelchair users because grade transitions for driveways will be accommodated within the planting strip rather than the sidewalk.
- Install sidewalks with a 2% cross-slope to direct storm flow to bioretention BMPs.
- Use permeable pavements to allow infiltration or increase the time of concentration of storm flows.

Stream Crossings

Numerous studies have correlated increased TIA with declining stream and wetland conditions (Azous and Horner, 2000), (Booth et al., 2002), (May et al., 1997). Research in western Washington suggests that the number of stream crossings per linear foot of stream length may be a stronger indicator of stream health (expressed through Benthic Index of Biotic Integrity) than TIA (Avolio, 2003).

Site designers should consider minimizing stream crossings because of the significant stress on stream ecological health that can result from concentrating and directing storm flows and contaminants to receiving waters (Avolio, 2003), (May et al., 1997). Culvert and bridge designs that place supporting structures in the floodplain or active channel confines streamflows should also be avoided.

Commercial and Industrial Design Strategies

Parking

Parking lots and rooftops are the largest contributors to impervious surface coverage in commercially zoned areas. Typical parking stall dimensions are approximately 9 to 10 feet wide by 18 to 20 feet long. The result is as much as 200 square feet (sf) per stall excluding driveways, access aisles, curbs, landscape islands, and perimeter planting strips. A typical parking lot with these features can require up to 500 sf per vehicle or > 1 acre per 100 spaces. The large EIA coverage associated with parking tends to accumulate high pollutant loads from particulate deposition and vehicle use. As a result, commercial parking lots can produce greater levels of petroleum hydrocarbons and trace metals (cadmium, copper, zinc, and lead) than many other urban land uses (Schueler, 1995), (Bannerman et al., 1993).

Most jurisdictions specify parking requirements as a minimum number of spaces that must be provided for the use based on the number of employees, gross floor area, or other parking need metric. While parking infrastructure is a significant expense for commercial development, many national chain retailers have parking formulas that result in the construction of parking that exceeds standards by 30% to 50% (Schueler, 1995). In some instances, the total number of parking stalls provided is a function of a peak demand observed only 1 or 2 days each year during the holiday shopping season.

Limiting parking ratios to reflect need is the most effective of several methods to reduce impervious parking coverage. The following strategies to reduce impervious surface coverage, storm flows, and pollutant loads from commercial parking areas should be explored:

- Assess required parking requirements to determine if the minimum number of spaces is within the marketplace of standards. The Institute of Transportation Engineers publishes parking demand for the land uses included in the latest version of its Trip Generation Manual. For more information, refer to the following web address:

  https://www.ite.org/tripgeneration/index.asp

- Provide incentives to reduce parking by allowing an increase in allowable Floor Area Ratio when transit facilities are provided.
- Establish maximum parking standards that can only be exceeded through the approval of a parking study. Many communities express the maximum parking standard as a function or a percentage of its minimum parking standard.
- Allow 20% to 30% of parking to compact spaces (typically 7.5 by 15 feet).
- Use a diagonal parking stall configuration with a one-way drive aisle between stalls to reduce width of parking stalls. This design solution, where feasible, can result in a reduction of overall lot coverage by 5% to 10%.
- Consider structured parking where density and land values warrant. Structured parking can be located underground or at-grade below the building for a multistory structure.
- Use permeable pavement materials for driveways, drive aisles, parking spaces, and walkways where feasible.
- Designs should include appropriate measures for protecting sole source aquifers (e.g., treatment liners, underdrains, etc.) where applicable.
- Integrate bioretention into parking lot islands or planter strips distributed throughout the parking area to infiltrate, store, and/or slowly convey storm flows. Where allowed, credit these bioretention BMPs toward landscaping requirements that may apply to the interior or perimeter of a parking lot.
- Encourage cooperative parking agreements to coordinate use of adjacent or nearby parking areas that serve land uses with noncompeting hours of operation.

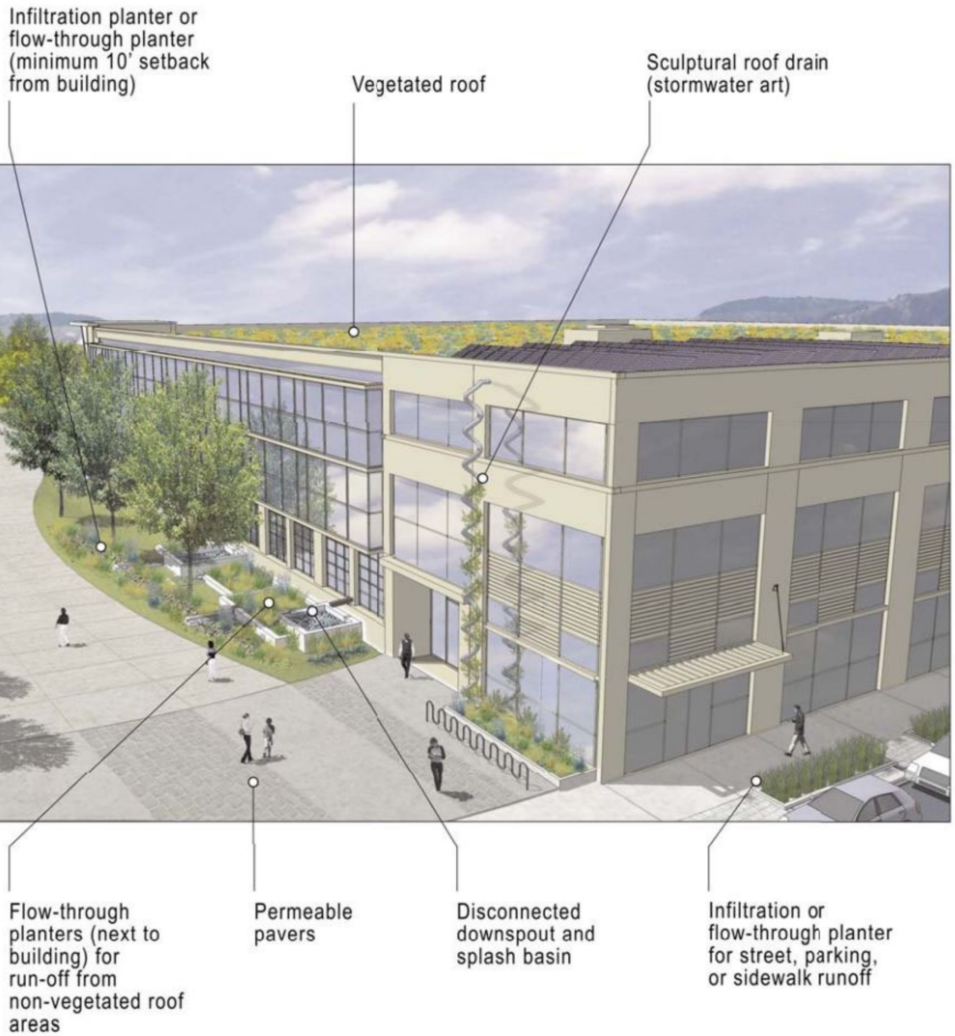
Building Design

Objectives for building design are to minimize storm flows and site disturbance, using the following types of strategies (Figure 3.12: Building Applications):

- Reducing building footprints by designing smaller and/or taller structures. Smaller building footprints can result in less land disturbance during construction. Proposals to construct taller buildings can also present specific fire, safety, and health issues that may need to be addressed. For example, multifamily residences over 2.5 stories may require a fire escape and/or a sprinkler system.

- Using vegetated roofs or heavily landscaped rooftop patio areas, with generous landscaped planters. Vegetated roofs are routinely used in other arid or semiarid part of the country for managing stormwater, as well as the economic benefits associated with improved aesthetics, increased useable space, and reduced energy consumption due to the insulating properties of the roof.
- Capturing, harvesting and reusing rooftop rain water for irrigation or other nonpotable building water through cisterns or other rain water collection systems. Rain water reuse is especially applicable for areas where infiltration is not feasible, such as sites situated over sole source aquifers, high water tables, or shallow depth to bedrock.
- Controlling roof water on-site and direct roof drainage to splash blocks and bioretention BMPs.
- Using minimal excavation foundations where appropriate.
- Limiting clearing and grading of the site.

Figure 3.12: Building Applications



Source: Low Impact Development Approaches Handbook (CleanWater Services, 2009)

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Building Applications

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Chapter 4 - Hydrologic Analysis and Design

4.1 Introduction to Hydrologic Analysis and Design

The purpose of this chapter is to provide guidance for sizing runoff treatment Best Management Practices (BMPs) to protect the quality of receiving waters and flow control BMPs to protect stream morphology and habitat.

The chapter does *not* provide guidance for sizing flood control BMPs, conveyance systems, or subsurface infiltration BMPs (drywells), but these methods may be used for design of those and other stormwater infrastructure components. Contact the local jurisdiction regarding design criteria and requirements.

In the general design of flow control BMPs, the optimal placement of multiple small-scale retention/infiltration BMPs within a contributing area may require less total storage capacity to meet a given peak flow rate target than a single large BMP at the outlet of the contributing area.

4.2 Hydrologic Analysis Methods and Applicability

4.2.1 Introduction

One or more of the following methods may be approved to analyze stormwater runoff from projects for design of runoff treatment Best Management Practices (BMPs) in a jurisdiction:

- Single-event hydrograph methods:
  - Soil Conservation Service (SCS) hydrograph
  - Santa Barbara Urban Hydrograph (SBUH)
- SCS curve number equations
- Level-pool routing method
- Rational Method

Flow control BMPs must be sized using a single-event hydrograph method and the level-pool routing method. If available and approved, a continuous runoff model or other hydrograph modeling method may be used.

Other hydrograph models based on peer-reviewed methods and supported by local data also may be approved by agencies or local jurisdictions; some may require special expertise and experience in their application.

Table 4.1: Comparison of Hydrologic Analysis Methods for Runoff Treatment and Flow Control BMP Design (continued) provides a short description of each of the hydrologic analysis methods, summarizes the advantages and disadvantages of each method, and summarizes the situations in which each of these methods may be used. 4.5 Single-Event Hydrograph Methods through 4.8 Rational Method describe their use in greater detail.

Table 4.1: Comparison of Hydrologic Analysis Methods for Runoff Treatment and Flow Control BMP Design

Method	Description	Advantages	Disadvantages	Applicability
Soil Conser-vation Service (SCS) hydrograph	Single-event hydrograph method that involves routing a proposed development hydrograph and rainfall distribution through a BMP to compare against allowable release rates.	Commercially available computer programs	Some SCS hydrograph models such as TR-55 are restricted to 24-hour hyetographs and will not allow the regional and short-duration storm hyetographs developed for eastern Washington.	• Flow control BMPs (required) • Peak flow rates and runoff volumes for runoff treatment BMPs (allowed)
Santa Barbara Urban Hydrograph (SBUH)		• Commercially available computer programs • Most accurate for small basins (< 100 acres)	• Not accurate for large basins (≥ 100 acres) where groundwater flow can be a major contributor to the total flow • Should not be used for basins > 1,000 acres	
Soil Conser-vation Service (SCS) curve number (CN) equations	Estimate total runoff volume based on precipitation depth and CN. Typically used in conjunction with a single-event hydrograph method (SCS hydrograph or SBUH).	• Does not require use of a computer program; can be determined using a calculator • Commonly used for small and large basins	• Is not linked to a rainfall distri-bution (only precipitation depth) • Selection of CN is inherently subjective and may require adjustment for high groundwater, shallow bedrock, soil compacted by	Runoff volumes for runoff treatment BMPs (based on SCS hydrograph method)

Table 4.1: Comparison of Hydrologic Analysis Methods for Runoff Treatment and Flow Control BMP Design (continued)

Method	Description	Advantages	Disadvantages	Applicability
			heavy equipment, etc. • Method origins are from large rural basins	
Level-pool routing method	Method to route a hydrograph through an existing retention/detention BMP or closed depression. Typically used in conjunction with a single-event hydrograph method (SCS or SBUH).	Commercially available computer programs	None identified	Flow control BMPs (required)
Rational Method	Calculation based on Q = CIA, where: • Q = runoff (cfs) • C = runoff coefficient based on land cover and slope • I = rainfall intensity (inches/hour) • A = contributing area (acres)	• Does not require use of a computer program; can be determined using a calculator • Most accurate for small basins (< 100 acres) and developed conditions with large areas of impervious surface (e.g., pavement, rooftops)	• Precipitation intensity is variable and does not fall at a constant rate • Not accurate for large basins (≥ 100 acres) since the effects of infilt-ration are often not properly accounted for • Should not be used for basins > 1,000 acres	• Flow-rate-based treatment BMPs (allowed) • Used for biofiltration swale, oil and water separator, and drywell sizing • Used for conveyance system sizing
Modified Rational	This method is used to estimate storage	Produces a peak flow rate and runoff	• May underes-timate the	Peak flow rates and runoff volumes

Table 4.1: Comparison of Hydrologic Analysis Methods for Runoff Treatment and Flow Control BMP Design (continued)

Method	Description	Advantages	Disadvantages	Applicability
Method (Bowstring Method)	requirements for a given design storm using a series of hydrographs for different storm durations.	volume (compared to peak flow rate only for the Rational Method)	required storage volume for any given storm event • Limited to contributing areas < 20 acres with generally uniform surface cover and topography	
Water Budget Method	This method uses average monthly precipitation and pan evaporation values to estimate the net stormwater runoff volume increase during a 2-year cycle.	Accounts for seasonal variations in precipitation, pan evaporation, and antecedent runoff conditions	• May be difficult to account for imported water sources (e.g., irrigation, septic systems, natural springs, foundation drains, dewatering wells, etc.) • May be difficult to account for groundwater seepage	Evaporation pond design
Other hydrograph models	Peer-reviewed methods and supported by local data	Varies	Varies	Varies

4.2.2 Hydrologic Analysis for Core Element #5: Runoff Treatment

Runoff treatment BMPs designed to meet 2.4.5 CE5: Runoff Treatment treat stormwater runoff from pollution-generating surfaces. Each runoff treatment BMP is sized based on a water quality design volume, or a water quality design flow rate. 2.4.5 CE5: Runoff Treatment identifies the design volume or flow rate that needs to be treated. Agencies and local jurisdictions should adopt criteria to provide for consistent sizing of runoff treatment BMPs (see 2.4.5 CE5: Runoff Treatment). Various modeling approaches can be used to determine design and sizing requirements for runoff treatment BMPs; the recommended methods for predicting runoff volumes and flow rates are included in this chapter. Specific design criteria for runoff treatment BMPs also may be identified in Chapter 6 - Runoff Treatment, Flow Control, and LID BMP Library in order to achieve the performance goal of a particular BMP.

4.2.3 Hydrologic Analysis for Core Element #6: Flow Control

Flow control BMPs designed to meet 2.4.6 CE6: Flow Control are intended to protect stream morphology and habitat; flood control and conveyance are not addressed. 2.4.6 CE6: Flow Control identifies the requirements for hydrologic analysis when designing flow control BMPs to protect stream morphology and habitat. 2.4.6 CE6: Flow Control also lists projects and locations that are exempt from the flow control requirement. In order to design a flow control BMP, a hydrograph model must be used to compare the predevelopment or existing condition to the postdevelopment condition. Agencies and local jurisdictions may impose predetermined or other stricter predevelopment or existing condition parameters. The suggested hydrograph method is a single-event hydrograph such as the SCS hydrograph or the SBUH method; agencies or local jurisdictions may adopt other methods to meet the intent of the flow control requirement and/or they may also require more stringent design criteria. SCS curve number equations may not be used to design flow control BMPs.

4.2.4 Flow Bypass and Additional Area Inflow

Bypassing Areas that Require Flow Control

This guidance applies to Flow Control BMPs that are not receiving flow from the entire amount of area that must be mitigated.

A portion of an area that requires a Flow Control BMP to meet a Flow Control based performance standard may bypass the Flow Control BMP, provided that all of the following conditions are met:

1. Runoff from both the bypass area and the Flow Control BMP converges within a quarter-mile downstream of the project site discharge location.
2. The Flow Control BMP is designed to compensate for the uncontrolled bypass area such that the net effect at the point of convergence downstream is the same with or without bypass.
3. The 100-year peak 15-minute discharge from the bypass area will not exceed 0.4 cfs.

4. Runoff from the bypass area will not create a significant adverse impact to downstream drainage systems or properties.
5. Runoff Treatment requirements applicable to the bypass area are met.

Inflow From Areas that Don't Require Flow Control

This guidance applies to Flow Control BMPs that are receiving flow from areas in addition to the areas that must be mitigated.

Depending on site layout and topography, Flow Control BMPs may need to be positioned on a site such that runoff from areas that do not need to be mitigated are directed to the Flow Control BMP. These additional areas may come from on-site or off-site.

For example, a redevelopment project may need to provide Flow Control for the new hard surfaces (and not for the replaced or existing hard surfaces), but the proposed Flow Control BMP is placed such that flow from the new AND replaced (and existing) hard surfaces is directed to it. The flow from the replaced and existing hard surfaces would be considered additional flow to the Flow Control BMP.

Runoff from these additional areas must be modeled using the acreages associated with the existing land use areas.

The performance of Flow Control BMPs can be compromised if the additional area, beyond the area that needs to be mitigated, is too large. Therefore, if the existing 100-year peak flow rate from the additional area is **greater** than 50% of the 100-year developed peak flow rate (undetained) from the area requiring mitigation, then the runoff from the additional area must not flow to the Flow Control BMP. The bypass of the additional area must be designed to achieve both of the following:

1. Any existing contribution of flows to an on-site wetland must be maintained.
2. Flows from the additional areas that are naturally attenuated by the project site under predeveloped conditions must remain attenuated, either by natural means or by providing additional on-site Flow Control BMP(s) so that peak flows do not increase.

4.2.5 Closed Depression Analysis

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 (see 2.3 Applicability of the Core Elements) and the local government's Sensitive Areas Ordinance and Rules (if applicable) 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 2.4.8 CE8: Wetlands Protection may apply. Review 2.3 Applicability of the Core Elements to determine which Core Elements apply to the site.

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.

4.3 Design Storm Distributions

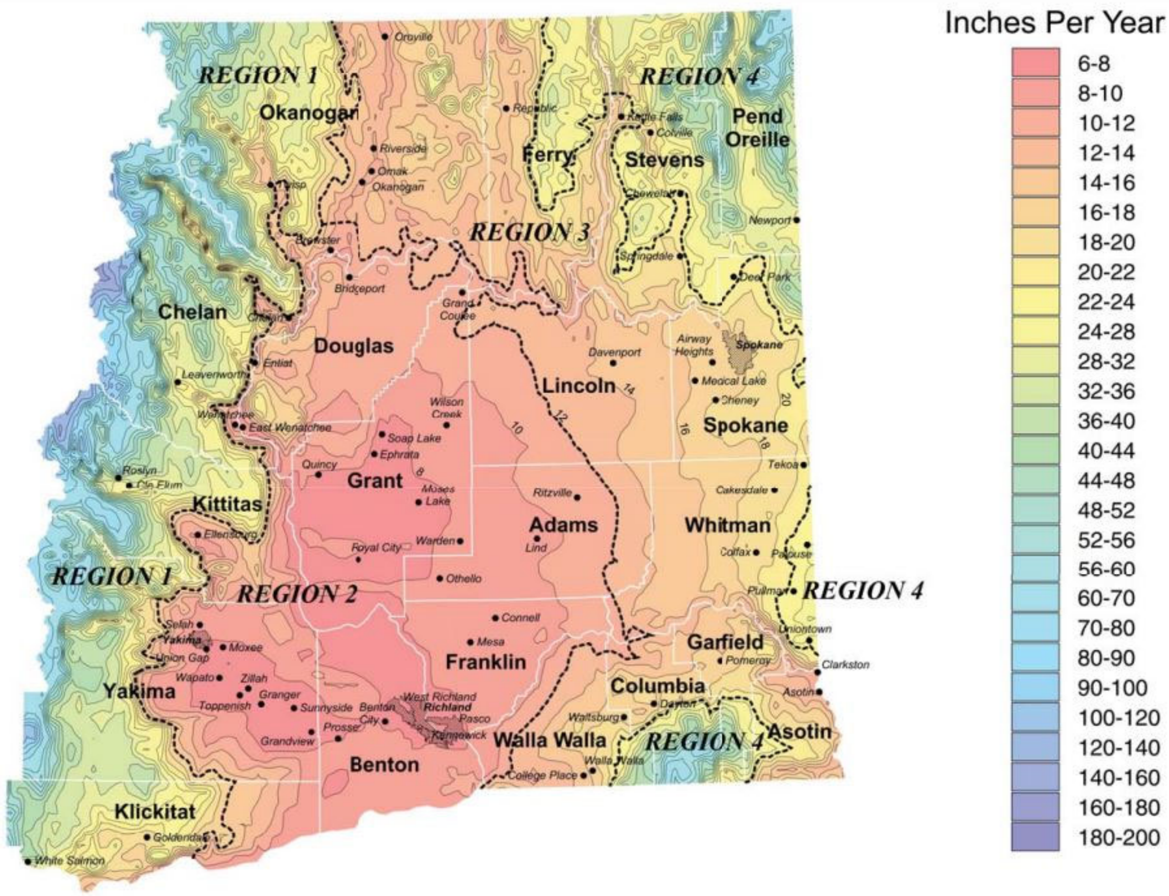
4.3.1 Climate Regions

Eastern Washington has been divided into four climate regions to reflect the differences in storm characteristics and the seasonality of storms. The boundaries of these climate regions are based on average annual precipitation contours as shown in Figure 4.1: Average Annual Precipitation and Climate Regions. See 4.3.6 Precipitation Magnitude/Frequency Analysis and 4.3.7 Precipitation Magnitude and Frequency for 24-Hour and Regional Storms for isopluvial maps used for sizing flow control and runoff treatment Best Management Practices (BMPs). Additional isopluvial maps can be found in 4.4 Precipitation Maps. The four climate regions are summarized in Table 4.2: Climate Region Summary.

Table 4.2: Climate Region Summary

Climate Region	Description	Average Annual Precipitation Range	Average Annual Precipitation Boundaries
Climate Region 1: East Slopes of Cascade Mountains	This climate region consists of mountain areas on the east slopes of the Cascade Mountains.	16 to > 60 inches	• Western boundary: Cascade crest • Eastern boundary: 16 inches
Climate Region 2: Central Basin	This climate region consists of the Columbia Basin and adjacent low-elevation areas in central Washington.	• 6 to 16 inches • Majority of cities = 8 inches of average annual precipitation	• Western boundary: 16 inches • Eastern boundary: 12 inches • Northern boundary: 2 to 14 inches
Climate Region 3: Okanogan, Spokane, Palouse	This climate region consists of intermountain areas and includes areas near Okanogan, Spokane, and the Palouse.	12 to 22 inches	• Northwest boundary: 16 inches • Southwest boundary: 12 inches • Northeast boundary: 22 inches • Southeast boundary: 22 inches
Climate Region 4: Northeastern Mountains and Blue Mountains	This climate region consists of mountain areas in the easternmost part of Washington.	22 to > 60 inches	• Northeast boundary: 22 inches • Southern boundary: 22 inches • Western boundary: 22 inches

Figure 4.1: Average Annual Precipitation and Climate Regions



Average Annual Precipitation
1961-1990
With Climate Regions

SOURCE: *Oregon Climate Service, U.S. Department of Agriculture, Natural Resources Conservation Service*

Map projection: State Plane Washington South, NAD 27

REGION 1: *East Slope Cascades*

REGION 2*: Central Basin*

REGION 3: *Okanogan, Spokane, Palouse*

REGION 4: *NE & Blue Mountains*

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Average Annual Precipitation
and Climate Regions

Revised March 2002

4.3.2 Distributions and Applicability

The design storms to be used in eastern Washington specify the following:

- Total rainfall volume (depth in inches)
- Rainfall distribution (dimensionless)

4.6.3 Curve Number through 4.3.8 Precipitation Magnitude and Frequency for Short-Duration Storms describe the total precipitation depth and precipitation distribution associated with a design storm. The design storm event is also specified by return period (months and/or years) and duration.

All rainfall-runoff hydrograph methods require the input of a rainfall distribution or design storm hyetograph. The hyetograph represents the portion of the total precipitation depth that falls during each increment of time for a given overall duration. It is usually presented as a dimensionless plot or table of unit precipitation depth (incremental precipitation depth for each time interval divided by the total precipitation depth) versus time.

Table 4.3: Comparison of Design Storm Distributions (continued) provides a short description of each of the following design storm distributions or precipitation depth options, summarizes the advantages and disadvantages of each distribution, and summarizes the applicability for when these distributions or depths may be used:

- 3-hour short-duration storm distribution
- 24-hour or longer regional storm distribution (based on the 72-hour long-duration storm for each climate region)
- 24-hour Soil Conservation Service (SCS) Type IA storm distribution
- Modified 24-hour SCS Type IA storm distribution
- 24-hour SCS Type II storm distribution
- Site runoff of 0.5 inches, depth only, no distribution
- 2-year mean precipitation depth (no distribution)
- Other design criteria adopted by agencies or local jurisdictions that meet or exceed the intent of the Core Elements for runoff treatment and flow control

The first five distributions listed (3-hour short-duration storm and 24-hour or longer storms) are discussed in further detail in 4.3.3 Short-Duration and Regional Design Storms through 4.3.5 Modified SCS Type IA and Regional Design Storms. Tabular values for the hyetographs associated with these storms are provided in Appendix 4-D: Design Storm Hyetographs.

Table 4.3: Comparison of Design Storm Distributions

Design Storm Distribution Type	Advantages	Disadvantages	Applicability
3-Hour Short-Duration Storm: A synthetic 3-hour custom design storm that represents rainfall during a typical summer thunderstorm in eastern Washington. Typically includes peak discharge in small urban watersheds.	Important where flood peak discharge and/or erosion are design considerations.	Only one short-duration storm for all four climate regions in eastern Washington.	• Flow-rate based treatment BMPs. • Conveyance structures.
Regional Storm: A synthetic distribution that represents the second event of the "long-duration storm" hydrograph (with lower rainfall intensities and larger runoff volumes than the short-duration storm). Includes more total precipitation than the 24-hour SCS Type IA, but are spread over more time.	• Important where both runoff volume and peak discharge are design considerations. • Separate long-duration storms were developed for each of the four eastern Washington climate regions. • Storms are similar to the SCS Type IA storm for Climate Region 2 (no measurable difference), Climate Region 3 (< 7% greater), and Climate Region 4 (< 7% greater).	• First event of the "long-duration storm" hydrograph is not modeled. • Soil wetting produced by the first event must be accounted for by adjusting the modeling input parameters. • Storm does not match the SCS Type IA storm for Climate Region 1 (16% greater precipitation depth and 40% longer duration).	• Flow control BMPs. • Volume-based treatment BMPs.
24-Hour Soil Conservation Service (SCS) Type IA Storm: Lower rainfall intensities than the SCS Type II hydrograph.	• Similar to the four regional storms. • Recent analysis supports use in eastern Washington.	Not applicable to flow control BMP sizing in all climate regions.	• Flow control BMPs in Climate Regions 2 and 3. • Volume-based treatment

Table 4.3: Comparison of Design Storm Distributions (continued)

Design Storm Distribution Type	Advantages	Disadvantages	Applicability
	• May produce acceptable results without the added complexity of the regional storm. • 24-hour duration allows for easy use of the built-in storm pattern feature of most SCS Method software which reduces the potential for computational errors due to incorrect implementation of unique duration hydrographs.		BMPs.
Modified 24-Hour SCS Type IA Storm: Antecedent moisture conditions and precipitation depths are adapted from the SCS Type IA storm to more closely reflect typical conditions in eastern Washington.	Intended to more closely reflect historical precipitation patterns in eastern Washington compared to the standard Type IA design storm.	• Curve numbers (CNs) need to be adjusted based on engineering analysis and judgment of antecedent precipitation, soil characteristics, and surface conditions. • Not applicable to flow control BMP sizing for large projects (≥ 1 acre). • Not applicable to flow control BMP sizing in all climate regions.	• Flow control BMPs at small projects (< 1 acre) in Climate Regions 1 and 4. • Volume-based treatment BMPs.
24-Hour SCS Type II Storm: Hyetograph	Has been used in eastern Washington (and	Does not match historical records for the	• Volume-based treatment

Table 4.3: Comparison of Design Storm Distributions (continued)

Design Storm Distribution Type	Advantages	Disadvantages	Applicability
with high-intensity peak.	throughout the United States) since the 1970s.	short-duration storm and the long-duration storm in eastern Washington.	BMPs. • Flow-rate based treatment BMPs.
One-Half Inch of Runoff: Precipitation depth only, no distribution; included as Method 2 for BMP T5.21: Infiltration Swales.	Simple to apply (precipitation depth only, no distribution).	• Does not require treatment of permeable surfaces. • Does not give credit for infiltration through the bottom of BMP T5.21: Infiltration Swales.	• Runoff treatment volumes in Climate Regions 2 and 3. • One of the methods for sizing BMP T5.21: Infiltration Swales in Climate Regions 2 and 3.
2-Year Mean Precipitation Depth: Precipitation depth only, no distribution; used for determining peak flow rate by the Rational Method.	Most accurate for small basins (< 100 acres) and developed conditions with large areas of impervious surface (e.g., pavement, rooftops).	• Precipitation intensity is variable and does not fall at a constant rate. • Not accurate for large basins (≥ 100 acres) since the effects of infiltration are often not properly accounted for. • Should not be used for basins > 1,000 acres.	• Flow-rate based treatment BMPs. • Used with the Rational Method for biofiltration swale, oil and water separator, and drywell sizing. • Used with the Rational Method for conveyance system sizing.

4.3.3 Short-Duration and Regional Design Storms

Rainfall patterns during storms in eastern Washington were analyzed to identify short-duration and regional rainfall distributions for climate regions in eastern Washington (see Appendix 4-A:

Background Information on Design Storms and Selected Modeling Methods). Two primary storm types are of interest to hydrologic analysis for design of stormwater BMPs in eastern Washington: the thunderstorms and general storms. Thunderstorms are represented by the short-duration storm distribution and general storms are represented by the regional storm distribution. Both design storms were developed in a manner that replicated temporal characteristics observed in storms from climatologically similar areas in and near eastern Washington. See Table 4.3: Comparison of Design Storm Distributions (continued) for the advantages and disadvantages and a summary of the situations in which these design storms may be used.

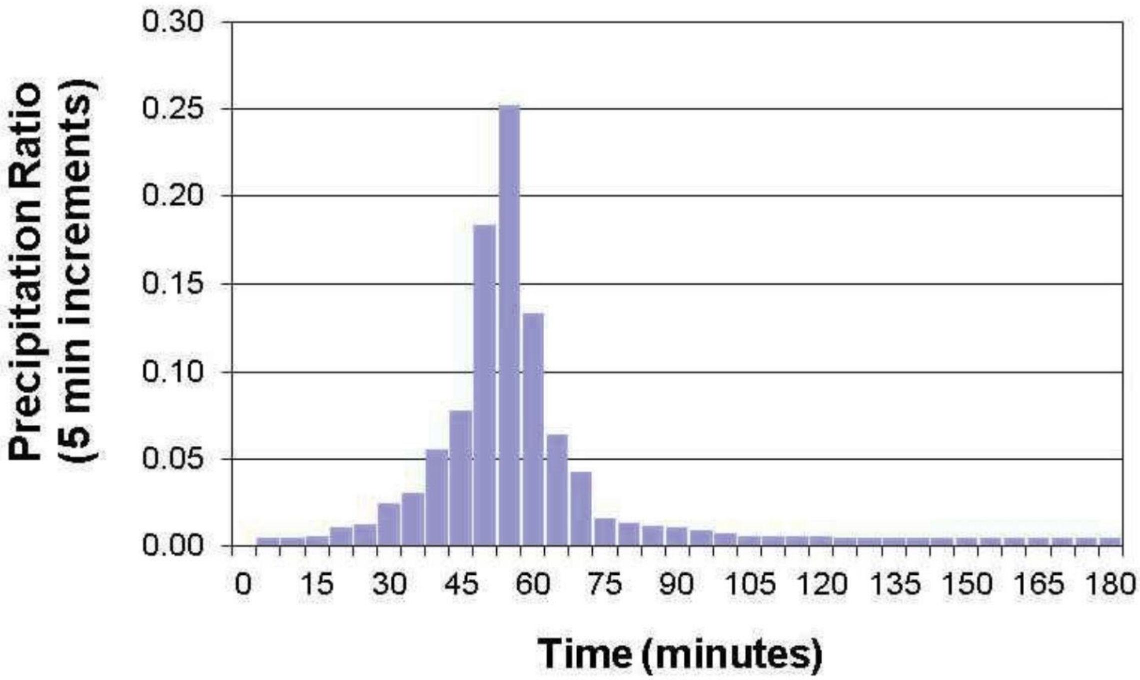
See Appendix 4-A: Background Information on Design Storms and Selected Modeling Methods for further discussion of the development and review of these design storms. 4.A.3 Review of Design Storms and Identification of Best Rainfall-Runoff Modeling Approaches for Eastern Washington includes a graphical representation of the standard SCS Type IA and II synthetic design storms and the long-duration storms for comparison on a unit basis.

Short-Duration Design Storm

Thunderstorms (short-duration storms) can occur in late spring through early fall and are characterized by high intensities for short periods of time over localized areas. Short-duration storms can produce high rates of runoff and flash flooding in urban areas and are important where flood peak discharge and/or erosion are design considerations. The effect of short-duration storms should also be considered in designing BMPs based on other design storms.

The short-duration storm hyetograph is 3 hours in duration. The storm temporal pattern is shown in Figure 4.2: Short-Duration Storm Unit Hyetograph as a unit hyetograph. Tabular values for this hyetograph are listed in Table 4.33: Short-Duration Storm Hyetograph Values for All Climate Regions. Total precipitation is 1.06 times the 2-hour precipitation amount. There is one short-duration storm for all climate regions in eastern Washington.

Figure 4.2: Short-Duration Storm Unit Hyetograph



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Short-Duration Storm Unit Hyetograph

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Regional Storm

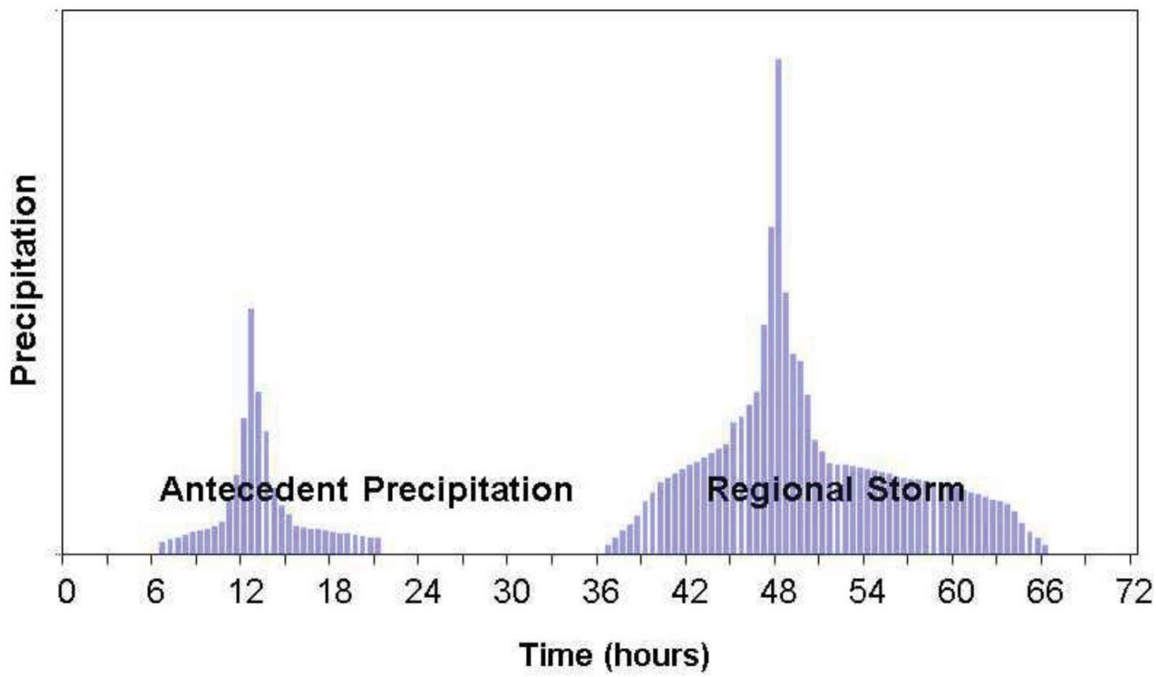
General storms (regional storms) can occur at any time of the year, but are more common in the late fall through winter period, and in the late spring and early summer periods. Regional storms in eastern Washington are characterized by sequences of storms and intervening dry periods, often occurring over several days. Low- to moderate-intensity precipitation is typical during the periods of storm activity. Regional storms can produce floods with moderate peak discharge and large runoff volumes. The runoff volume can be augmented by snowmelt when precipitation falls on snow during winter and early spring storms. Regional storms are important where both runoff volume and peak discharge are design considerations.

The synthetic distribution represents a series of two rainfall events separated by a dry intervening period and occurring during a total 72-hour period of time. A sample 72-hour long-duration storm hyetograph is shown in Figure 4.3: Sample Regional Storm Hyetograph.

The regional storms are derived from these hyetographs (see Appendix 4-A: Background Information on Design Storms and Selected Modeling Methods). The first, smaller precipitation event (occurring from 6 to 21 hours in Figure 4.3: Sample Regional Storm Hyetograph) is generally insufficient to generate runoff that is present when the larger second precipitation event commences and for that reason it is deemed unnecessary to directly model the smaller precipitation event and only the second, larger portion (beginning at 36 hours in Figure 4.3: Sample Regional Storm Hyetograph) is directly modeled. However, the soil wetting produced by the first event must still be accounted for by appropriately adjusting the modeling input parameters.

Tabular values of the regional storm hyetographs are listed in Table 4.34: Regional Storm Hyetograph Values for Climate Region 1: Cascade Mountains (continued) through Table 4.37: Regional Storm Hyetograph Values for Climate Region 4: Eastern Mountains (continued). The regional storms are similar to the 24-hour SCS Type IA storm distribution. An adapted version of applying the Type IA distribution is discussed in 4.3.5 Modified SCS Type IA and Regional Design Storms. Comparison of precipitation depth, antecedent moisture condition (AMC), and necessary adjustments and modeling requirements for the regional storms are discussed in 4.3.5 Modified SCS Type IA and Regional Design Storms.

Figure 4.3: Sample Regional Storm Hyetograph



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Sample Regional Storm Hyetograph

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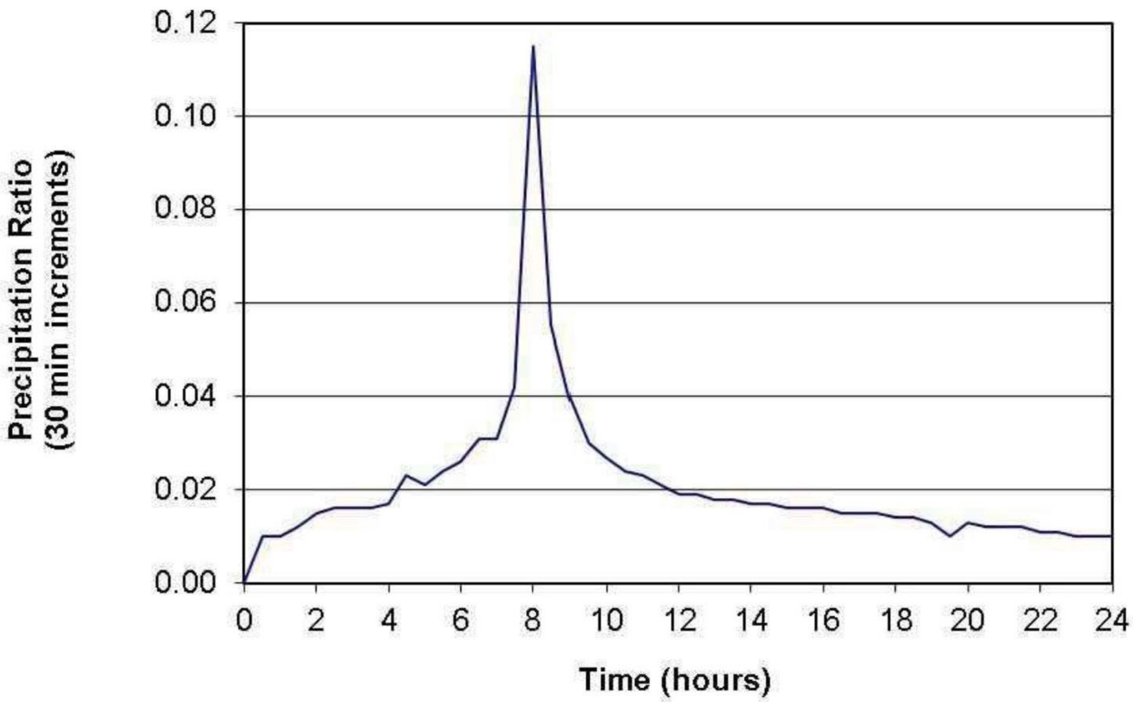
4.3.4 SCS Type IA and Type II Standard Design Storms

The Soil Conservation Service (SCS) is the former name of the Natural Resources Conservation Service (NRCS).

SCS Type IA and Type II are two of the four standard 24-hour rainfall distributions that are commonly used in the SCS hydrograph method. See Table 4.3: Comparison of Design Storm Distributions (continued) for the advantages and disadvantages and a summary of the situations in which these design storms may be used.

See Figure 4.4: SCS Type IA Hyetograph and Figure 4.5: SCS Type II Hyetograph for graphical representations of these two SCS hyetographs. Tabular values of these hyetographs are included in Table 4.31: SCS Type IA Storm Hyetograph Values (continued) and Table 4.32: SCS Type II Storm Hyetograph Values (continued). See 4.A.3 Review of Design Storms and Identification of Best Rainfall-Runoff Modeling Approaches for Eastern Washington for a graphical representation of these two storms and the long-duration storms for comparison on a unit basis.

Figure 4.4: SCS Type IA Hyetograph



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SCS Type IA Hyetograph

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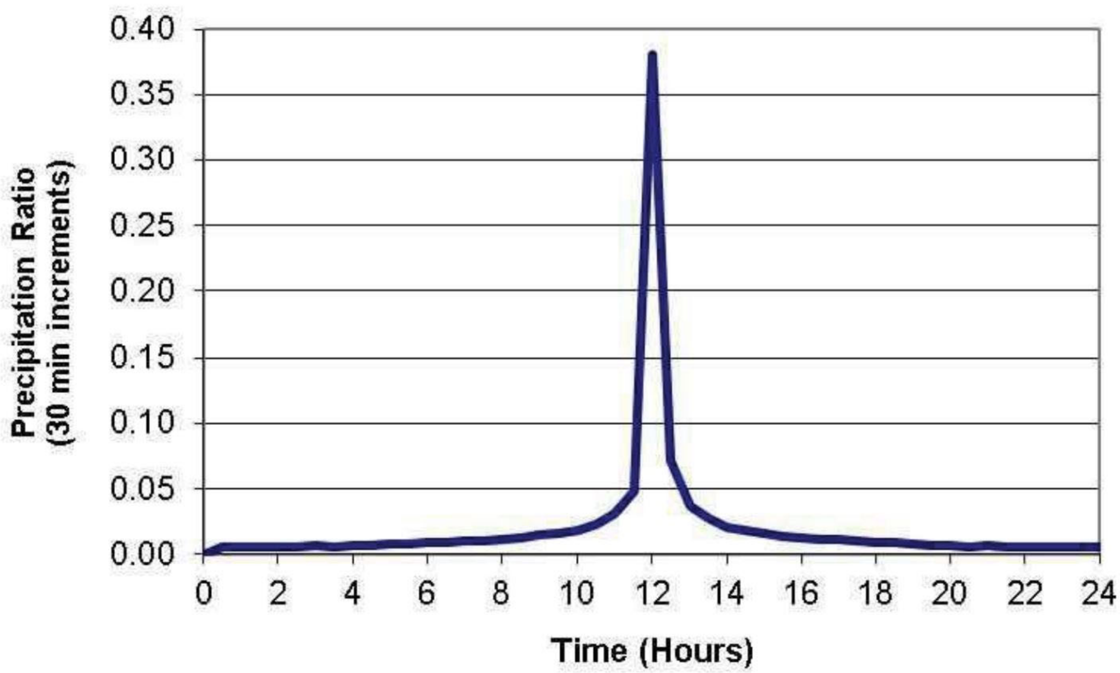
Figure 4.5: SCS Type II Hyetograph



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SCS Type II Hyetograph

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4.3.5 Modified SCS Type IA and Regional Design Storms

The modified SCS Type IA design storm is an adapted application of the standard SCS Type IA design storm intended to more closely reflect historical precipitation patterns in eastern Washington. AMC and precipitation depths are modified to reflect more typical conditions. See Table 4.4: Antecedent Precipitation Prior to Regional Storm for the advantages and disadvantages and a summary of the situations in which these design storms may be used.

If the 24-hour SCS Type IA storm is used directly, the precipitation totals are the 24-hour amounts without adjustment. If the modified Type IA is used, the precipitation totals need to be adjusted as indicated in 4.3.7 Precipitation Magnitude and Frequency for 24-Hour and Regional Storms; these adjustment factors are also in the notes in Table 4.34: Regional Storm Hyetograph Values for Climate Region 1: Cascade Mountains (continued) through Table 4.37: Regional Storm Hyetograph Values for Climate Region 4: Eastern Mountains (continued).

The prior soil wetting produced by the previous storm event in the long-duration storm (the portion that is not included in the modeling exercise) still needs to be accounted for by appropriately adjusting the modeling input parameters. Regardless of whether the 24-hour SCS Type IA or regional storm hyetographs are used for modeling, this adjustment must be made. The amount of antecedent precipitation can be expressed as a percentage of the total precipitation modeled, as shown in Table 4.4: Antecedent Precipitation Prior to Regional Storm.

Table 4.4: Antecedent Precipitation Prior to Regional Storm

Climate Region Number and Name	Antecedent Precipitation as Percentage of 24-Hour SCS Type IA Storm Precipitation	Antecedent Precipitation as Percentage of Regional Long-Duration Storm Hyetograph Precipitation
1 - East Slope Cascades	33%	28%
2 - Central Basin	19%	19%
3 - Okanogan, Spokane, Palouse	27%	25%
4 - Northeastern & Blue Mountains	36%	34%

Curve number (CN) adjustments based on engineering analysis and judgment of the antecedent precipitation, soils characteristics, and surface conditions must be considered. The AMC (see 4.6.3 Curve Number) is one basis for adjustment. Another is the use of the SCS county surveys that include estimates of permeability and/or infiltration rates.

Note: Precipitation magnitudes and frequencies are adjusted as discussed in 4.3.6 Precipitation Magnitude/Frequency Analysis.

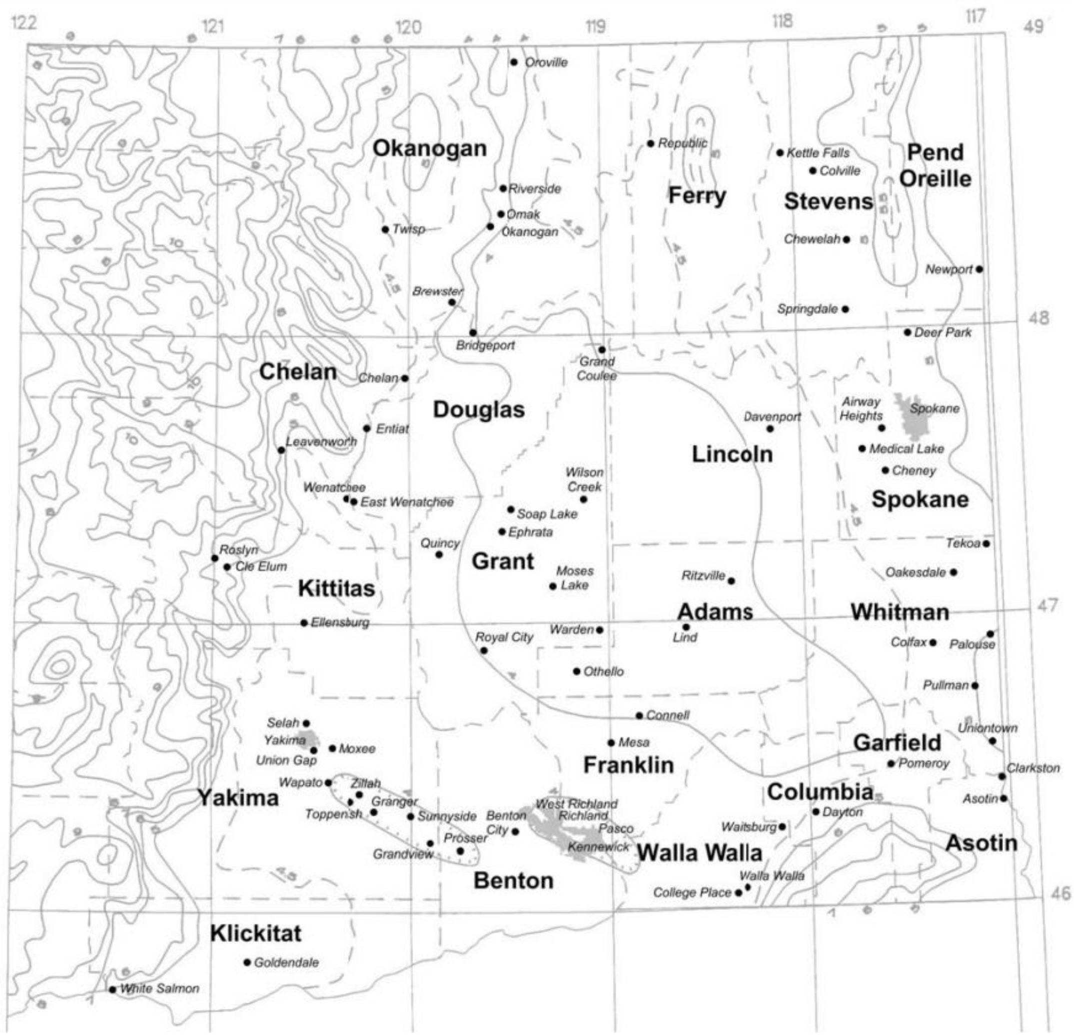
4.3.6 Precipitation Magnitude/Frequency Analysis

The current source for precipitation magnitude-frequency estimates is National Oceanic and Atmospheric Administration (NOAA) Atlas 2 (Miller et al., 1973), which is based on data collected from about 1940 through 1966, and NOAA Technical Report NWS 36 (NOAA, 1983), which used data through the late 1970s. In both of these studies, precipitation statistics were computed for each gauge and used to produce point precipitation estimates at each site. The accuracy of the estimates was strongly related to the length of record at each site: estimates are generally better for common events than for rare events.

The total depth of rainfall (in tenths of an inch) for storms of 2-, 5-, 10-, 25-, 50-, and 100-year recurrence intervals and 24-hour duration are published by NOAA in the form of isopluvial maps for each state. Isopluvial maps are contour maps where the contours represent total amount of rainfall. The 2-year isopluvial maps for eastern Washington can be found in this section and 4.3.7 Precipitation Magnitude and Frequency for 24-Hour and Regional Storms. The remaining isopluvial maps (10-, 25-, 50-, and 100-year) are provided in 4.4 Precipitation Maps for reference. The 24-hour isopluvial maps are used for designs based on the regional storm and 24-hour storms. A 2-year isopluvial map is necessary because a 6-month isopluvial map is not available. The user must scale the 2-year precipitation depth to get a 6-month precipitation depth.

An isopluvial map for the 2-year, 2-hour storm is shown in Figure 4.6: 2-Year, 2-Hour Isopluvial Map. This map is from the Dam Safety Guidelines (Ecology, 1993c). It is used for sizing flow-rate-based treatment BMPs with the short-duration storm.

Figure 4.6: 2-Year, 2-Hour Isopluvial Map



Precipitation in tenths of an inch

SOURCE: *Dam Safety Guidelines, Technical Note 3, Design Storm Construction, Washington State Department of Ecology, Water Resources Program, report 92-55G April 1993.*

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2-Year, 2-Hour Isopluvial Map

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4.3.7 Precipitation Magnitude and Frequency for 24-Hour and Regional Storms

The frequency of the water quality design storm is a 6-month recurrence interval or return period, expected to happen twice per year on the average. NOAA maps were not developed for the 6-month recurrence interval, so a conversion is necessary. Use the following equation to determine the 6-month precipitation from the 2-year, 24-hour precipitation.

Equation 4.1: Water Quality Design Storm

$$P_{wqs} = C_{wqs} * P_{2yr24hr}$$

where:

P_{wqs} = 6-month, 24-hour precipitation (inches)

C_{wqs} = coefficient from Table 4.5: Values of Coefficient Cwqs for Computing 6-Month, 24-Hour Precipitation for converting the
2-year, 24-hour precipitation to the 6-month, 24-hour precipitation

$P_{2yr24hr}$ = 2-year, 24-hour precipitation (inches), from Figure 4.7: 2-Year, 24-Hour Isopluvial Map

P_{wqs} is used with the regional storm hyetograph or SCS Type IA or Type II hyetographs. Table 4.5: Values of Coefficient Cwqs for Computing 6-Month, 24-Hour Precipitation lists values of the coefficient C_{wqs} for the four climate regions. Table 4.6: Factors for Converting From 24-Hour to Regional Storm Precipitation Depth provides the multipliers for converting the 24-hour precipitation P_{wqs} to the regional storm precipitation.

Figure 4.7: 2-Year, 24-Hour Isopluvial Map

Source: Miller et. al., 1973

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2-Year, 24-Hour Isopluvial Map

Revised March 2005

Table 4.5: Values of Coefficient C_{wqs} for Computing 6-Month, 24-Hour Precipitation

Climate Region Number	Climate Region Name	C_{wqs}
1	East Slope Cascades	0.70
2	Central Basin	0.66
3	Okanogan, Spokane, Palouse	0.69
4	Northeastern & Blue Mountains	0.70

Note: Values of C_{wqs} are based on the generalized extreme value (GEV) distribution whose distribution parameters can be expressed as a function of mean annual precipitation for eastern Washington.

Table 4.6: Factors for Converting From 24-Hour to Regional Storm Precipitation Depth

Climate Region Number	Climate Region Name	Multiplication Factor for Converting From 24-Hour to Regional Storm Precipitation Depth
1	East Slope Cascades	1.16
2	Central Basin	1.00
3	Okanogan, Spokane, Palouse	1.06
4	Northeastern & Blue Mountains	1.07

4.3.8 Precipitation Magnitude and Frequency for Short-Duration Storms

Design of flow-rate-based treatment BMPs using the single-event hydrograph method requires a determination of the 6-month, 3-hour precipitation depth for use with the 3-hour short-duration design storm hyetograph. (The updated design storm is indexed to sum to unity at 3 hours, so the 3-hour precipitation depth is needed to scale the hyetograph.) Design of other BMPs or conveyance elements based on the short-duration storm may also require the conversion of the 2-year, 2-hour precipitation to a 3-hour precipitation depth for a different recurrence interval.

The isopluvial map that is used as the starting point for determining the design precipitation depth for a 3-hour short-duration storm is a 2-year, 2-hour precipitation isopluvial map (Figure 4.6: 2-Year, 2-Hour Isopluvial Map).

The following equation is used to determine 3-hour precipitation for a selected return period:

Equation 4.2: Short-Duration Storm

$$P_{sds} = 1.06 * C_{sds} * P_{2yr2hr}$$

where:

P_{sds} = 3-hour precipitation (inches) for a selected return period for the short-duration storm

1.06 = multiplier used for all climate regions to convert
x-year, 2-hour precipitation to x-year, 3-hour precipitation

C_{sds} = coefficient (from Table 4.7: Values of the Coefficient Csds for Using 2-Year, 2-Hour Precipitation to Compute 2-Hour Precipitation for Selected Periods of Return) for converting 2-year, 2-hour precipitation to x-year, 2-hour precipitation depth

P_{2yr2hr} = 2-year, 2-hour precipitation (inches) from Figure 4.6: 2-Year, 2-Hour Isopluvial Map

Table 4.7: Values of the Coefficient Csds for Using 2-Year, 2-Hour Precipitation to Compute 2-Hour Precipitation for Selected Periods of Return lists values of the coefficient C_{sds} for selected return periods for various magnitudes of mean annual precipitation. An isopluvial map of average annual precipitation is shown in Figure 4.1: Average Annual Precipitation and Climate Regions and can be used to determine the mean annual precipitation for the site.

Table 4.7: Values of the Coefficient C_{sds} for Using 2-Year, 2-Hour Precipitation to Compute 2-Hour Precipitation for Selected Periods of Return

Climate Region Number	Mean Annual Precipitation (inches)	6-Month	1-Year	10-Year	25-Year	50-Year	100-Year
2	6-8	0.61	0.79	1.63	2.17	2.68	3.29
	8–10	0.62	0.80	1.60	2.09	2.55	3.09
	10–12	0.64	0.81	1.56	2.02	2.44	2.92
2, 3	12–16	0.66	0.82	1.51	1.90	2.26	2.66
3	16–22	0.67	0.83	1.47	1.82	2.13	2.48
1, 4	22–28	0.69	0.84	1.43	1.74	2.01	2.31
	28–40	0.70	0.85	1.40	1.68	1.92	2.19
	40–60	0.72	0.86	1.36	1.61	1.82	2.05
	60–120	0.74	0.87	1.33	1.55	1.74	1.93

Notes

- The value for 2-hour precipitation is converted to 3-hour precipitation using a multiplier of 1.06 for all recurrence intervals.
- Values of C_{sds} are based on the generalized extreme value (GEV) distribution whose distribution parameters can be expressed as a function of mean annual precipitation for eastern Washington.

4.3.9 Rain-on-Snow and Snowmelt Design

The following information on snow considerations, including rain-on-snow and snowmelt design, is optional guidance for detention and water quality design when required by the local jurisdiction. Other cold weather considerations for BMP design are included in 6.1.8 Cold Weather Considerations.

Considerations for Snow

In many regions, an inevitable consequence of cold weather is precipitation in the form of snow. Table 4.8: Average Annual Snowfall at Selected Locations in Eastern Washington (continued) illustrates some typical snowfall amounts for eastern Washington as compiled by Desert Research Institute in Nevada. While snowfall amounts are often converted to water equivalents and treated as individual events for the purpose of predicting annual precipitation events, in fact snowfall from multiple events may accumulate over time thus creating storage of potential runoff volumes. This storage may be released gradually over time in the form of snowmelt or it may be converted to runoff rapidly by rain-on-snow events. Gradual melting can cause problems because the runoff may fill or saturate stormwater BMPs prior to an actual design event and consequently produce wet soil conditions and more runoff. Refreezing during cold evenings may exacerbate some of the problems.

Table 4.8: Average Annual Snowfall at Selected Locations in Eastern Washington

Location	Period of Record	Average Annual Snowfall (inches)
Asotin 14 SW	1976–2000	14.5
Cle Elum	1931–2000	80.5
Dayton 1 WSW	1931–2000	17.8
Ellensburg	1901–2000	27.7
Ephrata Airport FCWOS	1949–2000	18.3
Goldendale	1931–2000	25.0
Kennewick	1948–2000	6.9
Leavenworth 3 S	1948–2000	95.2
Methow 2 S	1970–2000	38.3
Newport	1927–2000	59.4
Othello 6 ESE	1941–2000	4.2
Prosser 4 NE	1931–2000	7.9
Pullman 2 NW	1940–2000	28.1
Quincy 1 S	1941–2000	13.2
Richland	1948–2000	8.5
Spokane WSO Airport	1889–2000	41.4

Table 4.8: Average Annual Snowfall at Selected Locations in Eastern Washington (continued)

Location	Period of Record	Average Annual Snowfall (inches)
Walla Walla FAA Airport	1949–1995	17.4
Wenatchee	1877–2000	27.6
Yakima WSO AP	1946–2000	24.1
Source: Desert Research Institute (Nevada)		

Because of the many physical factors involved, snowmelt is a complicated process, with large annual variations in the melting rate frequently occurring. While the criteria presented here address the effects of rain-on-snow and snowmelt, several simplifying assumptions are made. Where local data or experiences are available, more sophisticated methods should be substituted.

Rain-on-Snow Considerations

For water quality volume, rain-on-snow events can be important in many eastern Washington regions. Although the size of rainfall events typically used in BMP design may or may not produce a significant amount of snowmelt, runoff produced by these events is high because of frozen and saturated ground conditions beneath the snow cover. The actual melting and runoff processes are quite complicated and require information not readily available in most areas. The *Stormwater BMP Design Supplement for Cold Climates* (CWP, 1997) suggested the following four-step simplified procedure. As with other referenced methodology, this approach has not been well tested for eastern Washington, however it does provide a basis for estimating rain-on-snow volumes which could be used and refined with experience.

Calculating Rain-on-Snow Volume (Center for Watershed Protection)

1. Develop a rain-on-snow data set of rainfall events that occurred only for those months when snow is on the ground. Snow events, as well as non-runoff-producing events ($P < 0.1$ inch), should be excluded from this data set. The result is a recurrence frequency for rain-on-snow events. Because the ground is frozen and/or saturated, this precipitation distribution is also the same as the runoff distribution.
2. Calculate a similar rainfall distribution for months without snow cover.
3. Determine the runoff distribution for months without snow cover. Because we have excluded non-runoff-producing events from the distribution, the runoff is equal to:

Equation 4.3: Runoff Distribution for Months without Snow Cover

$$R = 1.0 * P_{2yr24hr} * (0.05 + 0.9 * I)$$

where:

R = runoff (inches)

$P_{2yr24hr}$ = 2-year, 24-hour precipitation (inches)

I = impervious percentage

If the impervious percentage is known (assume 40%) then, for months without snow:

$$R = 0.41 * P_{2yr24hr}$$

A runoff distribution for “summer” is developed by multiplying all of the precipitation values used in Step 2 by the 0.41 multiplier determined previously in this step.

4. Take the “winter” runoff distribution data from Step 1 and combine it with the “summer” runoff distribution computed in Step 3. Sort the data and rank them accordingly to determine an overall annual runoff distribution. Determine the 90th percentile value and use it for design purposes as long as this value is greater than the summer precipitation event.

It should again be pointed out that this methodology does not include any contribution from snowmelt. As previously stated, it is predicated on the assumption that design storm precipitation quantities are not large enough to produce significant melt quantities.

The U.S. Army Corps of Engineers (USACE) developed an expression to estimate the snowmelt as a function of precipitation and rainfall temperature. The equation is:

Equation 4.4: Snowmelt as a Function of Precipitation and Temperature

$$M_s = 0.00695 * (T_{rain} - 32) * P_r$$

where:

M_s = snowmelt (inches)

T_{rain} = rainfall temperature (degrees Fahrenheit)

P_r = precipitation (inches)

This equation predicts that 2.5 inches of rainfall at a rainfall temperature of 50 degrees Fahrenheit (°F) would melt 0.31 inches of snow. Whether this represents a significant increase in required volume would depend on the site.

Note: A note concerning the impacts of snowmelt is warranted. Because the ground is generally frozen during snowmelt or rain-on-snow events, the difference between pre- and postproject discharges are often quite small. For this reason, snowmelt and rain-on-snow events rarely need to be considered when designing for channel or overbank protection.

Additional Rain-on-Snow Considerations

Rain-on-snow could affect the flow in the evaluation of the long-duration storms, especially in regions with high snowfall. Except for higher elevations with deeper snowpacks, it should be assumed that a long-duration design storm results in the complete melting and runoff of the typical snowpack. To determine the typical snowpack, calculate the average daily snow depth from December to February, which is available on the Internet for many eastern Washington locations. If the average daily snow depth is < 1 inch, then the rain-on-snow effect can be considered negligible and should not be considered in the analysis. Assuming 20% moisture content, determine the water equivalent. A sample of the average daily snow depths and precipitation adjustment amount for selected cities is in Table 4.9: Snowmelt Adjustment Factors.

Snowmelt can also be considered in water quality design. Melting snow from the roadways and from the snow piles alongside the roadways have significant amounts of pollutants generated from the vehicles, deicing chemicals, and roadway salts. The runoff treatment BMPs should be located downstream of the snowmelt areas and can be sized for snowmelt, especially in regions with high snowfall.

Table 4.9: Snowmelt Adjustment Factors

Location	Average Daily Snow Depth (inches)	Water Equivalent (inches) 24-Hour Storm Precipitation Adjustment	24-Hour: 72-Hour Precipitation Ratio Based on Climate Region	Regional Storm Precipitation Adjustment (inches)
Colville	5.00	1.0	0.70	0.70
Clarkston	0.33	N/A	N/A	N/A
Goldendale	1.67	0.33	0.67	0.22
Moses Lake	0.67	0.13	0.84	0.11
Omak	4.67	0.93	0.75	0.70
Pullman	1.33	0.27	0.70	0.19
Richland	0.33	N/A	N/A	N/A
Spokane Airport	2.33	0.47	0.75	0.35
Walla Walla	1.00	0.20	0.75	0.15
Wenatchee	2.67	0.53	0.84	0.45
Yakima	2.00	0.40	0.84	0.34

For projects that are located above 2,500 feet elevation, a separate study or local data should be used as the average snow depth is significant and varies widely.

The assumption is that the entire average daily snowmelt on the ground will melt during the long-duration storm. Since the long-duration storm is 72 hours in duration, the water equivalent for the peak 24 hours will be less than if the long-duration storm were only 24 hours. The adjustment factor is the ratio of the 24-hour precipitation to the 72-hour precipitation and varies based on climate region. In order to use the snowmelt factor with the long-duration storm hyetograph, the Long-Duration Storm Precipitation Adjustment should be added to the 24-hour design storm precipitation.

The CN used shall be for normal AMC II.

If the average annual precipitation at the project site varies from the average annual precipitation at the nearest known snow depth record location, the average daily snow depth will also vary. To determine the estimated average daily snow depth, multiply the known average daily snow depth and all other factors by the ratio of average annual precipitation at the project site to the average annual precipitation at the record location.

An example is a project located in Cashmere where the average annual precipitation is 14 inches. The nearest snow depth record location is Wenatchee. The snow depth at Wenatchee is 2.67 inches from Table 4.9: Snowmelt Adjustment Factors and the average annual precipitation from Figure 4.1: Average Annual Precipitation and Climate Regions is 10 inches.

The estimated snow depth for Cashmere is:

2.67 * 14/10 = 3.74 inches

Snowmelt

In relatively dry regions that receive much of their precipitation as snowfall, the sizing is heavily influenced by the snowmelt event. A typical recommendation is to oversize the BMP when average annual snowfall depth is greater than or equal to annual precipitation depth. This assumes snow is approximately 10% water. The sizing criteria for the treatment of water quality are based on the following four assumptions:

- BMPs should be sized to treat the spring snowmelt event.
- Snowmelt runoff is influenced by the moisture content of the spring snowpack and soil moisture.
- No more than 5% of the annual runoff volume should bypass treatment during the spring snowmelt event.
- Because snowmelt occurs over several days, BMPs can treat a snowmelt volume greater than their size would indicate.

Although snowmelt occurs continuously throughout the winter and spring months, the characteristics and rates of runoff may vary. As rules of thumb, one-half of the snowfall is assumed to melt in the winter if the average daily maximum January temperature is < 25°F and two-thirds of the snowfall melts if the temperature is between 25°F and 35°F. Winter melting events have high concentrations of soluble pollutants such as chlorides and metals because of “preferential elution” from the snowpack (Semkin and Jeffries, 1988). Conversely, spring snowmelt is higher in suspended solids and hydrophobic elements, such as hydrocarbons, which can remain in the snowpack until the last 5% to 10% of water leaves the snowpack (Marsalek, 1991).

Three methods for estimating snowmelt are available and are described in the following subsections.

Snowmelt Method 1 (Stahre and Urbonas)

Although snowmelt rates can be as high as 0.15 inches/hour (0.151 cubic feet per second [cfs]/acre) under extreme conditions, (Stahre and Urbonas, 1989) recommended the following minimum design values:

Equation 4.5: Snowmelt Method 1

$$M_s = A_i * 0.04 \text{ cfs/acre} + A_p * 0.02 \text{ cfs/acre}$$

where:

M_s = snowmelt (feet)

A_i = impervious surface area (acres)

A_p = pervious surface area (acres)

Snowmelt Method 2 (U.S. Army Corps of Engineers)

The snowmelt rates from the Stahre and Urbonas method (Snowmelt Method 1) are not universally accepted. (USACE, 1998) proposed the following temperature index solution for daily snowmelt (M_s):

Equation 4.6: Snowmelt Method 2

$$M_s = C_m * (T_{air} – T_{base})$$

where:

M_s = snowmelt (inches)

C_m = melt-rate coefficient in (inches/°F), which can vary, depending on site conditions. The relative magnitude of this factor is shown in Table 4.10: Melt Rate Coefficients for Various Conditions (Assuming Tbase = 32°F).

T_{air} = average daily air temperature (°F)

T_{base} = base temperature (°F); typically around 32°F when using average daily air temperature

Table 4.10: Melt Rate Coefficients for Various Conditions (Assuming T_{base} = 32°F)

Case	T_{air}(°F)	Melt(inches)	C_m(inches/°F)	Comment
1	70	2.57	0.068	Clear, low albedo
2	70	2.40	0.073	Case 1 with 40% forest
3	65	1.51	0.040	Case 1 with cloud cover
4	70	1.73	0.046	Case 1 with fresh snow
5	50	3.24	0.180	Heavy rain, windy
6	50	2.92	0.163	Light rain, windy
7	50	1.11	0.062	Light rain, light wind

Snowmelt Method 3 (Center for Watershed Protection)

The Stormwater BMP Design Supplement for Cold Climates (CWP, 1997) presents a straight-forward methodology for calculating snowmelt runoff in seven steps. The method is general and a specific application for eastern Washington has not yet been developed. However, it does provide a basis for estimation which could be used and refined as more knowledge becomes available with experience. The procedure is as follows:

1. The procedure is based on the assumption that oversizing is necessary if the average annual precipitation is less than half the average annual snowfall depth. For example, if the average annual precipitation is 15 inches and the average annual snowfall is ≥ 16 inches, oversizing will be required.
2. Determine the annual losses from sublimation and snow removal.
3. Determine the annual water equivalent loss from winter snowmelt events. This requires an assumption regarding the amount of water in an inch of snow.

Equation 4.7: Snowmelt Method 3

$$M_s = \{SWE * [S - (L_1 * S)]\} * F_T$$

where:

M_s = snowmelt (inches)

SWE = snow water equivalent (percentage)

S = average annual snowfall (inches)

L_1 = water loss to sublimation and snow removal (percentage)

F_T = temperature factor (one-half if the average daily maximum temperature is < 25°F; two-thirds if the temperature is between 25°F and 35°F)

For example, assuming that the water equivalence of the snow is 1:10, the average annual snowfall is 40 inches, 15% is lost to the combination of sublimation and snow removal, and the average daily maximum January temperature is 24°F, the total snowmelt is calculated as:

$$M_s = \{0.1 * [40 - (0.15 * 40)]\} * 0.5 = 1.7 \text{ inches}$$

4. Calculate the snowmelt runoff volume (R_s) using:

Equation 4.8: Snowmelt Runoff Volume (Snowmelt Method 3)

$$R_s = (1 - I) * [(M_s - Inf) + (I * M_s)]$$

where:

R_s = snowmelt runoff volume (inches)

I = impervious fraction of the watershed

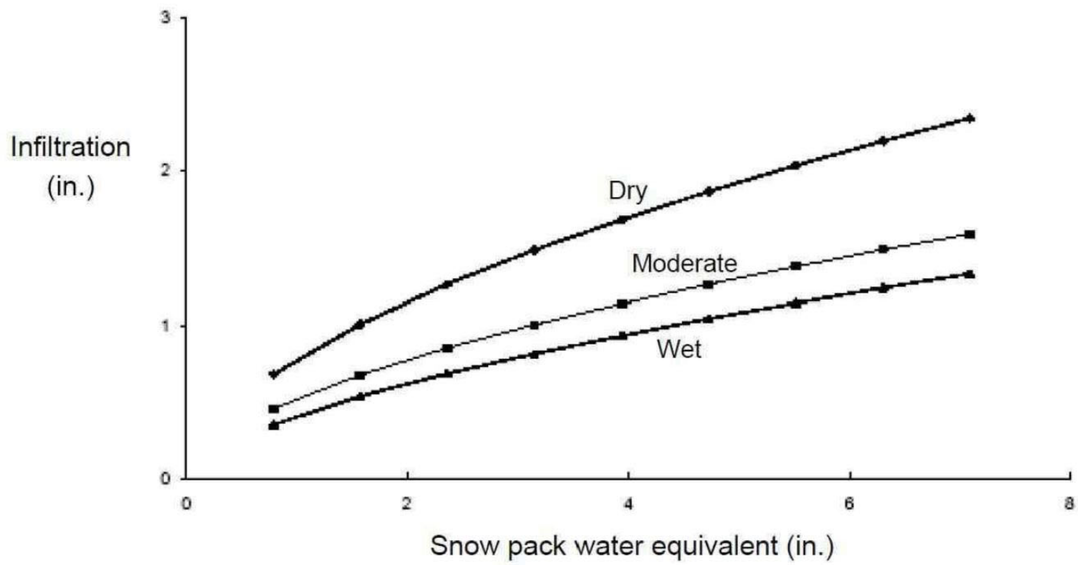
M_s = snowmelt (inches)

Inf = infiltration (inches)

For this example, use Figure 4.3.8 to determine the infiltration amount (0.65 inches) for moderate soil moisture conditions and 1.7 inches of snowpack water. Furthermore, if the impervious fraction is 0.4, then the snowmelt runoff volume (R_s) is calculated as:

$$R_s = (1 - 0.4) * [(1.7 - 0.65) + (0.4 * 1.7)] = 1.31 \text{ inches}$$

Figure 4.8: Snowmelt Infiltration as a Function of Soil Moisture



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5. Determine the annual runoff volume. While there are several acceptable ways of computing this value, Schueler (1987) proposed a “Simple Method” whereby annual runoff volume in inches is given by:

Equation 4.9: Simple Method for Annual Snowmelt Runoff Volume (Snowmelt Method 3)

$$R_a = 0.9 * P_a * [0.05 + (0.9 * I)]$$

where:

R_a = annual runoff volume (inches)

P_a = annual rainfall (inches)

I = impervious fraction of the watershed

Assuming the annual rainfall volume is 15 inches and the impervious fraction is 0.4, then, for this example:

$$R_a = 0.9 * 15 * [0.05 + (0.9 * 0.4)] = 5.54 \text{ inches}$$

6. Determine the runoff volume to be treated (V_t) for a 20-acre site.

Equation 4.10: Runoff Volume Treated (Snowmelt Method 3)

$$V_t = [R_s – (0.05 * R_a)] * (A/12)$$

where:

V_t = runoff volume to be treated (acre-feet)

R_s = snowmelt runoff volume (inches)

R_a = annual runoff volume (inches)

A = area (acres)

For this example:

$$V_t = [1.31 – (0.05 * 5.54)] * (50/12) = 4.3 \text{ acre-feet}$$

7. Because snowmelt occurs over several days or even weeks, the BMP does not have to treat the entire water quality volume over a 24-hour period. A 50% reduction in the volume is used to determine how much storage is required. Thus, the water quality treatment volume is given by:

Equation 4.11: Water Quality Treatment Volume (Snowmelt Method 3)

$$WQv = 0.5 * V_t$$

where:

WQv = water quality treatment volume (acre-feet)

V_t = runoff volume to be treated (acre-feet)

For this example:

$$WQv = 0.5 * 4.3 \text{ acre-feet} = 2.15 \text{ acre-feet}$$

Finally, this water quality treatment volume should be compared with the volume from precipitation considerations to determine which is more conservative.

4.4 Precipitation Maps

The 2-year isopluvial maps for eastern Washington can be found in 4.3.6 Precipitation Magnitude/Frequency Analysis and 4.3.7 Precipitation Magnitude and Frequency for 24-Hour and Regional Storms. The remaining isopluvial maps (10-, 25-, 50-, and 100-year) are provided in Figure 4.9: 10-Year, 24-Hour Isopluvial Map through Figure 4.12: 100-Year, 24-Hour Isopluvial Map for reference.

Figure 4.9: 10-Year, 24-Hour Isopluvial Map

Source: Miller et. al., 1973

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10-Year, 24-Hour Isopluvial Map

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Figure 4.10: 25-Year, 24-Hour Isopluvial Map

Source: Miller et. al., 1973

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25-Year, 24-Hour Isopluvial Map

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Figure 4.11: 50-Year, 24-Hour Isopluvial Map

Source: Miller et. al., 1973

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50-Year, 24-Hour Isopluvial Map

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Figure 4.12: 100-Year, 24-Hour Isopluvial Map

Source: Miller et. al., 1973

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100-Year, 24-Hour Isopluvial Map

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4.5 Single-Event Hydrograph Methods

4.5.1 Introduction

Applicability

Single-event hydrograph methods are required for designing flow control Best Management Practices (BMPs). They are an allowable method for computing peak runoff rates and runoff volumes for design of runoff treatment BMPs. Single-event hydrograph methods include the Soil Conservation Service (SCS) hydrograph and the Santa Barbara Urban Hydrograph (SBUH) methods. Commercially available computer programs for these methods may be used if the sponsor's designer acquires acceptance from the local jurisdiction. Such acceptance shall be obtained prior to submittal of plans and calculations.

Supplemental Guidelines

The SBUH method calculates only flow that will occur from surface runoff and thus is not accurate for large drainage basins where groundwater flow can be a major contributor to the total flow. The method is most accurate for drainage basins smaller than 100 acres and should not be used for drainage basins larger than 1,000 acres.

4.5.2 Hydrograph Design Process

This section presents the general process involved in conducting a hydrologic analysis using hydrograph methods to:

1. design retention/detention flow control BMPs and
2. determine water quality treatment volumes.

The exact step-by-step method for entering data into a computer model varies with the different models and is not described here. See the documentation or Help module of the computer program. Predevelopment or existing and proposed development site runoff conditions need to be determined and documented in the Stormwater Site Plan.

Process for Designing Retention/Detention Flow Control BMPs

For more information: Review 2.4.6 CE6: Flow Control to determine all flow control requirements that will apply to the proposed project.

The process for designing retention/detention flow control BMPs is described as follows:

1. Identify the climate region and average annual precipitation from Figure 4.1: Average Annual Precipitation and Climate Regions.
2. Identify two precipitation depths from Figure 4.7: 2-Year, 24-Hour Isopluvial Map and Figure 4.10: 25-Year, 24-Hour Isopluvial Map.
    - 2-year, 24-hour
    - 25-year (or other recurrence interval(s) required by the agency or local jurisdiction), 24-hour

3. Determine the predevelopment or existing and the proposed development drainage basin areas and identify pervious and impervious areas (in acres) for each condition.
4. Determine soil types and hydrologic soil groups (A, B, C, or D) from SCS maps.
5. Determine curve numbers (CNs) for pervious and impervious areas using hydrologic soil groups for both the predevelopment or existing conditions and the proposed development conditions.
6. Determine times of concentration for both predeveloped or existing and proposed development conditions; some computer models will do these calculations if the designer enters length, slope, roughness, and flow type.
7. Select storm hyetograph and analysis time interval; verify that the analysis time interval is appropriate for use with storm hyetograph time increment.
8. Input data obtained from steps 2, 3, 5, 6, and 7 into the computer model for both the predeveloped or existing and the proposed development conditions.
9. Have the computer model compute the hydrographs.
10. Review the peak flow rate for the predeveloped or existing condition in the 2-year and 25-year design storms. The allowable release rate for the entire volume of the 2-year storm is 50% of the predeveloped or existing 2-year peak flow rate. The allowable release rate for the 25-year storm is equal to the predeveloped or existing 25-year peak flow.

    Note: In some cases the predeveloped or existing 2-year peak flow rate may be 0 cubic feet per second (cfs), which means there is no discharge from the site. In this situation, the 2-year proposed development flow volume must be retained as dead storage that will ultimately infiltrate or evaporate.
11. Review the peak flow rate for the proposed development conditions in the 2-year and 25-year storms. Compare the increases in peak flow rates for 2-year and 25-year design storms to determine if there is an increase in runoff and a flow control BMP is therefore required. Also determine whether the project qualifies for applying dispersion BMPs.
12. Assume a size for the detention BMP and input this size into the computer model. Most computer models will allow a vault or a pond detention BMP, with or without infiltration. See the volume of the design storm hydrograph computed in Step 10 for a reasonable assumption of the detention volume required.
13. Assume a size for the orifice structure and input this size into the computer model. A single orifice at the bottom of the riser may suffice in some cases. In other projects, multiple orifices may result in decreased pond sizes. For a typical pond, a reasonable approximation is 1 inch of diameter orifice per 0.05 cfs outflow. Note that the designer should check with the local jurisdiction to determine the minimum allowable orifice diameter.
14. Use the computer model to route the proposed development hydrographs through the detention BMP and orifice structure. Compare the proposed development peak outflow rates to the allowable release rates identified in Step 11.

15. If the proposed development peak outflow rates exceed the allowable release rates, adjust the detention volume, orifice size, orifice height, and/or number of orifices. Continue iterations using the computer model and adjusting the parameters until the proposed development outflow rates are less than or equal to the allowable release rates.

16. Calculations are complete.

Process for Identifying Water Quality Treatment Volumes or Flow Rates

Note: The data required for many of the initial steps are data that are used in designing retention/-detention flow control BMPs as described above.

The process for identifying water quality treatment volumes or flow rates is described as follows.

1. Review 2.4.5 CE5: Runoff Treatment to determine all runoff treatment requirements that will apply to the proposed project.

2. Determine the climate region and average annual precipitation from Figure 4.1: Average Annual Precipitation and Climate Regions.

3. Determine one of the following precipitation depths (depending on the type of runoff treatment BMP) from Figure 4.6: 2-Year, 2-Hour Isopluvial Map or Figure 4.7: 2-Year, 24-Hour Isopluvial Map:

   - 2-year, 2-hour for flow-rate-based treatment BMPs

   - 2-year, 24-hour for volume-based treatment BMPs

4. Multiply the rainfall by the appropriate coefficient to convert the 2-year to the 6-month precipitation depth:

   - 1.06 * C_{sds} from Table 4.7: Values of the Coefficient Csds for Using 2-Year, 2-Hour Precipitation to Compute 2-Hour Precipitation for Selected Periods of Return for 6-month, 3-hour precipitation

   - C_{wqs} from Table 4.5: Values of Coefficient Cwqs for Computing 6-Month, 24-Hour Precipitation for 6-month, 24-hour precipitation

5. Determine the proposed development drainage basin areas and identify the pervious and impervious areas (in acres) that contribute flow to the treatment BMP.

6. Determine soil types and hydrologic soil groups (A, B, C, or D) from SCS maps.

7. Determine CNs for the pervious and impervious areas using the hydrologic soil group for the proposed development conditions.

8. Determine the time of concentration for the proposed development conditions; some computer models will do this calculation if the designer enters length, slope, roughness, and flow type.

9. If modeling the short- or long-duration storm hyetograph, select the 3-hour short-duration storm hyetographs (see Table 4.33: Short-Duration Storm Hyetograph Values for All

Climate Regions) or regional long-duration storm hyetographs for the climate region (see either Table 4.31: SCS Type IA Storm Hyetograph Values (continued) or Table 4.34: Regional Storm Hyetograph Values for Climate Region 1: Cascade Mountains (continued) to Table 4.37: Regional Storm Hyetograph Values for Climate Region 4: Eastern Mountains (continued)) and analysis time interval. Check to be certain that the analysis time interval is appropriate for use with the storm hyetograph time increment.

10. Input data obtained from Steps 4, 5, 7, 8, and 9 into the computer model for the proposed development conditions and storm event.
11. Have the computer model compute the hydrograph.
12. To design flow-rate-based treatment BMPs, use the computed peak flow from the 6-month, 3-hour hydrograph.
13. To design volume-based treatment BMPs, use the computed volume from the 6-month, 24-hour (or long-duration design) hydrograph.

All storm event hydrograph methods require the input of parameters that describe the physical drainage basin characteristics. These parameters provide the basis from which the runoff hydrograph is developed. The following section describes one of the three key parameters used to develop the runoff hydrograph using the SCS hydrograph or SBUH method: time of concentration. The other two parameters are area and CN, which are described in 4.6 SCS Curve Number Equations.

4.5.3 Travel Time and Time of Concentration

The time of concentration for rainfall shall be computed for all overland flow, ditches, channels, gutters, culverts, and pipe systems. When using the SBUH or SCS hydrograph methods, the time of concentration for the various surfaces and conveyances should be computed using the following methods, which are based on the methods described in *Urban Hydrology for Small Watersheds* (USDA et al., 1986).

Travel time is the time it takes water to travel from one location to another in a watershed. Travel time is a component of time of concentration, which is the time for runoff to travel from the hydraulically most distant point of the watershed. Time of concentration is computed by summing all the travel times for consecutive components of the drainage conveyance system. Time of concentration influences the shape and peak of the runoff hydrograph. Urbanization usually decreases time of concentration, thereby increasing the peak discharge. But time of concentration can be increased as a result of:

a. ponding behind small or inadequate drainage systems, including storm drain inlets and road culverts, or
b. reduction of land slope through grading.

Water moves 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.

Travel Time

Travel time is the ratio of flow length to flow velocity:

Equation 4.12: Travel Time

$$T_t = \frac{L}{60*V}$$

where:

T_t = travel time (minutes)

L = flow length (feet)

V = average velocity (feet per second [ft/sec])

60 = unit conversion factor from seconds to minutes

Time of Concentration

Time of concentration is the sum of travel time values for the various consecutive flow segments.

Equation 4.13: Time of Concentration

$$T_c = Tt_1 + Tt_2 + \ldots Tt_m$$

where:

T_c = time of concentration (minutes)

m = number of flow segments

Sheet Flow

Sheet flow is flow over plane surfaces. It usually occurs in the headwater of streams. With sheet flow, the friction value (n_s) (a modified Manning's effective roughness coefficient that includes the effect of raindrop impact; drag over the plane surface; obstacles such as litter, crop ridges, and rocks; and erosion and transportation of sediment) is used. These n_s values are for very shallow flow depths of about 0.1 foot and are only used for travel lengths up to 300 feet. Table 4.11: Values of n and k for Use in Computing Time of Concentration (continued) gives Manning's n. values for sheet flow for various surface conditions.

For sheet flow up to 300 feet, use Manning's kinematic solution to directly compute T_t:

Equation 4.14: Sheet Flow Travel Time

$$T_t = 0.42 * (n_s * L)^{0.8} / [(P_{2yr24hr})^{0.5} * (s_o)^{0.4}]$$

where:

T_t = travel time (minutes)

n_s = sheet flow Manning's effective roughness coefficient from Table 4.11: Values of n and k for Use in Computing Time of Concentration (continued)

L = flow length (feet)

$P_{2yr24hr}$ = 2-year, 24-hour rainfall from Figure 4.7: 2-Year, 24-Hour Isopluvial Map (inches) ($P_{2yr24hr}$ may be called P_2 in other forms of this equation)

s_o = slope of hydraulic grade line or land slope (feet per foot [ft/ft])

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 k_s values from Table 4.11: Values of n and k for Use in Computing Time of Concentration (continued) in which average velocity is a function of slope and channel type of the receiving water. After computing the average velocity using the Velocity Equation (Equation 4.15: Velocity Equation), the travel time for the shallow concentrated flow segment can be computed using the Travel Time Equation (Equation 4.12: Travel Time).

Velocity Equation

A commonly used method of computing average velocity of flow, once it has measurable depth, is the following equation:

Equation 4.15: Velocity Equation

$$V = k * \sqrt{S_o}$$

where:

V = velocity (ft/sec)

k = time of concentration velocity factor (ft/sec)

s_o = slope of flow path (ft/ft)

k values in Table 4.11: Values of n and k for Use in Computing Time of Concentration (continued) have been computed for various land covers and channel characteristics with assumptions made for hydraulic radius using the following rearrangement of Manning's equation:

Equation 4.16: Time of Concentration Velocity Factor

$$k = (1.49 * R^{0.667})/n$$

where:

R = assumed hydraulic radius

n = Manning's roughness coefficient for open channel flow, from Table 4.11: Values of n and k for Use in Computing Time of Concentration (continued) or Table 4.12: Other Values of the Roughness Coefficient n for Channel Flow (continued)

Open Channel Flow

Open channels are assumed to begin where surveyed cross-sectional information has been obtained, where channels are visible on aerial photographs, or where lines indicating streams appear (in blue) on U.S. Geological Survey (USGS) quadrangle sheets. The k_c values from Table 4.11: Values of n and k for Use in Computing Time of Concentration (continued) used in the Velocity Equation (Equation 4.15: Velocity Equation) or water surface profile information can be used to estimate average flow velocity. Average flow velocity is usually determined for bankfull conditions. After average velocity is computed the travel time for the channel segment can be computed using the Travel Time Equation (Equation 4.12: Travel Time).

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 method described in 4.7 Level-Pool Routing Method.

Limitations:

The following limitations apply in estimating travel time.

- Manning’s kinematic solution should not be used for sheet flow > 300 feet.
- In watersheds with drainage systems, carefully identify the appropriate hydraulic flow path to estimate time of concentration. Drainage systems generally handle only a small portion of a large event. The rest of the peak flow travels by streets, lawns, and so on, to the outlet. Consult a standard hydraulics textbook to determine average velocity in pipes for either pressure or nonpressure 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 4.11: Values of *n* and *k* for Use in Computing Time of Concentration

Flow Type	n or k Value
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
Shallow, Concentrated Flow	k_s
Forest with heavy ground litter and meadows (n = 0.10)	3

Table 4.11: Values of n and k for Use in Computing Time of Concentration (continued)

Flow Type	n or k Value
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 = 0.030)	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*

Table 4.12: Other Values of the Roughness Coefficient *n* for Channel Flow

Type of Channel and Description	Manning's n^a
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

Table 4.12: Other Values of the Roughness Coefficient n for Channel Flow (continued)

Type of Channel and Description	Manning's *n*[a]
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	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 1, but more stones and weeds	0.035
3. Clean, winding, some pools and shoals	0.040
4. Same as 3, 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 stand 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 4.12: Other Values of the Roughness Coefficient n for Channel Flow (continued)

Type of Channel and Description	Manning's n^a
B-2 Floodplains	
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 2, 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 4, but with flood stage reaching branches	0.120
[a] These *n* values are "normal" values for use in analysis of channels. For conservative design for channel capacity the "maximum" values listed in other references should be considered. For channel bank stability the minimum values should be considered.	

Example

The following is an example of travel time and time of concentration calculations.

Given: An existing drainage basin having a selected flow route composed of the following four segments.

Note: Drainage basin has a P_2 = 0.8 inches.

- **Segment 1:**
  - L = 200 ft, Forest with good cover (sheet flow)
  - s_o = 0.03 ft/ft, n_s = 0.80
- **Segment 2:**
  - L = 300 ft, Pasture (shallow concentrated flow)
  - s_o = 0.04 ft/ft, k_s = 11
- **Segment 3:**
  - L = 300 ft, Grass-lined waterway (intermittent channel)
  - s_o = 0.05, k_c = 17
- **Segment 4:**
  - L = 500 ft, Grass-lined stream (continuous)
  - s_o = 0.02, k_c = 27

Calculate: Calculate the travel times (T_t) for each reach and then sum them to calculate the drainage basin time of concentration (T_c).

- **Segment 1:** Sheet flow, (L < 300 feet)

  Use Equation 4.14: Sheet Flow Travel Time:

  $$T_1 = \frac{0.42 * (0.8 * 200)^{0.8}}{0.8^{0.5} * 0.03^{0.4}} = 111 \text{ minutes}$$

- **Segment 2:** Shallow concentrated flow

  Use Equation 4.15: Velocity Equation:

  $$V_2 = 11* \sqrt{0.04} = 2.2 \text{ ft/sec}$$

  $$T_2 = \frac{L}{60 * V} = \frac{300}{60 * 2.2} = 2 \text{ minutes}$$

- **Segment 3:** Intermittent channel flow

  Use Equation 4.15: Velocity Equation:

  $$V_3 = 17 * \sqrt{0.05} = 3.8 \text{ ft/sec}$$

  $$T_3 = \frac{300}{60 * 3.8} = 1 \text{ minute}$$

- **Segment 4:** Continuous stream

  Use Equation 4.15: Velocity Equation:

$$V_4 = 27 * \sqrt{0.02} = 3.8 \text{ ft/sec}$$

$$T_4 = \frac{500}{60 * 3.8} = 2 \text{ minutes}$$

Use Equation 4.13: Time of Concentration:

$$T_c = T_1 + T_2 + T_3 + T_4 = 111 + 2 + 1 + 2 = 116 \text{ minutes}$$

It is important to note how the initial sheet flow segment's travel time dominates the time of concentration computation. This will nearly always be the case for relatively small drainage basins and in particular for the existing site conditions. This also illustrates the significant impact urbanization has on the surface runoff portion of the hydrologic process.

The time of concentration should be calculated for each significantly different slope. Travel time for flow in pipes, ditches and gutters should be computed as a function of the velocity as defined by the Manning formula.

4.5.4 Hydrograph Synthesis

This section presents a description of the SBUH method. This method is used to synthesize the runoff hydrograph from precipitation excess (time distribution of runoff) and time of concentration.

The SBUH method was developed by the Santa Barbara County Flood Control and Water Conservation District, California. The SBUH method directly computes a runoff hydrograph without going through an intermediate process (unit hydrograph) as the SCS hydrograph method does. By comparison, the calculation steps of the SBUH method are much simpler and can be programmed on a calculator or a spreadsheet program. Commercial software is also available that can perform these calculations.

The SBUH method uses two steps to synthesize the runoff hydrograph:

1. Compute the instantaneous hydrograph
2. Compute the runoff hydrograph

Instantaneous Hydrograph

The instantaneous hydrograph is computed as follows:

Equation 4.17: Instantaneous Hydrograph

$$I(t) = [60.5 * R(t) * A] / dt$$

where:

I(t) = instantaneous hydrograph at each time interval dt (cfs)

R(t) = total runoff depth from both impervious and pervious runoff at time interval dt (inches). Also known as precipitation excess.

A = area (acres)

dt = time interval (minutes)

A maximum time interval of 5 minutes is used for all short-duration design storms. A maximum time interval of 30 minutes is used for all regional design storms.

Runoff Hydrograph

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:

Equation 4.18: Runoff Hydrograph

$$Q(t+1) = Q(t) + w * [I(t) + I(t+1) - 2 * Q(t)]$$

Equation 4.19: Routing Constant

$$w=dt / (2 * T_c + dt)$$

where:

Q(t) = runoff hydrograph or routed flow (cfs)

I(t) = instantaneous hydrograph at each time interval dt (cfs)

w = routing constant

dt = time interval (minutes)

Tc = time of concentration (minutes)

Example

To illustrate the SBUH method, Appendix 4-E: Example SBUH Runoff Hydrograph includes a runoff hydrograph computed by this method. These examples were prepared using spreadsheet program. These examples illustrate how the method can be performed with a personal computer. In order to save space, time increments with all values equal to zero have been omitted.

4.6 SCS Curve Number Equations

4.6.1 Introduction

Applicability

The Soil Conservation Service (SCS) curve number equations are an allowable method for computing storage volumes for volume-based treatment Best Management Practices (BMPs) based on the SCS hydrograph method. SCS curve numbers (CNs) are also used in the single-event hydrograph methods such as the SCS hydrograph and the Santa Barbara Urban Hydrograph (SBUH) methods.

This method can be used to size the volume of treatment BMPs when the design is based on the volume of runoff. Computer models are not required for this method. Required input consists of precipitation, pervious and impervious area and CNs.

4.6.2 Area

Drainage subbasin areas should be delineated in a manner that runoff characteristics are as homogeneous as practicable and in reasonable configurations. Subbasin configurations should be contiguous and consistent with surface runoff patterns. See 4.6.3 Curve Number for discussion regarding when weighted averaging is appropriate and not appropriate.

4.6.3 Curve Number

The Natural Resources Conservation Service (NRCS, formerly the Soil Conservation Service) has for many years conducted studies into the runoff characteristics of various land types. After gathering and analyzing extensive data, the NRCS has 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* (USDA, 2004) contains a detailed description of the development and use of the SCS curve number equations.

NRCS has developed CN values based on soil type and land use. The combination of soil type and land use is called the “soil-cover complex.” The soil-cover complexes have been assigned to one of four hydrologic soil groups, according to their runoff characteristics (see descriptions in the Hydrologic Soil Group Classifications section). SCS has classified over 4,000 soil types into these four soil groups.

Table 4.13: Hydrologic Soil Series for Selected Soils in Eastern Washington (continued) shows the hydrologic soil group of some of the common soil types in eastern Washington. For details of the hydrologic soil group for other soil types, see the SCS maps published for each county.

Table 4.13: Hydrologic Soil Series for Selected Soils in Eastern Washington

Soil Type	Hydrologic Soil Group	Soil Type	Hydrologic Soil Group
Athena	B	Laketon	C
Bernhill	B	Lance	B
Bong	A	Larkin	B
Bonner	B	Latah	D
Brickel	C	Marble	A
Bridgeson	D	Mondovi	B
Caldwell	C	Moscow	C
Cedonia	B	Naff	B
Cheney	B	Narcisse	C
Clayton	B	Nez Perce	C
Cocolalla	D	Palouse	B

Table 4.13: Hydrologic Soil Series for Selected Soils in Eastern Washington (continued)

Soil Type	Hydrologic Soil Group	Soil Type	Hydrologic Soil Group
Dearyton	C	Peone	D
Dragoon	C	Phoebe	B
Eloika	B	Reardan	C
Emdent	D	Schumacher	B
Freeman	C	Semiahmoo	D
Garfield	C	Snow	B
Garrison	B	Speigle	B
Glenrose	B	Spokane	C
Green Bluff	B	Springdale	A
Hagen	B	Tekoa	C
Hardesty	B	Uhlig	B
Hesseltine	B	Vassar	B
Konner	D	Wethey	C
Lakesol	B	Wolfeson	C
Source: (USDA et al., 1986)			

For more information: See SCS maps for additional soil types and hydrologic soil groups.

Hydrologic Soil Group Classifications

NRCS has classified soils into the following hydrologic soil groups:

A. Low runoff potential: Soils having high infiltration rates, even when thoroughly wetted, and consisting chiefly of deep, well-drained 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 have 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 layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very slow rate of water transmission.

The following are important criteria/considerations for selection of CN values.

Many factors may affect the CN value for a given land use. For example, the movement of heavy equipment over bare ground may compact the soil so that it has a lesser infiltration rate and greater runoff potential than would be indicated by strict application of the CN value based on predevelopment conditions at the site.

Separate CN values must be selected for the pervious and impervious areas of an urban basin or subbasin. For all developed areas, the impervious percentage must be estimated from best available plans, topography, or aerial photography and verified by field reconnaissance. Generally, the pervious area CN value shall be a weighted average of all the pervious area CN values within the subbasin. However, if two large homogeneous areas (such as a parking lot and a park) within the same subbasin have CN values which differ by more than 20 points, separate hydrographs need to be generated for the two areas and the hydrographs then summed. See the example provided later in this section.

Directly connected impervious areas are areas such as roofs and driveways from which runoff directly enters the drainage system without first traversing an area of pervious ground. Unconnected impervious areas are areas whose runoff is spread over a pervious area as sheet flow and include such items as a tennis court in the middle of a lawn. Unconnected impervious areas can be weighted with pervious areas.

Table 4.14: Runoff Curve Numbers (CNs) for Selected Agricultural, Suburban, and Urban Areas (continued) gives CN values for agricultural, suburban, and urban land use classifications. The CN values listed in Table 4.14: Runoff Curve Numbers (CNs) for Selected Agricultural, Suburban, and Urban Areas (continued) are applicable under a normal antecedent moisture condition (AMC II) and are the basis of design in eastern Washington.

High groundwater or shallow bedrock can cause a significant increase in runoff. If either of these conditions exists, it needs to be addressed by the designer. For a more complete discussion of computing weighted CN values, see *Urban Hydrology for Small Watersheds* (USDA et al., 1986).

Table 4.14: Runoff Curve Numbers (CNs) for Selected Agricultural, Suburban, and Urban Areas

Cover type and hydrologic condition	CNs for hydrologic soil group			
	A	B	C	D
Open space (lawns, parks, golf courses, cemeteries, landscaping, etc.)[a]				
Poor condition (grass cover <50% of the area)	68	79	86	89
Fair condition (grass cover on 50% to 75% of the area)	49	69	79	84
Good condition (grass cover on >75% of the area)	39	61	74	80
Impervious areas				

Table 4.14: Runoff Curve Numbers (CNs) for Selected Agricultural, Suburban, and Urban Areas (continued)

Cover type and hydrologic condition	CNs for hydrologic soil group			
	A	B	C	D
Open water bodies: lakes, wetlands, ponds etc.	100	100	100	100
Paved parking lots, roofs, driveways, etc. (excluding right-of-way)	98	98	98	98
Permeable pavers and permeable interlocking concrete (assumed as 85% impervious and 15% lawn)				
Fair lawn condition (weighted average CNs)	95	96	97	97
Gravel (including right-of-way)	76	85	89	91
Dirt (including right-of-way)	72	82	87	89
Pasture, grassland, or range-continuous forage for grazing				
Poor condition (ground cover <50% or heavily grazed with no mulch)	68	79	86	89
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
Cultivated agricultural lands				
Row Crops (good) e.g., corn, sugar beets, soy beans	64	75	82	85
Small Grain (good) e.g., wheat, barley, flax	60	72	80	84
Meadow				
Continuous grass, protected from grazing and generally mowed for hay	30	58	71	78
Brush (brush-weed-grass mixture with brush the major element)				
Poor (<50% ground cover)	48	67	77	83
Fair (50% to 75% ground cover)	35	56	70	77
Good (>75% ground cover)	30[b]	48	65	73
Woods-grass combination (orchard or tree farm)[c]				
Poor	57	73	82	86
Fair	43	65	76	82
Good	32	58	72	79

Table 4.14: Runoff Curve Numbers (CNs) for Selected Agricultural, Suburban, and Urban Areas (continued)

Cover type and hydrologic condition	CNs for hydrologic soil group			
	A	B	C	D
Woods				
Poor (Forest litter, small trees, and brush destroyed by heavy grazing or regular burning)	45	66	77	83
Fair (Woods are grazed but not burned, and some forest litter covers the soil)	36	60	73	79
Good (Woods are protected from grazing, and litter and brush adequately cover the soil)	30	55	70	77
Herbaceous (mixture of grass, weeds, and low-growing brush, with brush the minor element)				
Poor (<30% ground cover)	n/a[d]	80	87	93
Fair (30% to 70% ground cover)		71	81	89
Good (>70% ground cover)		62	74	85
Sagebrush with grass understory				
Poor (<30% ground cover)	n/a[d]	67	80	85
Fair (30% to 70% ground cover)		51	63	70
Good (>70% ground cover)		35	47	55

[a]Composite CNs may be computed for other combinations of open space cover type.

[b]Actual CN is < 30; use CN = 30 for runoff computations.

[c]The indicated CNs were computed for areas with 50% woods and 50% grass (pasture) cover. Other combinations of conditions may be computed from the CNs for woods and pasture.

[d]CNs have not been developed for hydrologic soil group A.

For more information: For a more detailed and complete description of land use curve numbers (CNs), see *Urban Hydrology for Small Watersheds* (USDA et al., 1986).

Antecedent Moisture Condition

The moisture condition in a soil at the onset of a storm event, referred to as the antecedent moisture condition (AMC), has a significant effect on both the volume and rate of runoff. Recognizing that fact, the SCS developed three antecedent soil moisture conditions (I, II, and III), which are described as follows:

- **AMC I:** Soils are dry but not to wilting point.
- **AMC II:** Average conditions.

- **AMC III:** Heavy rainfall, or light rainfall and low temperatures have occurred within the last 5 days; near saturated or saturated soil.

Table 4.15: Total 5-Day Antecedent Rainfall gives seasonal rainfall limits for the three antecedent soil moisture conditions.

Table 4.15: Total 5-Day Antecedent Rainfall

Antecedent Moisture Condition	Dormant Season (inches)	Growing Season (inches)
I	< 0.5	< 1.4
II	0.5 to 1.1	1.4 to 2.1
III	> 1.1	> 2.1

Varying AMC values are used in the design of evaporation pond BMPs in BMP F6.30: Evaporation Ponds. See Table 4.16: Curve Number Conversions for Antecedent Moisture Conditions (Case Ia = 0.2S) (continued) for the CN conversions for different AMC values for the case of Ia = 0.2S. For other conversions, see the *National Engineering Handbook* (USDA, 2004).

Table 4.16: Curve Number Conversions for Antecedent Moisture Conditions (Case Ia = 0.2S)

Curve No. for AMC II	Curve No. for AMC I	Curve No. for AMC III		Curve No. for AMC II	Curve No. for AMC I	Curve No. for AMC III
100	100	100		76	58	89
99	97	100		75	57	88
98	94	99		74	55	88
97	91	99		73	54	87
96	89	99		72	53	86
95	87	98		71	52	86
94	85	98		70	51	85
93	83	98		69	50	84
92	81	97		68	48	84
91	80	97		67	47	83
90	78	96		66	46	82
89	76	96		65	45	82
88	75	95		64	44	81
87	73	95		63	43	80

Table 4.16: Curve Number Conversions for Antecedent Moisture Conditions (Case Ia = 0.2S) (continued)

Curve No. for AMC II	Curve No. for AMC I	Curve No. for AMC III		Curve No. for AMC II	Curve No. for AMC I	Curve No. for AMC III
86	72	94		62	42	79
85	70	94		61	41	78
84	68	93		60	40	78
83	67	93		59	39	78
82	66	92		58	38	76
81	64	92		57	37	75
80	63	91		56	36	75
79	62	91		55	35	74
78	60	90		54	34	73
77	59	89		50	31	70
Source: (USDA, 2004)						

Supplemental Guidelines

Local jurisdictions may wish to restrict the CNs used to describe the predeveloped or existing condition and generate the runoff in the proposed development condition. The lower CNs result in lower runoff and mitigate for past changes to the natural drainage patterns. Restricting the allowable CNs can also reduce the subjectivity that is inherent in the selection of CNs.

Example

The following is an example of how CN values are selected for a sample project.

Select CNs for the following development:

- Existing land use: woods (thin stand, poor cover)
- Future land use: 80% impervious
- Basin size: 10 acres
- Soil type: 80% Garfield, 20% Bonner, split between the pervious and impervious areas

Table 4.13: Hydrologic Soil Series for Selected Soils in Eastern Washington (continued) shows that Garfield soil belongs to the “C” hydrologic soil group and Bonner soil belongs to the “B” group. Therefore, for the existing condition, CNs of 77 and 66 are read from Table 4.14: Runoff Curve Numbers (CNs) for Selected Agricultural, Suburban, and Urban Areas (continued) and area weighted to obtain a CN value of 75.

For the proposed development condition with 80% impervious, the impervious and pervious areas are 8.0 acres and 2.0 acres, respectively. The impervious area CN value is 98. The 2.0 acres of pervious area consists of 70% grass landscaping covering the same proportions of Garfield and Bonner soil (80% and 20%, respectively). Therefore, for fair condition open space, CNs of 79 and 69 are read from Table 4.14: Runoff Curve Numbers (CNs) for Selected Agricultural, Suburban, and Urban Areas (continued) and area weighted to obtain a pervious area CN value of 77. The results of this example are summarized in Table 4.17: Curve Number Example.

Table 4.17: Curve Number Example

On-Site Condition	Existing	Proposed
Land use	Woods	Multifamily
Pervious area	10.0 acres	2.0 acres
Curve number of pervious area	75	77
Impervious area	0 acres	8.0 acres
Curve number of impervious area	Not applicable	98

SCS Curve Number Equations

The rainfall-runoff equation of the SCS curve number equations relate a land area's runoff depth (precipitation excess) to the precipitation it receives and to its natural storage capacity. The runoff depth from a given watershed is solved with the following equations:

Equation 4.20: SCS Curve Number Equation 1

$$Q = \frac{[P - (0.2 * S)]^2}{P + (0.8 * S)}$$

Equation 4.21: SCS Curve Number Equation 2

$$S = \frac{1{,}000}{CN} - 10$$

Q = 0 *for* P < 0.2 * S

where:

Q = actual direct runoff depth (inches)

P = total precipitation depth over the area (inches)

S = potential abstraction or potential maximum natural detention over the area due to infiltration, storage, etc. (inches)

CN = runoff curve number

The combination of Equation 4.20: SCS Curve Number Equation 1 and Equation 4.21: SCS Curve Number Equation 2 allows for estimation of the total runoff volume by computing the total runoff depth given the total precipitation depth for the storm of interest.

Example

The following is an example for determining design treatment volume.

- Project location: Walla Walla
- Area requiring treatment: 80% impervious
- CN: 98
- S: (1,000/98) - 10 = 0.20
- $P_{2year,24hour}$, from Figure 4.7: 2-Year, 24-Hour Isopluvial Map: 1.2 inches
- C_{wqs} for Climate Region 3, from Table 4.5: Values of Coefficient Cwqs for Computing 6-Month, 24-Hour Precipitation: 0.69
- 24-hour to regional storm precipitation depth conversion factor for Climate Region 3, from Table 4.6: Factors for Converting From 24-Hour to Regional Storm Precipitation Depth: 1.06

The total amount of rainfall during the 24-hour storm is:

$$P_{wqs} = C_{wqs} * P_{2year,24hour} = (0.69) * (1.2 \text{ inches}) = 0.83 \text{ inches}$$

The total amount of rainfall during the regional storm is:

$$P_{wqs} = (0.69) * (1.2 \text{ inches}) * (1.06) = 0.88 \text{ inches}$$

Continuing on with the rainfall from the regional storm, the amount (*depth*) of rainfall that becomes runoff is:

$$Q = [0.88 - 0.2 * (0.20)]^2 / [0.88 + 0.8 * (0.20)] = 0.68 \text{ inches}$$

This depth value represents inches over the entire contributing area. The total *volume* of runoff is found by multiplying this depth by the area, with necessary conversion from inches * acres to cubic feet (cf):

$$\text{Total runoff volume (cf)} = (3{,}630 \text{ cf/acre-in}) * Q * A$$

The total runoff volume is:

$$3{,}630 \text{ cf/acre-in} * 0.68 \text{ inches} * 4.5 \text{ acres} = 11{,}108 \text{ cf}$$

This is the basis for design of runoff treatment BMPs for which the design is based on the total volume of runoff during the water quality design storm.

When developing the runoff hydrograph, Equation 4.20: SCS Curve Number Equation 1 is used to compute the incremental runoff depth for each time interval from the incremental precipitation depth given by the design storm hyetograph. This time distribution of runoff depth is often referred to as the precipitation excess and provides the basis for synthesizing the runoff hydrograph.

4.7 Level-Pool Routing Method

This section presents a general description of the methodology for routing a hydrograph through an existing retention/detention BMP or closed depression, or for sizing a new retention/detention BMP using hydrograph analysis.

The “level-pool routing” technique presented here is one of the simplest and most commonly used hydrograph routing methods. This method, which is described in the *Handbook of Applied Hydrology* (Chow, 1964), is based on the continuity equation:

Equation 4.22: Level-Pool Routing Method Equation 1

Inflow - Outflow = Change in storage

$$\left[\frac{I_1 + I_2}{2} - \frac{O_1 + O_2}{2}\right] = \frac{S}{t} = S_2 - S_1$$

where:

I_1 and I_2 = inflow at time 1 (t_1) and time 2 (t_2) (cubic feet [cf])

O_1 and O_2 = outflow at t_1 and t_2 (cf)

S_1 and S_2 = storage at t_1 and t_2 (cubic feet per minute [cf/min])

Δt = time interval, or t_2 minus t_1 (minutes)

The time interval, Δt, must be consistent with the time interval used in developing the inflow hydrograph. The time interval used for the 6-hour storm is 5 minutes, while the time interval for the 72-hour storm is 30 minutes. The Δt variable can be eliminated by dividing it into the storage variables to obtain the following rearranged equation:

Equation 4.23: Level-Pool Routing Method Equation 2

$$I_1 + I_2 + (2 * S_1) - O_1 = O_2 + (2 * S_2)$$

The terms on the left-hand side Equation 4.23: Level-Pool Routing Method Equation 2 are known from the inflow hydrograph and from the storage and outflow values of the previous time step. The unknowns (O_2 and S_2) can be solved interactively from the given stage-storage and stage-discharge curves.

The following steps are required in performing level-pool routing:

- Develop stage-storage relationship, which is a function of inflow and pond geometry.
- Develop the routing curve for the hydrograph and pond, which is a graph of outflow from the pond at a given stage versus the quantity O + (2 * S) for the same stage. The outflow is a function of stage (head above the orifice) and the control structure configuration.
- Route the inflow hydrograph through the proposed BMP by applying the continuity equation (Equation 4.22: Level-Pool Routing Method Equation 1) at each time step, where the inflow

hydrograph supplies values of I, the stage-storage relationship supplies values of S, and the routing curve supplies values of O.

Note: The commercially available SBUH computer models use the level-pool routing method to shift hydrographs and size infiltration and detention BMPs.

4.8 Rational Method

4.8.1 Introduction

Applicability

The Rational Method is an allowable method for computing peak runoff rates for flow-based runoff treatment BMPs such as biofiltration swales and oil and water separators. It is also a common method for computing the peak runoff rate for design of drywells and conveyance systems.

Supplemental Guidelines

The greatest accuracy is obtained for areas smaller than 100 acres and for developed conditions with large areas of impervious surface (e.g., pavement, rooftops). Basins up to 1,000 acres may be evaluated using the rational formula; however, results for large basins often do not properly account for effects of infiltration and thus are less accurate. Designers should never perform a Rational Method analysis on a basin that is larger than the lower limit specified for the U.S. Geological Survey (USGS) regression equations because the USGS regression equations will yield a more accurate flow prediction for that size of basin.

Procedure

Design peak runoff rates may be determined by the Rational Method formula:

Equation 4.24: Rational Method

$$Q = C * I * A$$

where:

Q = runoff (cubic feet per second [cfs])

C = runoff coefficient (dimensionless units)

I = rainfall intensity (inches per hour [in/hr])

A = contributing area (acres)

The runoff coefficient C should be based on Table 4.18: Values of Runoff Coefficient C for Use in Rational Method With Return Intervals of 10 Years or Less (continued).

The coefficients in Table 4.18: Values of Runoff Coefficient C for Use in Rational Method With Return Intervals of 10 Years or Less (continued) are applicable for peak storms of 10-year frequency. Less frequent, higher intensity storms will require the use of higher coefficients because infiltration and other losses have a proportionally smaller effect on runoff. Generally, the coefficient should be increased by 10% when designing for a 25-year frequency; by 20% for 50-year; and by 25% for 100-year. The runoff coefficient should not be increased to > 0.95 unless approved by the local jurisdiction. Higher values may be appropriate for steeply sloped areas and/or longer return periods, because in these cases infiltration and other losses have a proportionally smaller effect on runoff.

The equation for calculating rainfall intensity is:

Equation 4.25: Rainfall Intensity (Rational Method)

$$I = \frac{m}{(T_c)^n}$$

where:

I = rainfall intensity (in/hr)

T_c = time of concentration (minutes)

m and n = rainfall intensity coefficients (dimensionless units), from Table 4.19: Values of Rainfall Coefficients m and n for Selected Cities (continued) for selected cities in eastern Washington; these coefficients have been determined for all major cities for the 2-, 10-, 25-, 50-, and 100-year mean recurrence intervals (MRIs) based on NOAA Atlas 2 (Miller et al., 1973).

Table 4.18: Values of Runoff Coefficient *C* for Use in Rational Method With Return Intervals of 10 Years or Less

Cover	Flat	Rolling 2% to 10%	Hilly > 10%
Pavement and Roofs	0.90	0.90	0.90
Earth Shoulders	0.50	0.50	0.50
Drives and Walks	0.75	0.80	0.85
Gravel Pavement	0.50	0.55	0.60
City Business Areas	0.80	0.85	0.85
Suburban Residential	0.25	0.35	0.40
Single Family Residential	0.30	0.40	0.50
Lawns, Sandy Soil	0.10	0.15	0.20
Lawn, Heavy Soil	0.17	0.22	0.35
Grass Shoulders	0.25	0.25	0.25
Side Slopes, Earth	0.60	0.60	0.60
Side Slopes, Turf	0.30	0.30	0.30
Median Areas, Turf	0.25	0.30	0.30
Cultivated Land, Clay and Loam	0.50	0.55	0.60

Table 4.18: Values of Runoff Coefficient C for Use in Rational Method With Return Intervals of 10 Years or Less (continued)

Cover	Flat	Rolling 2% to 10%	Hilly > 10%
Cultivated Land, Sand and Gravel	0.25	0.30	0.35
Industrial Areas, Light	0.50	0.70	0.80
Industrial Areas, Heavy	0.60	0.80	0.90
Parks and Cemeteries	0.10	0.15	0.25
Playgrounds	0.20	0.25	0.30
Woodland and Forests	0.10	0.15	0.20
Meadows and Pasture Land	0.25	0.30	0.35
Pasture with Frozen Ground	0.40	0.45	0.50
Unimproved Areas	0.10	0.20	0.30
Source: WSDOT *Hydraulics Manual* (WSDOT, 2017).			

Table 4.19: Values of Rainfall Coefficients *m* and *n* for Selected Cities

Location	2-Year MRI		10-Year MRI		25-Year MRI		50-Year MRI		100-Year MRI	
	m	n	m	n	m	n	m	n	m	n
Clarkston and Colfax	5.02	0.628	8.24	0.635	10.07	0.638	11.45	0.639	12.81	0.639
Colville	3.48	0.558	6.98	0.610	9.07	0.626	10.65	0.635	12.26	0.642
Ellensburg	2.89	0.590	7.00	0.649	9.43	0.664	11.30	0.672	13.18	0.678
Leavenworth	3.04	0.530	5.62	0.575	7.94	0.594	9.75	0.606	11.08	0.611
Moses Lake	2.61	0.583	6.99	0.655	9.58	0.671	11.61	0.681	13.63	0.688
Omak	3.04	0.583	6.63	0.633	8.74	0.647	10.35	0.654	11.97	0.660
Pasco and Kennewick	2.89	0.590	7.00	0.649	9.43	0.664	11.30	0.672	13.18	0.678
Snoqualmie Pass	3.61	0.417	6.56	0.459	7.72	0.459	8.78	0.461	10.21	0.476
Spokane	3.47	0.556	6.98	0.609	9.09	0.626	10.68	0.635	12.33	0.643
Stevens Pass	4.73	0.462	8.19	0.500	8.53	0.484	10.61	0.499	12.45	0.513

Table 4.19: Values of Rainfall Coefficients m and n for Selected Cities (continued)

Location	2-Year MRI		10-Year MRI		25-Year MRI		50-Year MRI		100-Year MRI	
	m	n	m	n	m	n	m	n	m	n
Walla Walla	3.33	0.569	7.30	0.627	9.67	0.645	11.45	0.653	13.28	0.660
Wenatchee	3.15	0.535	6.19	0.579	7.94	0.592	9.32	0.600	10.68	0.605
Yakima	3.86	0.608	7.37	0.644	9.40	0.654	10.93	0.659	12.47	0.663

Source: WSDOT *Hydraulics Manual* (WSDOT, 2017).

Note: *m* and *n* are rainfall intensity coefficients in dimensionless units (English).

MRI = mean recurrence interval.

4.8.2 Time of Concentration for Rational Method

Time of concentration (T_c) is defined as the time for runoff to travel from the hydraulically most distant point of the watershed to a point of interest in the watershed. Travel time (T_t) is the time it takes water to travel from one location to another in a watershed. Travel time is a component of time of concentration, which is computed by summing all the travel times for consecutive components of the drainage flow path. This concept assumes that rainfall is applied at a constant rate over a drainage basin which would eventually produce a constant peak rate of runoff.

Actual precipitation does not fall at a constant rate. A precipitation event will generally begin with low rainfall intensity and then, sometimes very quickly, build to peak intensity, and eventually taper down to no rainfall. Because rainfall intensity is variable, the time of concentration is included in the rational method so that the designer can determine the proper rainfall intensity to apply across the basin. The intensity that should be used for design purposes is the highest intensity that will occur with the entire basin contributing flow to the location where the designer is interested in knowing the flow rate. It is important to note that this may be a much lower intensity than the absolute maximum intensity. The reason is that it often takes several minutes before the entire basin is contributing flow, but the absolute maximum intensity lasts for a much shorter time so the rainfall intensity that creates the greatest runoff is less than the maximum by the time the entire basin is contributing flow.

Most drainage basins will consist of different types of ground covers and conveyance systems that flow must pass over or through. These are referred to as flow segments. It is common for a basin to have flow segments that are overland flow and flow segments that are open channel flow. Urban drainage basins often have flow segments that are flow through a storm drain pipe in addition to the other two types. A travel time (the amount of time required for flow to move through a flow segment) must be computed for each flow segment. The time of concentration is equal to the sum of all the flow segment travel times.

For a few contributing areas, a unique situation occurs where the time of concentration that produces the largest amount of runoff is less than the time of concentration for the entire basin. This can occur when two or more subbasins have dramatically different types of cover (i.e., different runoff coefficients). The most common case would be a large paved area together with a long narrow strip of natural area. In this case, the designer should check the runoff produced by the paved area alone to determine if this scenario would cause a greater peak runoff rate than the peak runoff rate produced when both land segments are contributing flow. The scenario that produces the greatest runoff should be used, even if the entire basin is not contributing flow to this runoff.

The procedure described in Equation 4.26: Time of Concentration for Overland Flow and Equation 4.27: Travel Time of Flow Segment for determining the time of concentration for overland flow was developed by the Natural Resources Conservation Service (NRCS). It is sensitive to slope, type of ground cover, and the size of channel. If the total time of concentration is < 5 minutes, a minimum of 5 minutes should be used as the duration. The time of concentration can be calculated as follows:

Equation 4.26: Time of Concentration for Overland Flow

$$T_c = T_{t1} + T_{t2} + \ldots + T_{tnz}$$

using:

Equation 4.27: Travel Time of Flow Segment

$$T_t = \frac{L}{K\sqrt{S}} = \frac{L^{1.5}}{K\sqrt{\ \ H}}$$

where:

T_c = time of concentration (minutes)

T_t = travel time of flow segment (minutes)

L = length of segment (feet or meters)

K = ground cover coefficient from Table 4.8.3 (feet/minute or meters/minute)

S = slope of segment $\frac{H}{L}$ (feet per foot or meter per meter)

ΔH = elevation change in elevation across segment (feet or meters)

Table 4.20: Values of Ground Cover Coefficient K

Cover or Channel Type	Depth or Diameter	K (English)	K (Metric)
Forest with heavy ground cover	Not applicable	150	50
Minimum tillage cultivation	Not applicable	280	75
Short pasture grass or lawn	Not applicable	420	125
Nearly bare ground	Not applicable	600	200
Small roadside ditch w/grass	Not applicable	900	275
Paved area	Not applicable	1,200	375

Table 4.20: Values of Ground Cover Coefficient K (continued)

Cover or Channel Type	Depth or Diameter	K (English)	K (Metric)
Gutter flow	4 inches (100 mm) deep	1,500	450
	6 inches (150 mm) deep	2,400	725
	8 inches (200 mm) deep	3,100	950
Drainage system	1 foot (300 mm) diameter	3,000	925
	18 inches (450 mm) diameter	3,900	1,200
	2 foot (600 mm) diameter	4,700	1,425
Open channel flow (n = 0.040)	1 foot (300 mm) deep	1,100	350
in a narrow channel (w/d = 1)	2 feet (600 mm) deep	1,800	550
	4 feet (1.20 meters) deep	2,800	850
Open channel flow (n = 0.040)	1 foot (300 mm) deep	2,000	600
in a wide channel (w/d = 9)	2 feet (600 mm) deep	3,100	950
	4 feet (1.20 m) deep	5,000	1,525

Source: WSDOT *Hydraulics Manual* (WSDOT, 2017)

d = depth
mm = millimeters
n = Manning's *n*
w = width

Appendix 4-A: Background Information on Design Storms and Selected Modeling Methods

4.A.1 Introduction

As an early step in the process of developing a technical stormwater manual, short- and long-duration design storms were identified for eastern Washington by MGS Engineering Consultants at the request of the Eastern Washington Stormwater Management Project Steering Committee for the 2004 *Stormwater Management Manual for Eastern Washington* (manual). Questions were raised by some members of the Manual Subcommittee for the 2004 manual and during the public review and comment period on the first draft of the 2004 manual concerning the practical application and reliability of using the long-duration design storms as input for commonly used modeling methods and software. For the final draft version of the manual, subsequent work was performed by Harper Houf Righellis, Inc., at the request of the Eastern Washington Stormwater Management Project Manual Subcommittee and Technical Advisory Group. Harper Houf Righellis, Inc., reviewed the work by MGS Engineering Consultants and recommended appropriate modeling approaches for use by the general engineering and project design community.

This appendix includes summaries of the work performed by both MGS Engineering Consultants (4.A.2 Development of Short- and Long-Duration Design Storms for Eastern Washington) and Harper Houf Righellis, Inc. (4.A.3 Review of Design Storms and Identification of Best Rainfall-Runoff Modeling Approaches for Eastern Washington).

Appendix 4-B: Historical Storms Used to Develop Design Storms in Eastern Washington and Appendix 4-C: Long-Duration Storm Hyetographs for Eastern Washington provide additional detailed information about the short- and long-duration design storms: the precipitation data used to identify the four climate regions of eastern Washington and generate the storms; and the resulting 72-hour, two-peak hyetographs for each of the four climate regions.

The 72-hour long-duration hyetographs published in Appendix 4-C: Long-Duration Storm Hyetographs for Eastern Washington are not currently recommended for direct use. There is concern that the single-event hydrograph methods do not produce realistic results when using multipeak hyetographs. In the Soil Conservation Service (SCS) hydrograph method, the initial abstraction (loss) is computed from the first contribution of rainfall with no accounting for the dry period between the two hyetographs to allow for initial abstraction again. This produces greater peak flows and runoff volumes than would otherwise be computed using just the second hyetograph, even while the first hyetograph is not sufficient to generate direct runoff or substantially increase soil moisture present at the start of the second hyetograph.

4.A.2 Development of Short- and Long-Duration Design Storms for Eastern Washington

This section summarizes the work performed by MGS Engineering Consultants for the 2004 manual.

Overview of Storm Types

There are two storm types of interest for stormwater analyses in eastern Washington. Short-duration thunderstorms can occur in the late spring through early fall seasons and are characterized by high intensities for short periods of time over localized areas. These types of storms can produce high rates of runoff and flash flooding and are important where flood peak discharge and/or erosion are design considerations.

Long-duration general storms can occur at any time of the year, but are more common in the late fall through winter period, and in the late spring and early summer periods. General storms in eastern Washington are characterized by sequences of storm activity and intervening dry periods, often occurring over several days. Low- to moderate-intensity precipitation is typical during the periods of storm activity. These types of events can produce floods with large runoff volumes and moderate peak discharge. The runoff volume can be augmented by snowmelt when precipitation falls on snow during winter and early spring storms. These types of storm events are important where both runoff volume and peak discharge are design considerations.

Design storms are constructed using two components: a precipitation magnitude for a specified duration and a dimensionless storm pattern. The precipitation magnitude for the specified duration is determined based on the desired level of service (return period of the storm, years) and is used to scale the dimensionless storm pattern to produce the design storm. Specifically, the 2-hour precipitation amount for a selected return period is used for scaling the short-duration thunderstorm. The 24-hour precipitation amount for a selected return period is used for scaling the long-duration general storm.

This appendix provides information on the methods and data that were used for analysis and development of design storms for both short-duration thunderstorms and long-duration general storms. The dimensionless storm patterns for the short-duration thunderstorm and long-duration general storm were developed from analyses of historical storms and contain storm characteristics that are representative of the conditions frequently observed in significant storms.

Climate Regions

Eastern Washington has been divided into four climate regions to reflect differences in storm characteristics and the seasonality of storms. The four climate regions (see Figure 4.1: Average Annual Precipitation and Climate Regions) are described below.

Climate Region 1 – East Slopes of Cascade Mountains

This climate region consists of mountain areas on the east slopes of the Cascade Mountains. It is bounded to the west by the Cascade crest and bounded to the east by a generalized contour line of 16 inches of mean annual precipitation.

Climate Region 2 – Central Basin

This climate region consists of the Columbia Basin and adjacent low-elevation areas in central Washington. It is bounded to the west by the generalized contour line of 16 inches of mean annual precipitation that forms the east slopes of the Cascade Mountains, and bounded to the north by the contour line of 12 to 14 inches of mean annual precipitation and to the east by the contour line of 12 inches of mean annual precipitation. Many of the larger cities in eastern Washington are in this climate region including: Ellensburg, Kennewick, Moses Lake, Pasco, Richland, Wenatchee, and Yakima.

Climate Region 3 – Okanogan, Spokane, Palouse

This climate region consists of intermountain areas and includes areas near Okanogan, Spokane, and the Palouse. It is bounded to the west by the east slopes of the Cascade Mountains and the Central Basin, bounded to the northeast by the Kettle River Range and Selkirk Mountains, and bounded to the southeast by the Blue Mountains. It generally occupies an area with mean annual precipitation ranging from 14 to 22 inches.

Climate Region 4 – Northeastern Mountains and Blue Mountains

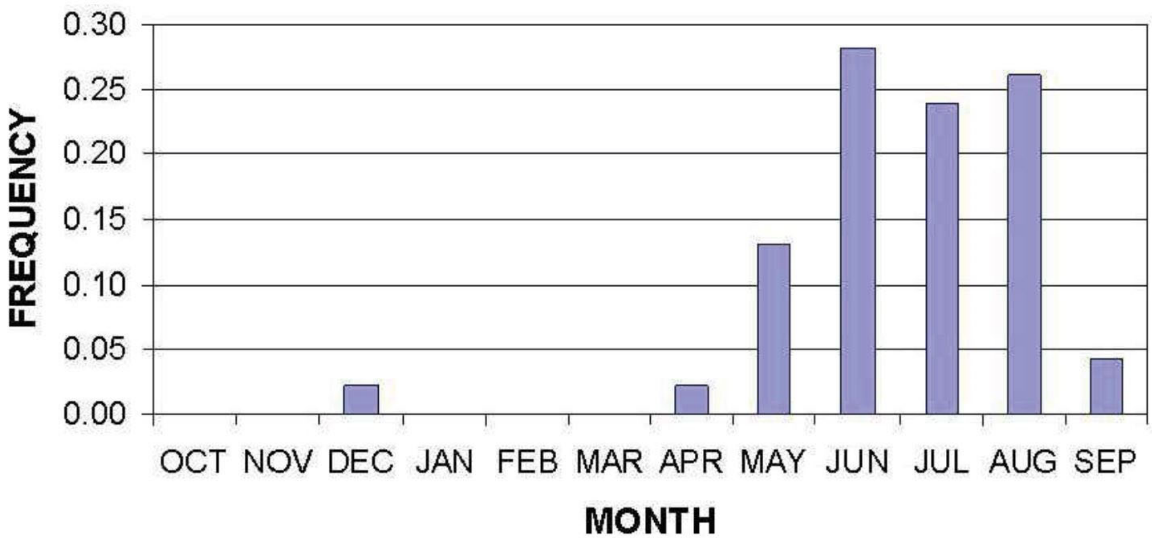
This climate region consists of mountain areas in the easternmost part of Washington State. It includes portions of the Kettle River Range and Selkirk Mountains in the northeast, and includes the Blue Mountains in the southeast corner of eastern Washington. Mean annual precipitation ranges from a minimum of 22 to over 60 inches. The western boundary of this climate region is a generalized contour line of 22 inches mean annual precipitation.

Seasonality of Storms

Information on the seasonality of storms is useful in providing information for selection of antecedent conditions to be used with the design storms for rainfall-runoff modeling at undeveloped sites.

Short-duration thunderstorms are warm season events that occur from late spring through early fall throughout eastern Washington (Figure 4.13: Seasonality of Short-Duration Thunderstorms in Eastern Washington). Antecedent conditions for rainfall-runoff modeling of thunderstorms should be selected consistent with the conditions expected at the time of year when thunderstorms have historically occurred.

Figure 4.13: Seasonality of Short-Duration Thunderstorms in Eastern Washington



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Seasonality of Short-Duration Thunderstorms in Eastern Washington

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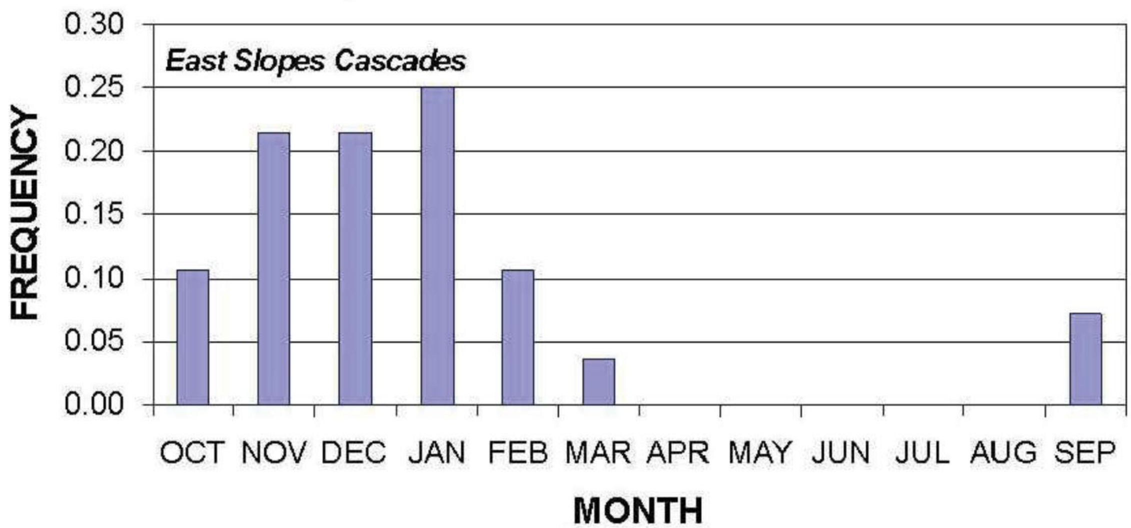
The seasonality of long-duration general storms varies across eastern Washington. General storms occur in late fall and winter on the east slopes of the Cascade Mountains (Figure 4.14: Seasonality of Long-Duration General Storms for the East Slopes of the Cascade Mountains) and are generally associated with concurrent storm activity in western Washington. In contrast, general storms in the more eastern climate regions may or may not be associated with concurrent storms in western Washington. Long-duration general storms occur in both the cool and warm seasons in the Central Basin, Okanogan, Spokane, and Palouse regions. The storm seasons are reasonably well defined with more frequent storm activity from fall through early spring, and from late spring through early summer (Figure 4.15: Seasonality of Long-Duration General Storms for the Central Basin, Okanogan, Spokane, and Palouse). The seasonality of long-duration general storms in the eastern mountain areas is similar to that for Climate Regions 2 and 3, except that the winter season is dominant (Figure 4.16: Seasonality of Long-Duration General Storms for the Northeastern Mountains and Blue Mountains) with a greater frequency of storm events in the winter season. These seasonalities of storm occurrences should be considered when selecting antecedent conditions for rainfall-runoff modeling.

Figure 4.14: Seasonality of Long-Duration General Storms for the East Slopes of the Cascade Mountains



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Seasonality of Long-Duration General Storms for the East Slopes of the Cascade Mountains

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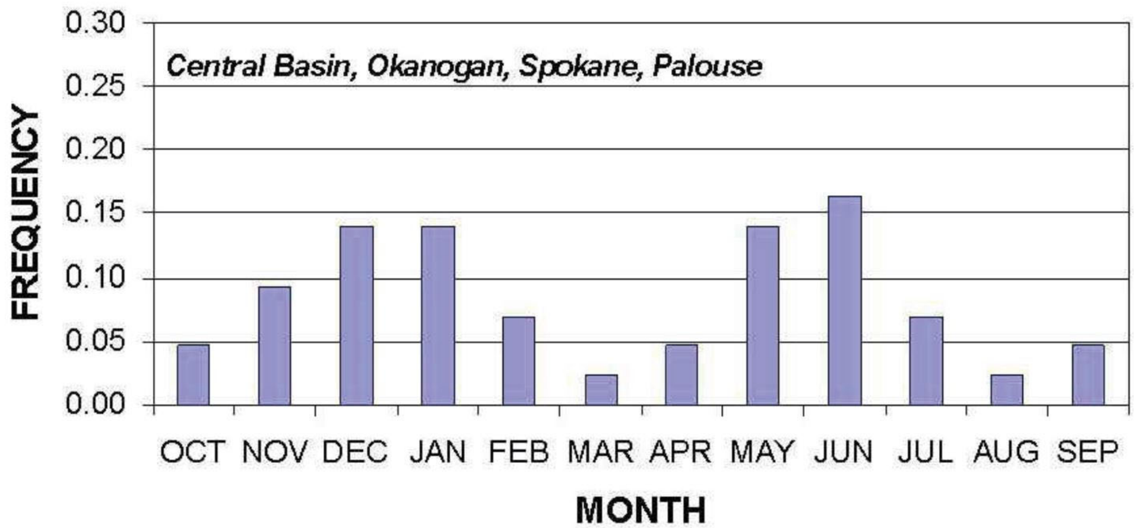
Figure 4.15: Seasonality of Long-Duration General Storms for the Central Basin, Okanogan, Spokane, and Palouse



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Seasonality of Long-Duration General Storms for the Central Basin, Okanogan, Spokane, and Palouse

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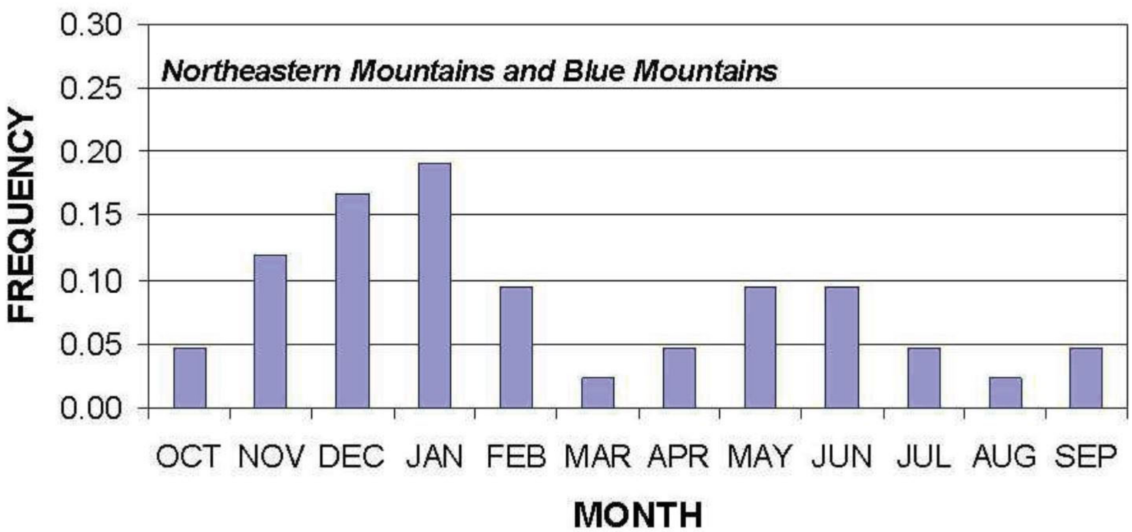
Figure 4.16: Seasonality of Long-Duration General Storms for the Northeastern Mountains and Blue Mountains



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Seasonality of Long-Duration General Storms for the Northeastern Mountains and Blue Mountains

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Dimensionless Design Storm Patterns

The temporal pattern of a design storm is important because it influences the magnitude of the flood peak discharge and runoff volume produced by the storm. Elements of the design storm that are important in rainfall-runoff modeling include total storm volume; storm duration; maximum intensity during the storm; duration of the high-intensity portion(s) of the storm; elapsed time to the high-intensity portion of the storm; and the magnitude, sequencing and temporal pattern of incremental precipitation amounts within the storm. Each of these storm characteristics was examined in the analysis of historical storms in eastern Washington. The storm characteristics were analyzed using a variety of procedures developed by the National Weather Service (Frederick et al., 1981), (National Weather Service, 1994), (Schaefer, 1989), and the U.S. Geological Survey (Parrett, 1998). A total of 37 short-duration thunderstorms and 59 long-duration general storms that occurred in the period from 1940 to 2000 were analyzed. Appendix 4-B: Historical Storms Used to Develop Design Storms in Eastern Washington contains a listing of storm dates, locations, and precipitation amounts for storms that were analyzed.

Dimensionless design storms for the short-duration thunderstorm and long-duration general storm were developed in a manner to contain storm characteristics that are representative of the conditions observed in historical storms. Specifically, mean values of storm characteristics and commonly occurring temporal patterns were used in assembling the design storm temporal patterns.

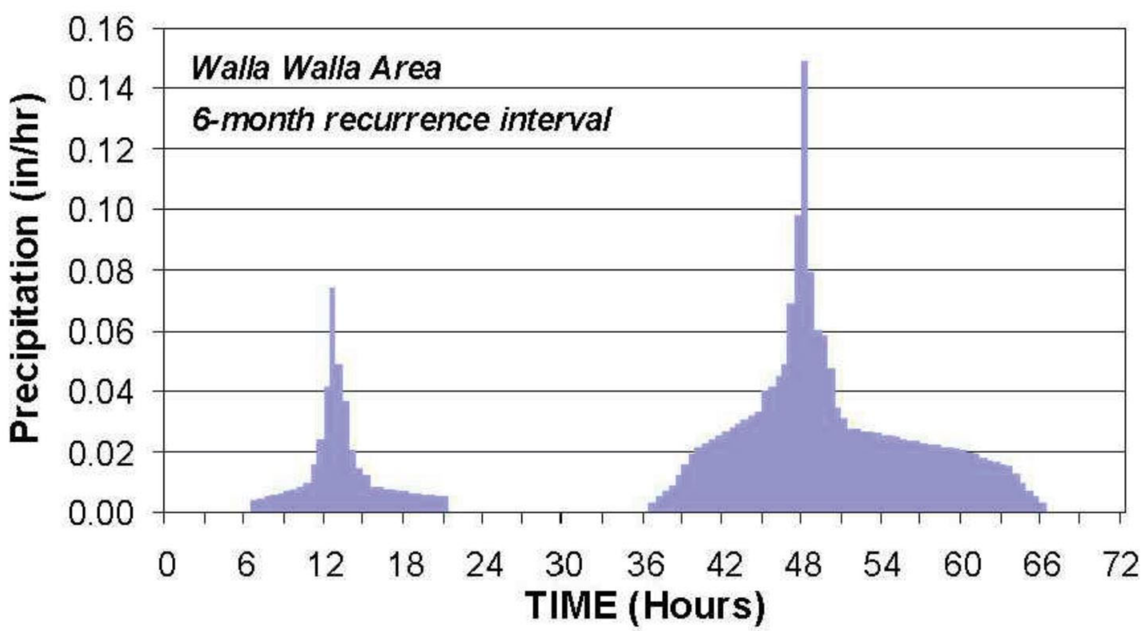
Long-Duration General Storms

Long-duration general storms in eastern Washington are associated with organized weather systems that produce low- to moderate-intensity precipitation over broad areas. General storms typically consist of sequences of storm activity and intervening dry periods, often occurring over several days. Each of these important characteristics is preserved in the long-duration dimensionless storm patterns.

While many of the characteristics of general storms are similar throughout eastern Washington, some storm characteristics vary by climate region. For example, in mountain areas, the duration of precipitation is longer and the length of intervening dry periods is shorter, relative to that in the Central Basin. Thus, separate long-duration design storm patterns were needed for each climate region.

An example of a scaled long-duration design storm is shown in Figure 4.17: Example Long-Duration Design Storm, which was obtained by scaling (multiplying) the incremental ordinates of the dimensionless design storm (see Table 4.28: 72-Hour Long-Duration Storm Hyetograph Values for Climate Region 2: Central Basin (continued)) by a 24-hour precipitation value of 0.82 inches. Differences in temporal patterns between the four climate regions can be seen in Figure 4.20: Long-Duration Design Storm for Climate Region 1 through Figure 4.23: Long-Duration Design Storm for Climate Region 4, which compare long-duration water quality design storms for the four climate regions.

Figure 4.17: Example Long-Duration Design Storm



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Example Long-Duration Design Storm

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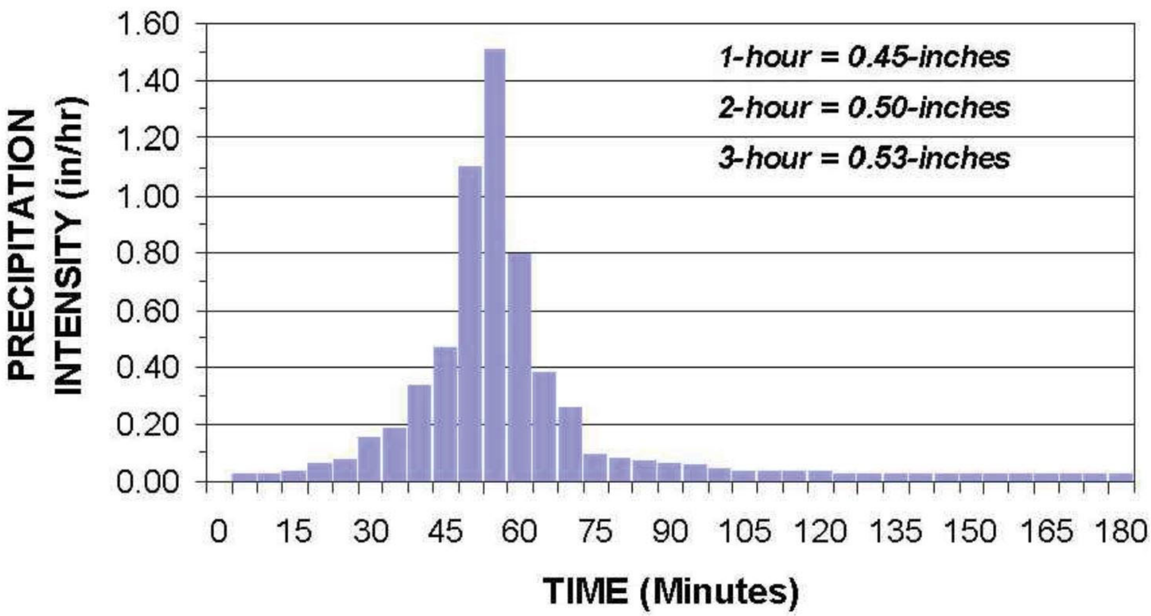
Short-Duration Thunderstorms

Short-duration thunderstorms are characterized by very high intensity rainfall occurring over isolated areas. The duration of the high-intensity portion of the storm may last from 5 to 30 minutes with a total duration typically ranging from less than an hour to several hours. These storms are convective events, commonly occurring in the late afternoon and early-evening hours in the summer where atmospheric instabilities are often driven by solar heating. They are frequently accompanied by lightning and thunder.

Analysis of historical storms indicates that short-duration thunderstorms have similar characteristics throughout eastern Washington. Therefore, one dimensionless design storm pattern is applicable to all four climate regions. An example of a scaled short-duration design storm is shown in Figure 4.18: Example Short-Duration Design Storm, which was obtained by scaling (multiplying) the incremental ordinates of the dimensionless design storm (see Table 4.7: Values of the Coefficient Csds for Using 2-Year, 2-Hour Precipitation to Compute 2-Hour Precipitation for Selected Periods of Return) by a 2-hour precipitation value of 0.50 inches.

Figure 4.18: Example Short-Duration Design Storm



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Example Short-Duration Design Storm

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4.A.3 Review of Design Storms and Identification of Best Rainfall-Runoff Modeling Approaches for Eastern Washington

This section summarizes the work performed by Harper Houf Righellis, Inc.

Overview

The best available modeling approaches for using short- and long-duration design storms to size runoff treatment and flow control Best Management Practices (BMPs) in eastern Washington were identified and recommended in a concurrent effort. A “big picture” approach was implemented and three storm types were reviewed:

- Short-duration storm (3-hour), intended to represent a summer thundershower.
- Soil Conservation Service (SCS) Type II storm (24-hour), the standard storm pattern established by the SCS for eastern Washington. This is not the only storm pattern that can occur. It is the storm pattern that was designated in an era when sizing conveyance system components (pipes, culverts, channels, and bridges) was a primary consideration and using that storm type produced the maximum peak flow rate.
- Long-duration storm (72-hour), intended to represent a winter or spring rainfall.

Review of the Short- and Long-Duration Design Storms

The design storms (short-duration and long-duration) developed by MGS Engineering Consultants appear appropriate in temporal pattern. The short-duration and SCS Type II storms hyetographs are common patterns used in arid regions. They are patterns characterized by intense rainfall over relatively short periods within their duration.

The rainfall distributions of the four regional long-duration storm hyetographs do not appear like the majority of the 57 gauged precipitation events used to create the four hyetographs. The gauged multiple peaks appear random. They vary in relative size from small to large, large to small, and sometimes similar. The spacing between peaks varies significantly. From a macro pattern perspective, the long-duration storm hyetographs appear appropriate, but implementation is a concern. Event-based runoff modeling is time dependent; thus hyetograph shape is an important parameter.

The design storms developed by MGS Engineering Consultants appear appropriate in intensities. The precipitation maps and adjustment equations are reasonable.

Identification of Best Rainfall-Runoff Modeling Approaches for Eastern Washington

There are a variety of computational methods available for computing runoff volumes and peak flow rates. Literature other than the work prepared by and cited by MGS Engineering Consultants appears nonexistent for arid region long-duration storms. As MGS Engineering Consultants concluded: “Accuracy of uncalibrated runoff estimation methods is generally poor for undeveloped sites in arid and semiarid environments. Without runoff data for verification, it is not possible to say which of the off-the-shelf runoff estimation methods would likely yield the more accurate results.”

Potential methods are Exponential Loss, Green-Ampt, Holtan, Initial Abstraction and Uniform Loss Rate, Soil Moisture Accounting, Hydrological Simulation Program–Fortran (HSPF), Soil Conservation Service (SCS) curve number equations, Rational Method, and Regression Equations. Many of these methods could be appropriate for long-duration runoff modeling if calibrated. MGS Engineering Consultants recommended: "The selection of runoff estimation methods should be made from commonly used methods that are readily available in computer programs for computation of runoff hydrographs."

The above list of commonly used methods is broader than what may be commonly used by designers who are not hydrologic specialists. The methods most commonly used by regulatory agencies, design professionals, and software vendors are the SCS curve number equations, Rational Method, and Regression Equations. Only commonly used methods should be considered until quality data can be collected and rainfall-runoff calibration efforts performed.

With commonly used methods, the expertise of regulatory agencies, design professionals, and software vendors offer the best opportunity to use reasonable input values and produce reasonable output. Thus even though not technically calibrated, results that meet the standard of care for the industry are more likely using common uncalibrated methods than uncommon uncalibrated methods.

Of the three commonly used methods listed above (SCS curve number equations, Rational Method, and Regression Equations), only the SCS curve number equations are recommended for computing flow rates and runoff volumes for long-duration storms. The Rational Method is a good method for computing peak flow rates of small urban basins but has no capability to determine reasonable hydrographs and runoff volumes. Regression Equations require quality-measured data to create meaningful regression equations, but necessary data are lacking; peak flow rate determination is the common use of regression equations as runoff volume regression equations appear nonexistent.

The SCS Method is commonly used for small and large basins, though method origins are from large rural basins. The engineering community has experience implementing this method.

<u>Discussion and Recommendation of Modified SCS Modeling Approach</u>

Short-Duration Storm (3-Hour) and SCS Type II Storm (24-Hour)

The short-duration 3-hour storm and the SCS Type II 24-hour storm hyetographs can be directly modeled by readily available hydrologic modeling software and produce intended results.

Long-Duration Storm (72-Hour)

The multipeak long-duration storm can also be directly modeled by readily available hydrologic modeling software, but does not necessarily produce intended results. NRCS staff has verbally stated that the SCS Method should not be applied to multipeak hyetographs. The caution may have been due merely to an unintended use or due to possible computational inaccuracies, but the latter appears to be the case.

With this limitation, another approach is necessary to model the long-duration storm hyetographs. Two key characteristics are apparent from the multipeak long-duration hyetographs.

- The first portion of the four regional hyetographs is small compared to the second portion. The first portion of the hyetograph is 16% to 25% of the total hyetograph, depending on the climate region. For most eastern Washington 72-hour precipitation amounts, the precipitation amount in the first portion hyetograph is diminutive.
- The period of no precipitation between the end of the first portion and beginning of the second portion of the hyetograph ranges from about 12 to 18 hours, depending on the climate region.

These two characteristics result in hydrographs that have no flow for the entire time between the two hyetographs and sometimes no flow during the first hyetograph. This means there is no compelling reason to directly model the first portion.

If only the second portion needs to be modeled, it may be possible to substitute another standard storm distribution: the SCS Type IA storm pattern of the coastal region of the state where winter rainfall originates. Figure 4.19: Standard and Regional Storm Distribution Curves on a Unit Basis shows only the second portion of the hyetographs for the four regional long-duration storms as cumulative precipitation and the SCS Type IA and Type II 24-hour storms in order to make a visual comparison.

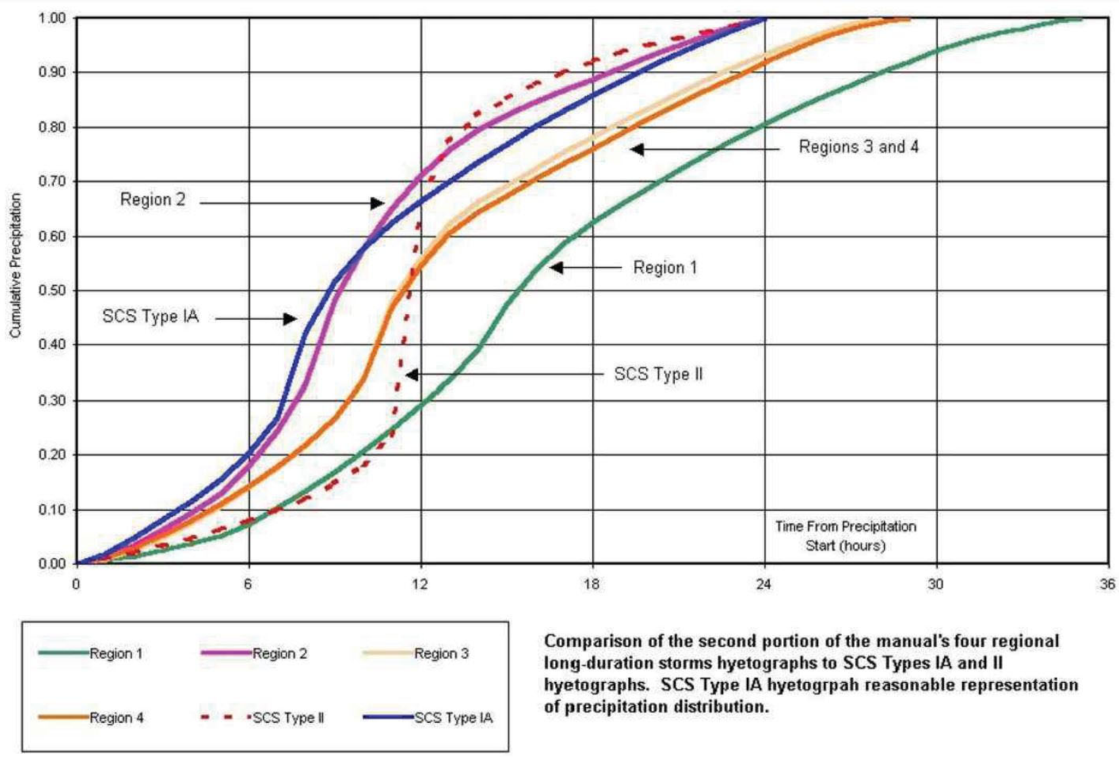
The Type IA storm is similar in shape to the second portion of all four regional long-duration storms. With this similarity, the Type IA may produce acceptable results without the added complexity. Its 24-hour duration allows for easy use of the built-in storm pattern feature of most SCS Method software. This reduces potential for computational errors due to incorrect implementation of unique duration hyetographs. Actual duration analysis provides computations that more directly reflect the second portion of the long-duration storm hyetographs, but those durations are not precise, they are statistical representations.

Table 4.21: Comparisons to the Type IA Storm provides key comparisons to the Type IA storm.

Table 4.21: Comparisons to the Type IA Storm

Second Portion of Long-Duration Hyetograph	Climate Region 1	Climate Region 2	Climate Region 3	Climate Region 4
Duration (hours)	35	24	28	29
Duration as Ratio of 24 Hours	1.46	1.00	1.16	1.21
Precipitation as Ratio of 24-Hour Precipitation	1.16	1.00	1.06	1.07

Figure 4.19: Standard and Regional Storm Distribution Curves on a Unit Basis



Comparison of the second portion of the manual's four regional long-duration storms hyetographs to SCS Types IA and II hyetographs. SCS Type IA hyetogrpah reasonable representation of precipitation distribution.

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Standard and Regional Storm Distribution Curves on a Unit Basis

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Climate Region 1 could be considered for 35-hour duration and 1.16 x 24-hour precipitation storm analysis. 16% more precipitation spread over 46% more time should produce less peak flow but more runoff volume than the Type IA storm. Many of the differences compared to the Type IA storm is in the waning hours of the hyetograph, thus would have less impact than might be expected. The second portions of the long-duration hyetographs for Climate Regions 2, 3, and 4 show no or only minor variation from SCS Type IA 24-hour storm; thus use of 24-hour storm is sufficiently accurate.

Short-Duration Storm (3-Hour) and SCS Type II Storm (24-Hour)

Modeling of the short-duration 3-hour storm and the SCS Type II 24-hour storm are to be per standard methods for those hyetographs.

Long-Duration Storm (72-Hour)

The recommended approach for modeling the long-duration storm is as follows.

- Rainfall Modeling:

  Emulate only the second portion of the long-duration storm hyetograph, but account for the first portion by adjusting antecedent moisture conditions.

- Rainfall Distribution:

  Use the SCS Type IA 24-hour storm. This provides the simplest modeling approach and reduces the chance for error by implementing a nonstandard hyetograph. If an agency or local jurisdiction prefers the long-duration distributions, the second portion of the long-duration storm hyetograph can be implemented instead.

- Rainfall Intensity:

  Use 24-hour intensity if using the SCS Type IA storm. If using the second portion of the long-duration storm hyetograph, use the precipitation ratio in Table 4.21: Comparisons to the Type IA Storm.

- Curve Numbers:

  Adjust curve numbers to account for saturation conditions due to first portion of hyetograph that is not directly modeled. Engineering analysis and judgment is needed for curve number adjustment depending on soil characteristics, surface conditions, and first-portion precipitation amount.

Sensitivity Analysis

The primary concern regarding the SCS Method that arose in this study effort was the implementation of the multipeak hyetographs. To test the concern, the Hydrologic Engineering Center, Hydrologic Modeling System (HEC-HMS) was used to compute hydrographs. Three 25-year event hyetographs were modeled for an 8-acre basin with four basin coverage conditions.

For the 72-hour storm, as the initial loss rate decreased, runoff was generated earlier in the second hyetograph than in the SCS Type IA and second-portion only storm hyetographs. This means there was less initial abstraction (loss) computed in the more critical portion of the 72-hour hyetograph than the other storms. This is counterintuitive as the bulk of the 0.55 inches first-portion hyetograph rainfall occurs 24 hours prior to the start of the second hyetograph, thus there should be opportunity for the entire initial loss to occur again at the start of the second hyetograph.

This initial loss computational difference and the impact it may have on second-portion hydrograph flow rates supports the NRCS contention regarding the modeling of multipeak hyetographs. The peak flow rates computed in the multipeak long-duration 72-hour storm did not match well with the peak flow rates computed from the other two hyetographs.

Further Recommendations

A future effort of rainfall-runoff data collection and modeling correlation should be undertaken. This will improve the best available science beyond what exists today. Precipitation gauges that can measure in small time increments should be placed within drainage basins where runoff flows can be measured in similar small time increments. To be effective, this data collection effort should include broad ranges of drainage basins based on total annual precipitation, elevation, grades, soils types, development types, and degree of development.

Upon storm type segregation, further data analysis should include determination of effective modeling parameters such as lag times and SCS curve numbers and comparing them to values commonly used.

Appendix 4-B: Historical Storms Used to Develop Design Storms in Eastern Washington

4.B.1 Long-Duration General Storms

Table 4.22: Long-Duration Storms for Climate Region 1 – Cascade Mountains

Precipitation Station	Storm Date	Precipitation 24-Hour (in)	Precipitation 72-Hour (in)
Carson Fish Hatch	9-Dec-1987	6.20	7.90
Diablo Dam	24-Oct-1945	6.42	9.23
Diablo Dam	9-Feb-1951	6.47	12.99
Diablo Dam	16-Feb-1949	8.12	9.64
Easton	8-Feb-1996	4.10	8.90
Easton	22-Nov-1990	6.40	10.20
Glenwood	28-Dec-1998	3.70	4.70
Glenwood	27-Oct-1994	3.80	4.10
Hood River Exp Station	6-Jan-1948	3.33	4.53
Lake Wenatchee	9-Jan-1990	5.30	7.60
Lucerne 2NNW	19-Nov-1962	3.05	3.45
Lucerne 2NNW	1-Dec-1975	3.17	5.99
Mazama	12-Jan-1980	3.20	3.62
Mazama	27-Feb-1972	3.80	5.97
Mount Adams RS	13-Jan-1973	6.00	11.39
Satus Pass	24-Nov-1960	3.12	4.46
Satus Pass	13-Dec-1977	3.30	5.02
Satus Pass	15-Jan-1974	3.60	6.05
Stehekin 4NW	23-Jan-1982	5.00	6.80
Stevens Pass	3-Dec-1982	6.50	7.40
Underwood	11-Dec-1946	4.04	7.27
Source: Ecology Water Resources Program, Dam Safety Office.			

Table 4.23: Long-Duration Storms for Climate Region 2 – Central Basin

Precipitation Station	Storm Date	Precipitation 24-Hour (in)	Precipitation 72-Hour (in)
Centerville	19-Jan-1953	2.36	2.76
Chief Joe Dam	18-Sep-1986	1.50	1.70
Coulee Dam 1SW	28-May-1948	1.66	1.74
Ellensburg	4-Dec-1974	1.30	2.00
Harrington 1NW	23-Dec-1966	1.12	1.28
Harrington 4ENE	25-Sep-1948	1.51	1.65
Harrington 4ENE	21-Sep-1945	1.52	2.10
Lind 3NE	25-Jun-1942	1.53	1.77
McNary Dam	2-Oct-1957	3.15	3.17
Naches 10NW	14-Jan-1956	1.43	1.60
Wenatchee	10-Dec-1987	1.77	1.82
Yakima	24-Dec-1964	1.40	2.83
Yakima	19-Nov-1996	1.40	1.57
Source: Ecology Water Resources Program, Dam Safety Office.			

Table 4.24: Long-Duration Storms for Climate Region 3 – Okanogan/Spokane/Palouse

Precipitation Station	Storm Date	Precipitation 24-Hour (in)	Precipitation 72-Hour (in)
Colville Airport	16-Nov-1973	1.55	1.98
Dayton 9SE	2-Jan-1966	2.53	3.69
Dayton 9SE	22-Dec-1964	3.01	4.70
Dixie 4SE	23-Nov-1964	2.70	2.92
Moscow 5NE ID	9-Feb-1996	1.50	3.20
Moscow 5NE ID	11-Nov-1973	1.70	2.90

Table 4.24: Long-Duration Storms for Climate Region 3 – Okanogan/Spokane/Palouse (continued)

Precipitation Station	Storm Date	Precipitation 24-Hour (in)	Precipitation 72-Hour (in)
Moscow 5NE ID	23-Dec-1972	1.80	2.70
Ola ID	27-Dec-1996	3.10	5.00
Oroville	16-Nov-1950	1.96	2.04
Pullman 2NW	22-Nov-1961	1.96	2.52
Pullman 2NW	15-Sep-1947	2.10	2.60
Republic	27-May-1998	2.50	2.80
Spokane WSO AP	25-Nov-1960	1.41	1.86
Spokane WSO AP	13-Apr-2000	1.53	1.73
Spokane WSO AP	18-Dec-1951	1.58	1.67
Walla Walla WSO	14-Oct-1980	3.08	3.63
Whitman Mission	19-Nov-1996	2.00	2.40
Source: Ecology Water Resources Program, Dam Safety Office.			

Table 4.25: Long-Duration Storms for Climate Region 4 – Northeastern Mountains and Blue Mountains

Precipitation Station	Storm Date	Precipitation 24-Hour (in)	Precipitation 72-Hour (in)
Bonners Ferry 1SW	18-Nov-1946	2.78	4.09
Boundary Switchyard	4-Jan-1989	2.30	2.50
Boundary Switchyard	15-Feb-1986	3.10	3.19
Coeur d’Alene RS	15-Jan-1974	1.90	3.70
Colville Airport	16-Nov-1973	1.55	1.98
Dayton 9SE	2-Jan-1966	2.53	3.69
Dayton 9SE	22-Dec-1964	3.01	4.70
Dworshak Fish Hatch ID	2-Dec-1977	2.30	2.40

Table 4.25: Long-Duration Storms for Climate Region 4 – Northeastern Mountains and Blue Mountains (continued)

Precipitation Station	Storm Date	Precipitation 24-Hour (in)	Precipitation 72-Hour (in)
Moscow 5NE ID	9-Feb-1996	1.50	3.20
Moscow 5NE ID	11-Nov-1973	1.70	2.90
Moscow 5NE ID	23-Dec-1972	1.80	2.70
Northport	27-May-1998	2.40	2.80
Ola ID	27-Dec-1996	3.10	5.00
Plummer 3WSW ID	25-Dec-1980	2.10	2.80
Pullman 2NW	22-Nov-1961	1.96	2.52
Pullman 2NW	15-Sep-1947	2.10	2.60
Source: Ecology Water Resources Program, Dam Safety Office.			

4.B.2 Short-Duration General Storms

Table 4.26: Short-Duration Storms for All Climate Regions

Precipitation Station	Climate Region	Storm Date	Precip. 1-Hour (in)	Precip. 2-Hour (in)
Diablo Dam	1	20-Jul-1992	0.80	1.10
Easton	1	26-Aug-1983	1.80	1.80
Lake Wenatchee	1	11-Feb-1985	0.90	1.10
Mazama	1	16-Jul-1985	1.00	1.10
Stevens Pass	1	2-Jun-1998	1.00	1.00
Chief Joe Dam	2	23-Jul-1992	0.70	1.00
Chief Joe Dam	2	9-Jul-1993	1.10	1.10
Ellensburg	2	12-May-1943	0.31	0.62
Lind 3NE	2	22-Jul-1993	1.30	1.40
Methow	2	17-Jun-1950	0.89	0.89
Methow	2	8-Jul-1958	1.33	1.33

Table 4.26: Short-Duration Storms for All Climate Regions (continued)

Precipitation Station	Climate Region	Storm Date	Precip. 1-Hour (in)	Precip. 2-Hour (in)
Naches 10NW	2	5-May-1957	0.70	0.90
Naches 10NW	2	1-Aug-1984	0.80	0.80
Naches 10NW	2	7-Jul-1982	1.20	1.20
Sunnyside	2	7-Jun-1947	1.62	1.62
Wenatchee Exp Station	2	10-Aug-1952	1.29	1.29
Wilson Creek	2	24-Jul-1950	0.80	0.80
Wilson Creek	2	18-Jun-1950	1.50	1.50
Withrow 4WNW	2	14-Aug-1968	0.64	0.94
Yakima	2	18-Aug-1975	0.70	0.98
Chewelah	3	20-Jul-1983	0.90	1.00
Dayton 1WSW	3	8-Jul-1946	0.78	0.79
Dayton 1WSW	3	7-Jul-1978	1.20	1.20
Oroville	3	16-Jun-1947	1.19	1.25
Pomeroy	3	13-Sep-1966	1.12	1.12
Republic RS	3	10-Aug-1983	0.90	1.50
Republic RS	3	5-Jul-1958	1.10	1.10
Republic RS	3	9-Aug-1962	1.17	1.26
Walla Walla WSO	3	26-May-1971	1.64	1.75
Whitman Mission	3	5-Aug-1977	0.94	0.94
Boundary Switchyard	4	21-May-1981	0.90	1.10
Boundary Switchyard	4	23-May-1989	1.00	1.00
Colville	4	19-Jul-1950	0.92	1.00
Colville	4	6-Jul-1956	0.81	0.82
Colville	4	3-Jun-1999	1.00	1.90
Dixie 4SE	4	7-Aug-1992	0.70	0.90

Table 4.26: Short-Duration Storms for All Climate Regions (continued)

Precipitation Station	Climate Region	Storm Date	Precip. 1-Hour (in)	Precip. 2-Hour (in)
Northport	4	11-Jul-1998	1.10	1.10
Source: Ecology Water Resources Program, Dam Safety Office.				

Appendix 4-C: Long-Duration Storm Hyetographs for Eastern Washington

4.C.1 Introduction

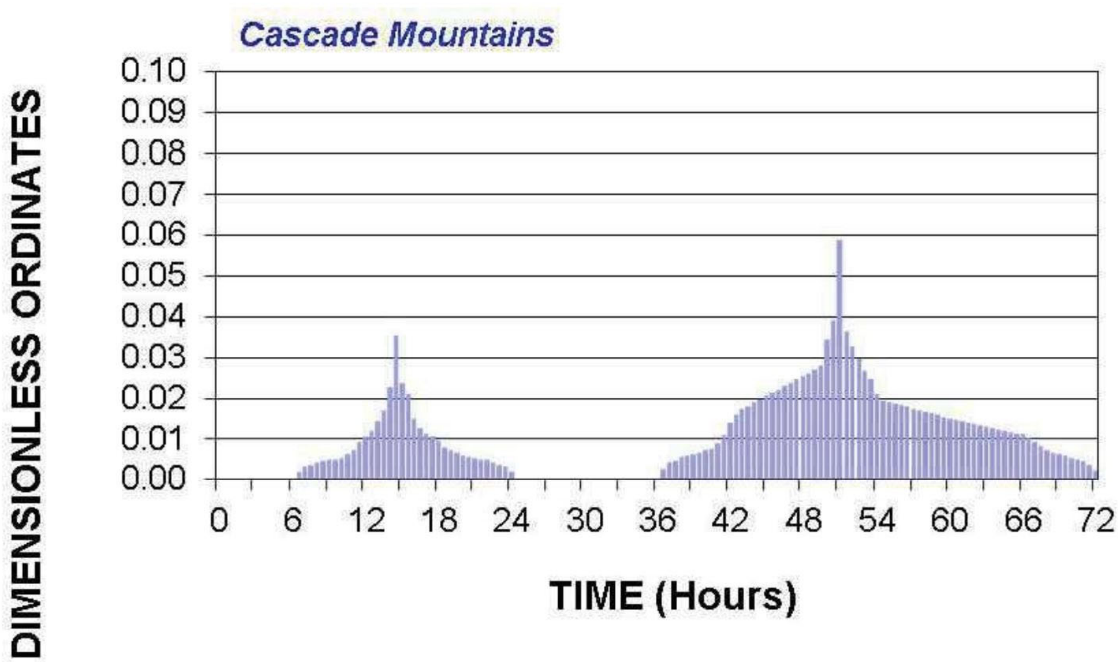
Graphical and tabular representations of the long-duration design storms developed by MGS Engineering Consultants are provided in Figure 4.20: Long-Duration Design Storm for Climate Region 1 through Figure 4.23: Long-Duration Design Storm for Climate Region 4 and Table 4.27: 72-Hour Long-Duration Storm Hyetograph Values for Climate Region 1: Cascade Mountains (continued) through Table 4.30: 72-Hour Long-Duration Storm Hyetograph Values for Climate Region 4: Eastern Mountains (continued).

Note: The 72-hour hyetographs are not unit hyetographs, but have maximum values equal to the ratio of the total 72-hour precipitation to the 24-hour precipitation.

For more information: See Appendix 4-A: Background Information on Design Storms and Selected Modeling Methods for additional information and limitations in applying these hyetographs.

4.C.2 Long-Duration Design Storm Figures

Figure 4.20: Long-Duration Design Storm for Climate Region 1



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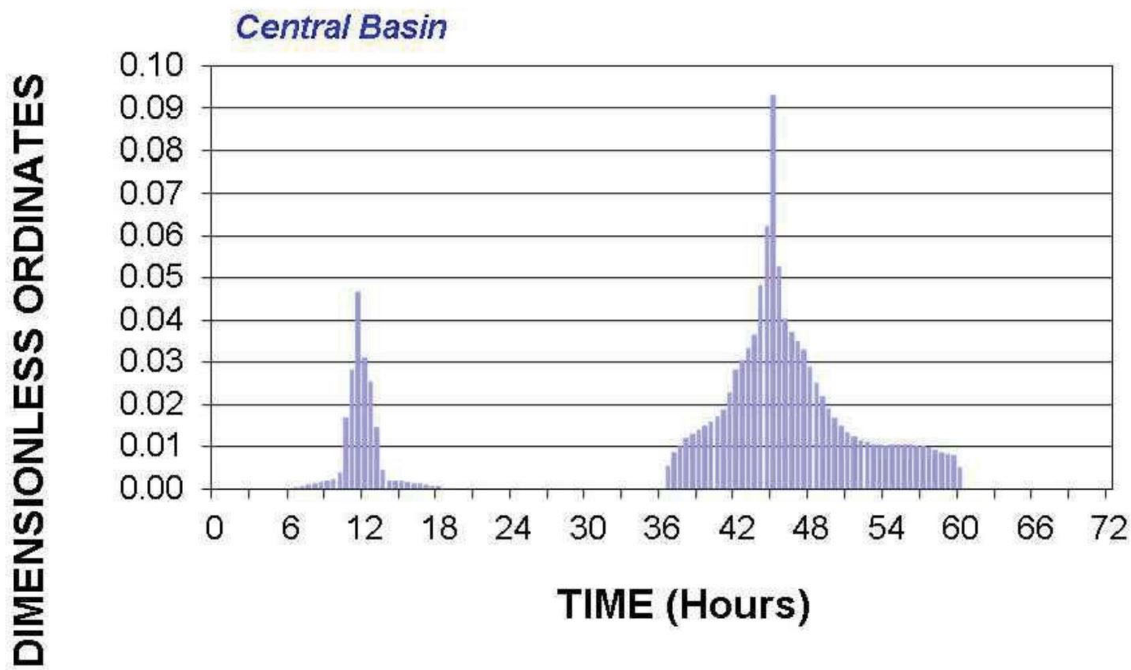
Long-Duration Design Storm for Climate Region 1

Revised September 2004

Figure 4.21: Long-Duration Design Storm for Climate Region 2



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Long-Duration Design Storm
for Climate Region 2

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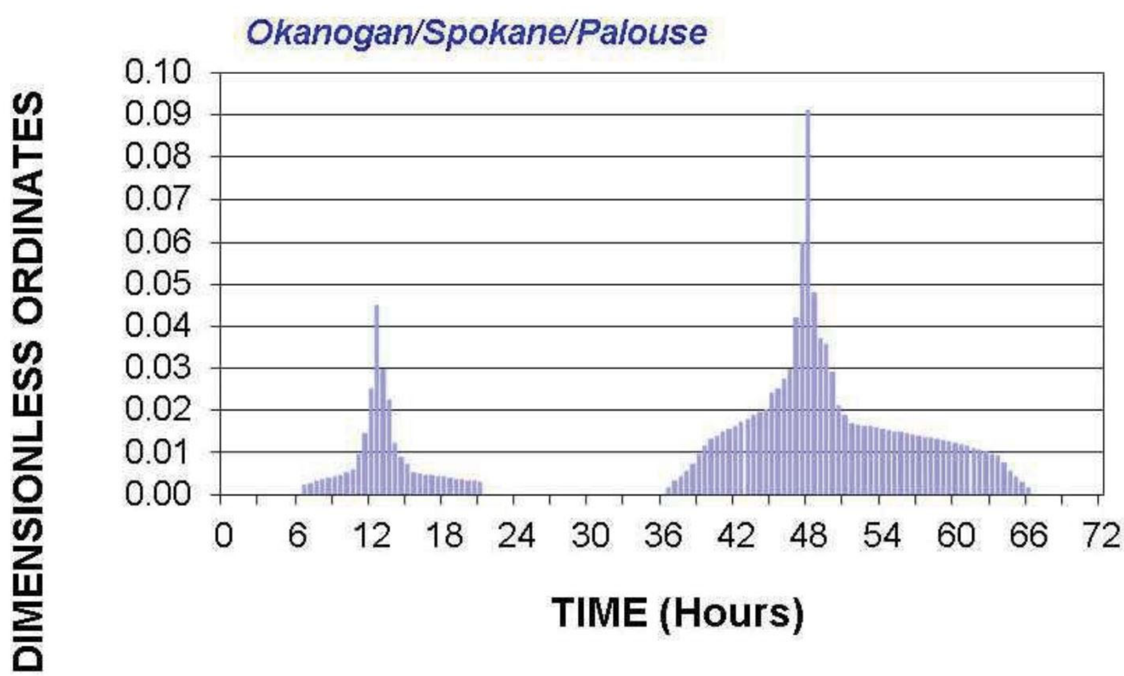
Figure 4.22: Long-Duration Design Storm for Climate Region 3



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Long-Duration Design Storm
for Climate Region 3

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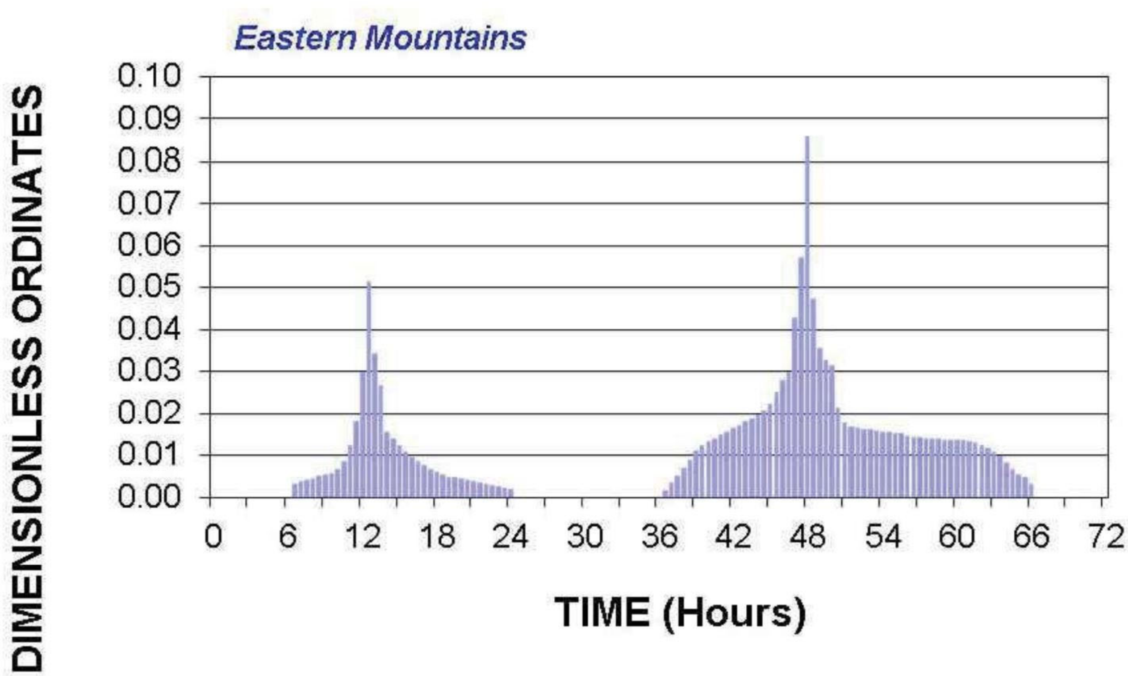
Figure 4.23: Long-Duration Design Storm for Climate Region 4



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Long-Duration Design Storm for Climate Region 4

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4.C.3 Climate Region 1: Cascade Mountains

Use 24-hour precipitation value to scale this storm hyetograph.

Table 4.27: 72-Hour Long-Duration Storm Hyetograph Values for Climate Region 1: Cascade Mountains

Time (hours)	Incremental Rainfall	Cumulative Rainfall		Time (hours)	Incremental Rainfall	Cumulative Rainfall
0.0	0.00000	0.00000		36.5	0.00277	0.33667
0.5	0.00000	0.00000		37.0	0.00423	0.34090
1.0	0.00000	0.00000		37.5	0.00467	0.34557
1.5	0.00000	0.00000		38.0	0.00550	0.35107
2.0	0.00000	0.00000		38.5	0.00590	0.35697
2.5	0.00000	0.00000		39.0	0.00630	0.36327
3.0	0.00000	0.00000		39.5	0.00670	0.36997
3.5	0.00000	0.00000		40.0	0.00723	0.37720
4.0	0.00000	0.00000		40.5	0.00760	0.38480
4.5	0.00000	0.00000		41.0	0.00907	0.39387
5.0	0.00000	0.00000		41.5	0.01116	0.40503
5.5	0.00000	0.00000		42.0	0.01387	0.41890
6.0	0.00000	0.00000		42.5	0.01600	0.43490
6.5	0.00179	0.00179		43.0	0.01740	0.45230
7.0	0.00321	0.00500		43.5	0.01820	0.47050
7.5	0.00370	0.00870		44.0	0.01900	0.48950
8.0	0.00420	0.01290		44.5	0.01980	0.50930
8.5	0.00470	0.01760		45.0	0.02060	0.52990
9.0	0.00490	0.02250		45.5	0.02140	0.55130
9.5	0.00510	0.02760		46.0	0.02220	0.57350
10.0	0.00530	0.03290		46.5	0.02300	0.59650
10.5	0.00634	0.03924		47.0	0.02380	0.62030
11.0	0.00740	0.04664		47.5	0.02460	0.64490
11.5	0.00920	0.05584		48.0	0.02550	0.67040
12.0	0.01080	0.06664		48.5	0.02620	0.69660

Table 4.27: 72-Hour Long-Duration Storm Hyetograph Values for Climate Region 1: Cascade Mountains (continued)

Time (hours)	Incremental Rainfall	Cumulative Rainfall	Time (hours)	Incremental Rainfall	Cumulative Rainfall
12.5	0.01214	0.07878	49.0	0.02720	0.72380
13.0	0.01424	0.09302	49.5	0.02820	0.75200
13.5	0.01712	0.11014	50.0	0.03445	0.78645
14.0	0.02288	0.13302	50.5	0.03920	0.82565
14.5	0.03540	0.16842	51.0	0.05880	0.88445
15.0	0.02360	0.19202	51.5	0.03652	0.92097
15.5	0.02101	0.21303	52.0	0.03280	0.95377
16.0	0.01499	0.22802	52.5	0.02980	0.98357
16.5	0.01279	0.24081	53.0	0.02680	1.01037
17.0	0.01144	0.25225	53.5	0.02484	1.03521
17.5	0.01070	0.26295	54.0	0.02116	1.05637
18.0	0.00960	0.27255	54.5	0.01943	1.07580
18.5	0.00814	0.28069	55.0	0.01910	1.09490
19.0	0.00730	0.28799	55.5	0.01870	1.11360
19.5	0.00657	0.29456	56.0	0.01830	1.13190
20.0	0.00598	0.30054	56.5	0.01790	1.14980
20.5	0.00551	0.30605	57.0	0.01750	1.16730
21.0	0.00516	0.31121	57.5	0.01710	1.18440
21.5	0.00494	0.31615	58.0	0.01670	1.20110
22.0	0.00485	0.32100	58.5	0.01630	1.21740
22.5	0.00420	0.32520	59.0	0.01590	1.23330
23.0	0.00370	0.32890	59.5	0.01550	1.24880
23.5	0.00320	0.33210	60.0	0.01510	1.26390
24.0	0.00180	0.33390	60.5	0.01470	1.27860
24.5	0.00000	0.33390	61.0	0.01430	1.29290
25.0	0.00000	0.33390	61.5	0.01390	1.30680
25.5	0.00000	0.33390	62.0	0.01360	1.32040

Table 4.27: 72-Hour Long-Duration Storm Hyetograph Values for Climate Region 1: Cascade Mountains (continued)

Time (hours)	Incremental Rainfall	Cumulative Rainfall		Time (hours)	Incremental Rainfall	Cumulative Rainfall
26.0	0.00000	0.33390		62.5	0.01330	1.33370
26.5	0.00000	0.33390		63.0	0.01300	1.34670
27.0	0.00000	0.33390		63.5	0.01270	1.35940
27.5	0.00000	0.33390		64.0	0.01240	1.37180
28.0	0.00000	0.33390		64.5	0.01210	1.38390
28.5	0.00000	0.33390		65.0	0.01180	1.39570
29.0	0.00000	0.33390		65.5	0.01150	1.40720
29.5	0.00000	0.33390		66.0	0.01120	1.41840
30.0	0.00000	0.33390		66.5	0.01020	1.42860
30.5	0.00000	0.33390		67.0	0.00920	1.43780
31.0	0.00000	0.33390		67.5	0.00820	1.44600
31.5	0.00000	0.33390		68.0	0.00734	1.45334
32.0	0.00000	0.33390		68.5	0.00675	1.46009
32.5	0.00000	0.33390		69.0	0.00630	1.46639
33.0	0.00000	0.33390		69.5	0.00585	1.47224
33.5	0.00000	0.33390		70.0	0.00540	1.47764
34.0	0.00000	0.33390		70.5	0.00495	1.48259
34.5	0.00000	0.33390		71.0	0.00450	1.48709
35.0	0.00000	0.33390		71.5	0.00350	1.49059
35.5	0.00000	0.33390		72.0	0.00225	1.49284
36.0	0.00000	0.33390				

4.C.4 Climate Region 2: Central Basin

Use 24-hour precipitation value to scale this storm hyetograph.

Table 4.28: 72-Hour Long-Duration Storm Hyetograph Values for Climate Region 2: Central Basin

Time (hours)	Incremental Rainfall	Cumulative Rainfall		Time (hours)	Incremental Rainfall	Cumulative Rainfall
0.0	0.00000	0.00000		36.5	0.00544	0.19701
0.5	0.00000	0.00000		37.0	0.00856	0.20557
1.0	0.00000	0.00000		37.5	0.01000	0.21557
1.5	0.00000	0.00000		38.0	0.01200	0.22757
2.0	0.00000	0.00000		38.5	0.01300	0.24057
2.5	0.00000	0.00000		39.0	0.01400	0.25457
3.0	0.00000	0.00000		39.5	0.01500	0.26957
3.5	0.00000	0.00000		40.0	0.01600	0.28557
4.0	0.00000	0.00000		40.5	0.01700	0.30257
4.5	0.00000	0.00000		41.0	0.01869	0.32126
5.0	0.00000	0.00000		41.5	0.02281	0.34407
5.5	0.00000	0.00000		42.0	0.02832	0.37239
6.0	0.00000	0.00000		42.5	0.03050	0.40289
6.5	0.00030	0.00030		43.0	0.03350	0.43639
7.0	0.00060	0.00090		43.5	0.03650	0.47289
7.5	0.00090	0.00180		44.0	0.04842	0.52131
8.0	0.00120	0.00300		44.5	0.06220	0.58351
8.5	0.00150	0.00450		45.0	0.09330	0.67681
9.0	0.00180	0.00630		45.5	0.05275	0.72956
9.5	0.00210	0.00840		46.0	0.04025	0.76981
10.0	0.00394	0.01234		46.5	0.03717	0.80698
10.5	0.01669	0.02903		47.0	0.03483	0.84181
11.0	0.02831	0.05734		47.5	0.03307	0.87488
11.5	0.04680	0.10414		48.0	0.02893	0.90381
12.0	0.03120	0.13534		48.5	0.02519	0.92900
12.5	0.02549	0.16083		49.0	0.02189	0.95089
13.0	0.01451	0.17534		49.5	0.01906	0.96995

Table 4.28: 72-Hour Long-Duration Storm Hyetograph Values for Climate Region 2: Central Basin (continued)

Time (hours)	Incremental Rainfall	Cumulative Rainfall		Time (hours)	Incremental Rainfall	Cumulative Rainfall
13.5	0.00445	0.17979		50.0	0.01670	0.98665
14.0	0.00202	0.18181		50.5	0.01480	1.00145
14.5	0.00192	0.18373		51.0	0.01336	1.01481
15.0	0.00172	0.18545		51.5	0.01234	1.02715
15.5	0.00152	0.18697		52.0	0.01156	1.03871
16.0	0.00132	0.18829		52.5	0.01096	1.04967
16.5	0.00112	0.18941		53.0	0.01054	1.06021
17.0	0.00092	0.19033		53.5	0.01032	1.07053
17.5	0.00072	0.19105		54.0	0.01028	1.08081
18.0	0.00052	0.19157		54.5	0.01038	1.09119
18.5	0.00000	0.19157		55.0	0.01046	1.10165
19.0	0.00000	0.19157		55.5	0.01046	1.11211
19.5	0.00000	0.19157		56.0	0.01040	1.12251
20.0	0.00000	0.19157		56.5	0.01025	1.13276
20.5	0.00000	0.19157		57.0	0.01004	1.14280
21.0	0.00000	0.19157		57.5	0.00974	1.15254
21.5	0.00000	0.19157		58.0	0.00926	1.16180
22.0	0.00000	0.19157		58.5	0.00868	1.17048
22.5	0.00000	0.19157		59.0	0.00832	1.17880
23.0	0.00000	0.19157		59.5	0.00781	1.18661
23.5	0.00000	0.19157		60.0	0.00500	1.19161
24.0	0.00000	0.19157		60.5	0.00000	1.19161
24.5	0.00000	0.19157		61.0	0.00000	1.19161
25.0	0.00000	0.19157		61.5	0.00000	1.19161
25.5	0.00000	0.19157		62.0	0.00000	1.19161
26.0	0.00000	0.19157		62.5	0.00000	1.19161
26.5	0.00000	0.19157		63.0	0.00000	1.19161

Table 4.28: 72-Hour Long-Duration Storm Hyetograph Values for Climate Region 2: Central Basin (continued)

Time (hours)	Incremental Rainfall	Cumulative Rainfall		Time (hours)	Incremental Rainfall	Cumulative Rainfall
27.0	0.00000	0.19157		63.5	0.00000	1.19161
27.5	0.00000	0.19157		64.0	0.00000	1.19161
28.0	0.00000	0.19157		64.5	0.00000	1.19161
28.5	0.00000	0.19157		65.0	0.00000	1.19161
29.0	0.00000	0.19157		65.5	0.00000	1.19161
29.5	0.00000	0.19157		66.0	0.00000	1.19161
30.0	0.00000	0.19157		66.5	0.00000	1.19161
30.5	0.00000	0.19157		67.0	0.00000	1.19161
31.0	0.00000	0.19157		67.5	0.00000	1.19161
31.5	0.00000	0.19157		68.0	0.00000	1.19161
32.0	0.00000	0.19157		68.5	0.00000	1.19161
32.5	0.00000	0.19157		69.0	0.00000	1.19161
33.0	0.00000	0.19157		69.5	0.00000	1.19161
33.5	0.00000	0.19157		70.0	0.00000	1.19161
34.0	0.00000	0.19157		70.5	0.00000	1.19161
34.5	0.00000	0.19157		71.0	0.00000	1.19161
35.0	0.00000	0.19157		71.5	0.00000	1.19161
35.5	0.00000	0.19157		72.0	0.00000	1.19161
36.0	0.00000	0.19157				

4.C.5 Climate Region 3: Okanogan, Spokane, Palouse

Use 24-hour precipitation value to scale this storm hyetograph.

Table 4.29: 72-Hour Long-Duration Storm Hyetograph Values for Climate Region 3: Okanogan, Spokane, Palouse

Time (hours)	Incremental Rainfall	Cumulative Rainfall		Time (hours)	Incremental Rainfall	Cumulative Rainfall
0.0	0.00000	0.00000		36.5	0.00180	0.26343
0.5	0.00000	0.00000		37.0	0.00320	0.26663

Table 4.29: 72-Hour Long-Duration Storm Hyetograph Values for Climate Region 3: Okanogan, Spokane, Palouse (continued)

Time (hours)	Incremental Rainfall	Cumulative Rainfall		Time (hours)	Incremental Rainfall	Cumulative Rainfall
1.0	0.00000	0.00000		37.5	0.00437	0.27100
1.5	0.00000	0.00000		38.0	0.00563	0.27663
2.0	0.00000	0.00000		38.5	0.00722	0.28385
2.5	0.00000	0.00000		39.0	0.00978	0.29363
3.0	0.00000	0.00000		39.5	0.01150	0.30513
3.5	0.00000	0.00000		40.0	0.01340	0.31853
4.0	0.00000	0.00000		40.5	0.01400	0.33253
4.5	0.00000	0.00000		41.0	0.01480	0.34733
5.0	0.00000	0.00000		41.5	0.01560	0.36293
5.5	0.00000	0.00000		42.0	0.01640	0.37933
6.0	0.00000	0.00000		42.5	0.01720	0.39653
6.5	0.00240	0.00240		43.0	0.01800	0.41453
7.0	0.00280	0.00520		43.5	0.01880	0.43333
7.5	0.00320	0.00840		44.0	0.01960	0.45293
8.0	0.00360	0.01200		44.5	0.02040	0.47333
8.5	0.00403	0.01603		45.0	0.02430	0.49763
9.0	0.00440	0.02043		45.5	0.02534	0.52297
9.5	0.00480	0.02523		46.0	0.02766	0.55063
10.0	0.00520	0.03043		46.5	0.03000	0.58063
10.5	0.00600	0.03643		47.0	0.04200	0.62263
11.0	0.00968	0.04611		47.5	0.06000	0.68263
11.5	0.01476	0.06087		48.0	0.09100	0.77363
12.0	0.02524	0.08611		48.5	0.04801	0.82164
12.5	0.04500	0.13111		49.0	0.03700	0.85864
13.0	0.03000	0.16111		49.5	0.03568	0.89432
13.5	0.02267	0.18378		50.0	0.02932	0.92364
14.0	0.01233	0.19611		50.5	0.02114	0.94478

Table 4.29: 72-Hour Long-Duration Storm Hyetograph Values for Climate Region 3: Okanogan, Spokane, Palouse (continued)

Time (hours)	Incremental Rainfall	Cumulative Rainfall		Time (hours)	Incremental Rainfall	Cumulative Rainfall
14.5	0.00901	0.20512		51.0	0.01900	0.96378
15.0	0.00731	0.21243		51.5	0.01680	0.98058
15.5	0.00520	0.21763		52.0	0.01660	0.99718
16.0	0.00500	0.22263		52.5	0.01640	1.01358
16.5	0.00480	0.22743		53.0	0.01620	1.02978
17.0	0.00460	0.23203		53.5	0.01600	1.04578
17.5	0.00440	0.23643		54.0	0.01570	1.06148
18.0	0.00420	0.24063		54.5	0.01540	1.07688
18.5	0.00400	0.24463		55.0	0.01510	1.09198
19.0	0.00380	0.24843		55.5	0.01480	1.10678
19.5	0.00360	0.25203		56.0	0.01450	1.12128
20.0	0.00340	0.25543		56.5	0.01420	1.13548
20.5	0.00320	0.25863		57.0	0.01390	1.14938
21.0	0.00300	0.26163		57.5	0.01379	1.16317
21.5	0.00000	0.26163		58.0	0.01361	1.17678
22.0	0.00000	0.26163		58.5	0.01338	1.19016
22.5	0.00000	0.26163		59.0	0.01310	1.20326
23.0	0.00000	0.26163		59.5	0.01276	1.21602
23.5	0.00000	0.26163		60.0	0.01236	1.22838
24.0	0.00000	0.26163		60.5	0.01192	1.24030
24.5	0.00000	0.26163		61.0	0.01148	1.25178
25.0	0.00000	0.26163		61.5	0.01104	1.26282
25.5	0.00000	0.26163		62.0	0.01061	1.27343
26.0	0.00000	0.26163		62.5	0.01018	1.28361
26.5	0.00000	0.26163		63.0	0.00976	1.29337
27.0	0.00000	0.26163		63.5	0.00918	1.30255
27.5	0.00000	0.26163		64.0	0.00782	1.31037

Table 4.29: 72-Hour Long-Duration Storm Hyetograph Values for Climate Region 3: Okanogan, Spokane, Palouse (continued)

Time (hours)	Incremental Rainfall	Cumulative Rainfall		Time (hours)	Incremental Rainfall	Cumulative Rainfall
28.0	0.00000	0.26163		64.5	0.00579	1.31616
28.5	0.00000	0.26163		65.0	0.00421	1.32037
29.0	0.00000	0.26163		65.5	0.00315	1.32352
29.5	0.00000	0.26163		66.0	0.00185	1.32537
30.0	0.00000	0.26163		66.5	0.00000	1.32537
30.5	0.00000	0.26163		67.0	0.00000	1.32537
31.0	0.00000	0.26163		67.5	0.00000	1.32537
31.5	0.00000	0.26163		68.0	0.00000	1.32537
32.0	0.00000	0.26163		68.5	0.00000	1.32537
32.5	0.00000	0.26163		69.0	0.00000	1.32537
33.0	0.00000	0.26163		69.5	0.00000	1.32537
33.5	0.00000	0.26163		70.0	0.00000	1.32537
34.0	0.00000	0.26163		70.5	0.00000	1.32537
34.5	0.00000	0.26163		71.0	0.00000	1.32537
35.0	0.00000	0.26163		71.5	0.00000	1.32537
35.5	0.00000	0.26163		72.0	0.00000	1.32537
36.0	0.00000	0.26163				

4.C.6 Climate Region 4: Eastern Mountains

Use 24-hour precipitation value to scale this storm hyetograph.

Table 4.30: 72-Hour Long-Duration Storm Hyetograph Values for Climate Region 4: Eastern Mountains

Time (hours)	Incremental Rainfall	Cumulative Rainfall		Time (hours)	Incremental Rainfall	Cumulative Rainfall
0.0	0.00000	0.00000		36.5	0.00167	0.35486
0.5	0.00000	0.00000		37.0	0.00333	0.35819
1.0	0.00000	0.00000		37.5	0.00510	0.36329
1.5	0.00000	0.00000		38.0	0.00690	0.37019

Table 4.30: 72-Hour Long-Duration Storm Hyetograph Values for Climate Region 4: Eastern Mountains (continued)

Time (hours)	Incremental Rainfall	Cumulative Rainfall		Time (hours)	Incremental Rainfall	Cumulative Rainfall
2.0	0.00000	0.00000		38.5	0.00879	0.37898
2.5	0.00000	0.00000		39.0	0.01121	0.39019
3.0	0.00000	0.00000		39.5	0.01240	0.40259
3.5	0.00000	0.00000		40.0	0.01320	0.41579
4.0	0.00000	0.00000		40.5	0.01400	0.42979
4.5	0.00000	0.00000		41.0	0.01480	0.44459
5.0	0.00000	0.00000		41.5	0.01560	0.46019
5.5	0.00000	0.00000		42.0	0.01640	0.47659
6.0	0.00000	0.00000		42.5	0.01720	0.49379
6.5	0.00300	0.00300		43.0	0.01800	0.51179
7.0	0.00390	0.00690		43.5	0.01880	0.53059
7.5	0.00423	0.01113		44.0	0.01960	0.55019
8.0	0.00456	0.01569		44.5	0.02050	0.57069
8.5	0.00490	0.02059		45.0	0.02230	0.59299
9.0	0.00523	0.02582		45.5	0.02500	0.61799
9.5	0.00556	0.03138		46.0	0.02800	0.64599
10.0	0.00650	0.03788		46.5	0.03000	0.67599
10.5	0.00868	0.04656		47.0	0.04295	0.71894
11.0	0.01246	0.05902		47.5	0.05720	0.77614
11.5	0.01824	0.07726		48.0	0.08580	0.86194
12.0	0.02976	0.10702		48.5	0.04751	0.90945
12.5	0.05160	0.15862		49.0	0.03549	0.94494
13.0	0.03440	0.19302		49.5	0.03265	0.97759
13.5	0.02655	0.21957		50.0	0.03135	1.00894
14.0	0.01545	0.23502		50.5	0.02140	1.03034
14.5	0.01388	0.24890		51.0	0.01790	1.04824
15.0	0.01232	0.26122		51.5	0.01670	1.06494

Table 4.30: 72-Hour Long-Duration Storm Hyetograph Values for Climate Region 4: Eastern Mountains (continued)

Time (hours)	Incremental Rainfall	Cumulative Rainfall		Time (hours)	Incremental Rainfall	Cumulative Rainfall
15.5	0.01089	0.27211		52.0	0.01650	1.08144
16.0	0.00961	0.28173		52.5	0.01630	1.09774
16.5	0.00848	0.29020		53.0	0.01610	1.11384
17.0	0.00748	0.29768		53.5	0.01590	1.12974
17.5	0.00661	0.30430		54.0	0.01570	1.14544
18.0	0.00590	0.31019		54.5	0.01550	1.16094
18.5	0.00532	0.31552		55.0	0.01535	1.17629
19.0	0.00489	0.32040		55.5	0.01508	1.19137
19.5	0.00459	0.32499		56.0	0.01471	1.20608
20.0	0.00430	0.32930		56.5	0.01442	1.22050
20.5	0.00401	0.33330		57.0	0.01421	1.23471
21.0	0.00372	0.33702		57.5	0.01407	1.24878
21.5	0.00343	0.34045		58.0	0.01395	1.26273
22.0	0.00313	0.34358		58.5	0.01385	1.27658
22.5	0.00284	0.34642		59.0	0.01377	1.29035
23.0	0.00255	0.34897		59.5	0.01370	1.30405
23.5	0.00226	0.35123		60.0	0.01365	1.31770
24.0	0.00197	0.35319		60.5	0.01358	1.33128
24.5	0.00000	0.35319		61.0	0.01338	1.34466
25.0	0.00000	0.35319		61.5	0.01300	1.35766
25.5	0.00000	0.35319		62.0	0.01245	1.37011
26.0	0.00000	0.35319		62.5	0.01174	1.38185
26.5	0.00000	0.35319		63.0	0.01085	1.39270
27.0	0.00000	0.35319		63.5	0.00975	1.40245
27.5	0.00000	0.35319		64.0	0.00825	1.41070
28.0	0.00000	0.35319		64.5	0.00654	1.41724
28.5	0.00000	0.35319		65.0	0.00546	1.42270

Table 4.30: 72-Hour Long-Duration Storm Hyetograph Values for Climate Region 4: Eastern Mountains (continued)

Time (hours)	Incremental Rainfall	Cumulative Rainfall		Time (hours)	Incremental Rainfall	Cumulative Rainfall
29.0	0.00000	0.35319		65.5	0.00484	1.42754
29.5	0.00000	0.35319		66.0	0.00316	1.43070
30.0	0.00000	0.35319		66.5	0.00000	1.43070
30.5	0.00000	0.35319		67.0	0.00000	1.43070
31.0	0.00000	0.35319		67.5	0.00000	1.43070
31.5	0.00000	0.35319		68.0	0.00000	1.43070
32.0	0.00000	0.35319		68.5	0.00000	1.43070
32.5	0.00000	0.35319		69.0	0.00000	1.43070
33.0	0.00000	0.35319		69.5	0.00000	1.43070
33.5	0.00000	0.35319		70.0	0.00000	1.43070
34.0	0.00000	0.35319		70.5	0.00000	1.43070
34.5	0.00000	0.35319		71.0	0.00000	1.43070
35.0	0.00000	0.35319		71.5	0.00000	1.43070
35.5	0.00000	0.35319		72.0	0.00000	1.43070
36.0	0.00000	0.35319				

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Appendix 4-D: Design Storm Hyetographs

4.D.1 Introduction

This appendix includes the Soil Conservation Service (SCS) Type IA and SCS Type II hyetograph values (Table 4.31: SCS Type IA Storm Hyetograph Values (continued) and Table 4.32: SCS Type II Storm Hyetograph Values (continued)). Hyetograph values are also included for the short-duration storm (Table 4.33: Short-Duration Storm Hyetograph Values for All Climate Regions) and the regional storm for each of the four climate regions (Table 4.34: Regional Storm Hyetograph Values for Climate Region 1: Cascade Mountains (continued) through Table 4.37: Regional Storm Hyetograph Values for Climate Region 4: Eastern Mountains (continued)).

4.D.2 SCS Type IA Storm Hyetograph Values

Table 4.31: SCS Type IA Storm Hyetograph Values

Time (0.1 hours)	Incremental Rainfall	Cumulative Rainfall		Time (0.1 hours)	Incremental Rainfall	Cumulative Rainfall
0.0	0.000	0.000		12.1	0.004	0.668
0.1	0.002	0.002		12.2	0.003	0.671
0.2	0.002	0.004		12.3	0.004	0.675
0.3	0.002	0.006		12.4	0.004	0.679
0.4	0.002	0.008		12.5	0.004	0.683
0.5	0.002	0.010		12.6	0.004	0.687
0.6	0.002	0.012		12.7	0.003	0.690
0.7	0.002	0.014		12.8	0.004	0.694
0.8	0.002	0.016		12.9	0.003	0.697
0.9	0.002	0.018		13.0	0.004	0.701
1.0	0.002	0.020		13.1	0.004	0.705
1.1	0.003	0.023		13.2	0.003	0.708
1.2	0.003	0.026		13.3	0.004	0.712
1.3	0.003	0.029		13.4	0.004	0.716
1.4	0.003	0.032		13.5	0.003	0.719
1.5	0.003	0.035		13.6	0.003	0.722
1.6	0.003	0.038		13.7	0.004	0.726
1.7	0.003	0.041		13.8	0.003	0.729

Table 4.31: SCS Type IA Storm Hyetograph Values (continued)

Time (0.1 hours)	Incremental Rainfall	Cumulative Rainfall		Time (0.1 hours)	Incremental Rainfall	Cumulative Rainfall
1.8	0.003	0.044		13.9	0.004	0.733
1.9	0.003	0.047		14.0	0.003	0.736
2.0	0.003	0.050		14.1	0.003	0.739
2.1	0.003	0.053		14.2	0.004	0.743
2.2	0.003	0.056		14.3	0.003	0.746
2.3	0.004	0.060		14.4	0.003	0.749
2.4	0.003	0.063		14.5	0.004	0.753
2.5	0.003	0.066		14.6	0.003	0.756
2.6	0.003	0.069		14.7	0.003	0.759
2.7	0.003	0.072		14.8	0.004	0.763
2.8	0.004	0.076		14.9	0.003	0.766
2.9	0.003	0.079		15.0	0.003	0.769
3.0	0.003	0.082		15.1	0.003	0.772
3.1	0.003	0.085		15.2	0.004	0.776
3.2	0.003	0.088		15.3	0.003	0.779
3.3	0.003	0.091		15.4	0.003	0.782
3.4	0.004	0.095		15.5	0.003	0.785
3.5	0.003	0.098		15.6	0.003	0.788
3.6	0.003	0.101		15.7	0.004	0.792
3.7	0.004	0.105		15.8	0.003	0.795
3.8	0.004	0.109		15.9	0.003	0.798
3.9	0.003	0.112		16.0	0.003	0.801
4.0	0.004	0.116		16.1	0.003	0.804
4.1	0.004	0.120		16.2	0.003	0.807
4.2	0.003	0.123		16.3	0.003	0.810
4.3	0.004	0.127		16.4	0.003	0.813
4.4	0.004	0.131		16.5	0.003	0.816
4.5	0.004	0.135		16.6	0.003	0.819
4.6	0.004	0.139		16.7	0.003	0.822

Table 4.31: SCS Type IA Storm Hyetograph Values (continued)

Time (0.1 hours)	Incremental Rainfall	Cumulative Rainfall		Time (0.1 hours)	Incremental Rainfall	Cumulative Rainfall
4.7	0.004	0.143		16.8	0.003	0.825
4.8	0.004	0.147		16.9	0.003	0.828
4.9	0.005	0.152		17.0	0.003	0.831
5.0	0.004	0.156		17.1	0.003	0.834
5.1	0.005	0.161		17.2	0.003	0.837
5.2	0.004	0.165		17.3	0.003	0.840
5.3	0.005	0.170		17.4	0.003	0.843
5.4	0.005	0.175		17.5	0.003	0.846
5.5	0.005	0.180		16.7	0.003	0.822
5.6	0.005	0.185		17.7	0.002	0.851
5.7	0.005	0.190		17.8	0.003	0.854
5.8	0.005	0.195		17.9	0.003	0.857
5.9	0.005	0.200		18.0	0.003	0.860
6.0	0.006	0.206		18.1	0.003	0.863
6.1	0.006	0.212		18.2	0.002	0.865
6.2	0.006	0.218		18.3	0.003	0.868
6.3	0.006	0.224		18.4	0.003	0.871
6.4	0.007	0.231		18.5	0.003	0.874
6.5	0.006	0.237		18.6	0.002	0.876
6.6	0.006	0.243		18.7	0.003	0.879
6.7	0.006	0.249		18.8	0.003	0.882
6.8	0.006	0.255		18.9	0.002	0.884
6.9	0.006	0.261		19.0	0.003	0.887
7.0	0.007	0.268		19.1	0.003	0.890
7.1	0.007	0.275		19.2	0.002	0.892
7.2	0.008	0.283		19.3	0.003	0.895
7.3	0.008	0.291		19.4	0.002	0.897
7.4	0.009	0.300		19.5	0.003	0.900
7.5	0.010	0.310		19.6	0.003	0.903

Table 4.31: SCS Type IA Storm Hyetograph Values (continued)

Time (0.1 hours)	Incremental Rainfall	Cumulative Rainfall		Time (0.1 hours)	Incremental Rainfall	Cumulative Rainfall
7.6	0.021	0.331		19.7	0.002	0.905
7.7	0.024	0.355		19.8	0.003	0.908
7.8	0.024	0.379		19.9	0.002	0.910
7.9	0.024	0.403		20.0	0.003	0.913
8.0	0.022	0.425		20.1	0.002	0.915
8.1	0.014	0.439		20.2	0.003	0.918
8.2	0.013	0.452		20.3	0.002	0.920
8.3	0.010	0.462		20.4	0.002	0.922
8.4	0.010	0.472		20.5	0.003	0.925
8.5	0.008	0.480		20.6	0.002	0.927
8.6	0.009	0.489		20.7	0.003	0.930
8.7	0.009	0.498		20.8	0.002	0.932
8.8	0.007	0.505		20.9	0.002	0.934
8.9	0.008	0.513		21.0	0.003	0.937
9.0	0.007	0.520		21.1	0.002	0.939
9.1	0.007	0.527		21.2	0.002	0.941
9.2	0.006	0.533		21.3	0.003	0.944
9.3	0.006	0.539		21.4	0.002	0.946
9.4	0.006	0.545		21.5	0.002	0.948
9.5	0.005	0.550		21.6	0.003	0.951
9.6	0.006	0.556		21.7	0.002	0.953
9.7	0.005	0.561		21.8	0.002	0.955
9.8	0.006	0.567		21.9	0.002	0.957
9.9	0.005	0.572		22.0	0.002	0.959
10.0	0.005	0.577		22.1	0.003	0.962
10.1	0.005	0.582		22.2	0.002	0.964
10.2	0.005	0.587		22.3	0.002	0.966
10.3	0.005	0.592		22.4	0.002	0.968
10.4	0.004	0.596		22.5	0.002	0.970

Table 4.31: SCS Type IA Storm Hyetograph Values (continued)

Time (0.1 hours)	Incremental Rainfall	Cumulative Rainfall		Time (0.1 hours)	Incremental Rainfall	Cumulative Rainfall
10.5	0.005	0.601		22.6	0.002	0.972
10.6	0.005	0.606		22.7	0.002	0.974
10.7	0.004	0.610		22.8	0.002	0.976
10.8	0.005	0.615		22.9	0.002	0.978
10.9	0.005	0.620		23.0	0.002	0.980
11.0	0.004	0.624		23.1	0.002	0.982
11.1	0.004	0.628		23.2	0.002	0.984
11.2	0.005	0.633		23.3	0.002	0.986
11.3	0.004	0.637		23.4	0.002	0.988
11.4	0.004	0.641		23.5	0.002	0.990
11.5	0.004	0.645		23.6	0.002	0.992
11.6	0.004	0.649		23.7	0.002	0.994
11.7	0.004	0.653		23.8	0.002	0.996
11.8	0.004	0.657		23.9	0.002	0.998
11.9	0.003	0.660		24.0	0.002	1.000
12.0	0.004	0.664				

4.D.3 SCS Type II Storm Hyetograph Values

Table 4.32: SCS Type II Storm Hyetograph Values

Time (0.1 hours)	Incremental Rainfall	Cumulative Rainfall		Time (0.1 hours)	Incremental Rainfall	Cumulative Rainfall
0.0	0.000	0.000		12.1	0.019	0.682
0.1	0.001	0.001		12.2	0.017	0.699
0.2	0.001	0.002		12.3	0.014	0.713
0.3	0.001	0.003		12.4	0.012	0.725
0.4	0.001	0.004		12.5	0.010	0.735
0.5	0.001	0.005		12.6	0.008	0.743
0.6	0.001	0.006		12.7	0.008	0.751
0.7	0.001	0.007		12.8	0.008	0.759

Table 4.32: SCS Type II Storm Hyetograph Values (continued)

Time (0.1 hours)	Incremental Rainfall	Cumulative Rainfall		Time (0.1 hours)	Incremental Rainfall	Cumulative Rainfall
0.8	0.001	0.008		12.9	0.007	0.766
0.9	0.001	0.009		13.0	0.006	0.772
1.0	0.002	0.011		13.1	0.006	0.778
1.1	0.001	0.012		13.2	0.006	0.784
1.2	0.001	0.013		13.3	0.005	0.789
1.3	0.001	0.014		13.4	0.005	0.794
1.4	0.001	0.015		13.5	0.005	0.799
1.5	0.001	0.016		13.6	0.005	0.804
1.6	0.001	0.017		13.7	0.004	0.808
1.7	0.001	0.018		13.8	0.004	0.812
1.8	0.002	0.020		13.9	0.004	0.816
1.9	0.001	0.021		14.0	0.004	0.820
2.0	0.001	0.022		14.1	0.004	0.824
2.1	0.001	0.023		14.2	0.003	0.827
2.2	0.001	0.024		14.3	0.004	0.831
2.3	0.002	0.026		14.4	0.003	0.834
2.4	0.001	0.027		14.5	0.004	0.838
2.5	0.001	0.028		14.6	0.003	0.841
2.6	0.001	0.029		14.7	0.003	0.844
2.7	0.002	0.031		14.8	0.003	0.847
2.8	0.001	0.032		14.9	0.003	0.850
2.9	0.001	0.033		15.0	0.004	0.854
3.0	0.002	0.035		15.1	0.002	0.856
3.1	0.001	0.036		15.2	0.003	0.859
3.2	0.001	0.037		15.3	0.003	0.862
3.3	0.001	0.038		15.4	0.003	0.865
3.4	0.002	0.040		15.5	0.003	0.868
3.5	0.001	0.041		15.6	0.002	0.870
3.6	0.001	0.042		15.7	0.003	0.873

Table 4.32: SCS Type II Storm Hyetograph Values (continued)

Time (0.1 hours)	Incremental Rainfall	Cumulative Rainfall		Time (0.1 hours)	Incremental Rainfall	Cumulative Rainfall
3.7	0.002	0.044		15.8	0.002	0.875
3.8	0.001	0.045		15.9	0.003	0.878
3.9	0.002	0.047		16.0	0.002	0.880
4.0	0.001	0.048		16.1	0.002	0.882
4.1	0.001	0.049		16.2	0.003	0.885
4.2	0.002	0.051		16.3	0.002	0.887
4.3	0.001	0.052		16.4	0.002	0.889
4.4	0.002	0.054		16.5	0.002	0.891
4.5	0.001	0.055		16.6	0.002	0.893
4.6	0.002	0.057		16.7	0.002	0.895
4.7	0.001	0.058		16.8	0.003	0.898
4.8	0.002	0.060		16.9	0.002	0.900
4.9	0.001	0.061		17.0	0.002	0.902
5.0	0.002	0.063		17.1	0.002	0.904
5.1	0.002	0.065		17.2	0.002	0.906
5.2	0.001	0.066		17.3	0.002	0.908
5.3	0.002	0.068		17.4	0.002	0.910
5.4	0.002	0.070		17.5	0.002	0.912
5.5	0.001	0.071		17.6	0.002	0.914
5.6	0.002	0.073		17.7	0.001	0.915
5.7	0.002	0.075		17.8	0.002	0.917
5.8	0.001	0.076		17.9	0.002	0.919
5.9	0.002	0.078		18.0	0.002	0.921
6.0	0.002	0.080		18.1	0.002	0.923
6.1	0.002	0.082		18.2	0.002	0.925
6.2	0.002	0.084		18.3	0.001	0.926
6.3	0.001	0.085		18.4	0.002	0.928
6.4	0.002	0.087		18.5	0.002	0.930
6.5	0.002	0.089		18.6	0.001	0.931

Table 4.32: SCS Type II Storm Hyetograph Values (continued)

Time (0.1 hours)	Incremental Rainfall	Cumulative Rainfall		Time (0.1 hours)	Incremental Rainfall	Cumulative Rainfall
6.6	0.002	0.091		18.7	0.002	0.933
6.7	0.002	0.093		18.8	0.002	0.935
6.8	0.002	0.095		18.9	0.001	0.936
6.9	0.002	0.097		19.0	0.002	0.938
7.0	0.002	0.099		19.1	0.001	0.939
7.1	0.002	0.101		19.2	0.002	0.941
7.2	0.002	0.103		19.3	0.001	0.942
7.3	0.002	0.105		19.4	0.002	0.944
7.4	0.002	0.107		19.5	0.001	0.945
7.5	0.002	0.109		19.6	0.002	0.947
7.6	0.002	0.111		19.7	0.001	0.948
7.7	0.002	0.113		19.8	0.001	0.949
7.8	0.003	0.116		19.9	0.002	0.951
7.9	0.002	0.118		20.0	0.001	0.952
8.0	0.002	0.120		20.1	0.001	0.953
8.1	0.002	0.122		20.2	0.002	0.955
8.2	0.003	0.125		20.3	0.001	0.956
8.3	0.002	0.127		20.4	0.001	0.957
8.4	0.003	0.130		20.5	0.001	0.958
8.5	0.002	0.132		20.6	0.002	0.960
8.6	0.003	0.135		20.7	0.001	0.961
8.7	0.003	0.138		20.8	0.001	0.962
8.8	0.003	0.141		20.9	0.002	0.964
8.9	0.003	0.144		21.0	0.001	0.965
9.0	0.003	0.147		21.1	0.001	0.966
9.1	0.003	0.150		21.2	0.001	0.967
9.2	0.003	0.153		21.3	0.001	0.968
9.3	0.004	0.157		21.4	0.002	0.970
9.4	0.003	0.160		21.5	0.001	0.971

Table 4.32: SCS Type II Storm Hyetograph Values (continued)

Time (0.1 hours)	Incremental Rainfall	Cumulative Rainfall		Time (0.1 hours)	Incremental Rainfall	Cumulative Rainfall
9.5	0.003	0.163		21.6	0.001	0.972
9.6	0.003	0.166		21.7	0.001	0.973
9.7	0.004	0.170		21.8	0.002	0.975
9.8	0.003	0.173		21.9	0.001	0.976
9.9	0.004	0.177		22.0	0.001	0.977
10.0	0.004	0.181		22.1	0.001	0.978
10.1	0.004	0.185		22.2	0.001	0.979
10.2	0.004	0.189		22.3	0.002	0.981
10.3	0.005	0.194		22.4	0.001	0.982
10.4	0.005	0.199		22.5	0.001	0.983
10.5	0.005	0.204		22.6	0.001	0.984
10.6	0.005	0.209		22.7	0.001	0.985
10.7	0.006	0.215		22.8	0.001	0.986
10.8	0.006	0.221		22.9	0.002	0.988
10.9	0.007	0.228		23.0	0.001	0.989
11.0	0.007	0.235		23.1	0.001	0.990
11.1	0.008	0.243		23.2	0.001	0.991
11.2	0.008	0.251		23.3	0.001	0.992
11.3	0.010	0.261		23.4	0.001	0.993
11.4	0.010	0.271		23.5	0.001	0.994
11.5	0.012	0.283		23.6	0.002	0.996
11.6	0.024	0.307		23.7	0.001	0.997
11.7	0.047	0.354		23.8	0.001	0.998
11.8	0.077	0.431		23.9	0.001	0.999
11.9	0.137	0.568		24.0	0.001	1.000
12.0	0.095	0.663				

4.D.4 Short-Duration Storm Hyetograph Values for All Climate Regions

Use the 2-hour precipitation value times 1.06 to determine the 3-hour total precipitation amount.

Table 4.33: Short-Duration Storm Hyetograph Values for All Climate Regions

Time (mins)	Time (hrs)	Incremental Rainfall	Cumulative Rainfall		Time (mins)	Time (hrs)	Incremental Rainfall	Cumulative Rainfall
0	0	0.0000	0.0000		95	1.58	0.0085	0.9133
5	0.08	0.0047	0.0047		100	1.67	0.0075	0.9208
10	0.17	0.0047	0.0094		105	1.75	0.0057	0.9265
15	0.25	0.0057	0.0151		110	1.83	0.0057	0.9322
20	0.33	0.0104	0.0255		115	1.92	0.0057	0.9379
25	0.42	0.0123	0.0378		120	2.00	0.0057	0.9436
30	0.50	0.0236	0.0614		125	2.08	0.0047	0.9483
35	0.58	0.0292	0.0906		130	2.17	0.0047	0.9530
40	0.67	0.0528	0.1434		135	2.25	0.0047	0.9577
45	0.75	0.0736	0.2170		140	2.33	0.0047	0.9624
50	0.83	0.1736	0.3906		145	2.42	0.0047	0.9671
55	0.92	0.2377	0.6283		150	2.50	0.0047	0.9718
60	1.00	0.1255	0.7538		155	2.58	0.0047	0.9765
65	1.08	0.0604	0.8142		160	2.67	0.0047	0.9812
70	1.17	0.0406	0.8548		165	2.75	0.0047	0.9859
75	1.25	0.0151	0.8699		170	2.83	0.0047	0.9906
80	1.33	0.0132	0.8831		175	2.92	0.0047	0.9953
85	1.42	0.0113	0.8944		180	3.00	0.0047	1.0000
90	1.50	0.0104	0.9048					

4.D.5 Climate Region 1: Cascade Mountains

Use the 24-hour precipitation value times 1.16 to determine the long-duration storm total precipitation amount.

Table 4.34: Regional Storm Hyetograph Values for Climate Region 1: Cascade Mountains

Time (hours)	Incremental Rainfall	Cumulative Rainfall		Time (hours)	Incremental Rainfall	Cumulative Rainfall
0.0	0.0000	0.0000		18.5	0.0168	0.6402
0.5	0.0024	0.0024		19.0	0.0165	0.6566
1.0	0.0036	0.0060		19.5	0.0161	0.6728
1.5	0.0040	0.0101		20.0	0.0158	0.6886
2.0	0.0047	0.0148		20.5	0.0154	0.7040
2.5	0.0051	0.0199		21.0	0.0151	0.7191
3.0	0.0054	0.0253		21.5	0.0148	0.7339
3.5	0.0058	0.0311		22.0	0.0144	0.7483
4.0	0.0062	0.0374		22.5	0.0141	0.7623
4.5	0.0066	0.0439		23.0	0.0137	0.7761
5.0	0.0078	0.0517		23.5	0.0134	0.7894
5.5	0.0096	0.0614		24.0	0.0130	0.8025
6.0	0.0120	0.0733		24.5	0.0127	0.8151
6.5	0.0138	0.0871		25.0	0.0123	0.8275
7.0	0.0150	0.1022		25.5	0.0120	0.8395
7.5	0.0157	0.1179		26.0	0.0117	0.8512
8.0	0.0164	0.1343		26.5	0.0115	0.8627
8.5	0.0171	0.1513		27.0	0.0112	0.8739
9.0	0.0178	0.1691		27.5	0.0110	0.8849
9.5	0.0185	0.1876		28.0	0.0107	0.8956
10.0	0.0192	0.2067		28.5	0.0104	0.9060
10.5	0.0198	0.2266		29.0	0.0102	0.9162
11.0	0.0205	0.2471		29.5	0.0099	0.9261
11.5	0.0212	0.2683		30.0	0.0097	0.9358
12.0	0.0220	0.2904		30.5	0.0088	0.9446
12.5	0.0226	0.3130		31.0	0.0079	0.9525
13.0	0.0235	0.3364		31.5	0.0071	0.9596

Table 4.34: Regional Storm Hyetograph Values for Climate Region 1: Cascade Mountains (continued)

Time (hours)	Incremental Rainfall	Cumulative Rainfall		Time (hours)	Incremental Rainfall	Cumulative Rainfall
13.5	0.0243	0.3608		32.0	0.0063	0.9659
14.0	0.0297	0.3905		32.5	0.0058	0.9717
14.5	0.0338	0.4243		33.0	0.0054	0.9772
15.0	0.0507	0.4750		33.5	0.0050	0.9822
15.5	0.0315	0.5066		34.0	0.0047	0.9869
16.0	0.0283	0.5349		34.5	0.0043	0.9912
16.5	0.0257	0.5606		35.0	0.0039	0.9950
17.0	0.0231	0.5837		35.5	0.0030	0.9981
17.5	0.0214	0.6051		36.0	0.0019	1.0000
18.0	0.0183	0.6234				

4.D.6 Climate Region 2: Central Basin

Use the 24-hour precipitation value (times 1.00) to determine the long-duration storm total precipitation amount.

Table 4.35: Regional Storm Hyetograph Values for Climate Region 2: Central Basin

Time (hours)	Incremental Rainfall	Cumulative Rainfall		Time (hours)	Incremental Rainfall	Cumulative Rainfall
0.0	0.0000	0.0000		12.5	0.0252	0.7374
0.5	0.0054	0.0054		13.0	0.0219	0.7593
1.0	0.0086	0.0140		13.5	0.0191	0.7783
1.5	0.0100	0.0240		14.0	0.0167	0.7950
2.0	0.0120	0.0360		14.5	0.0148	0.8098
2.5	0.0130	0.0490		15.0	0.0134	0.8232
3.0	0.0140	0.0630		15.5	0.0123	0.8355
3.5	0.0150	0.0780		16.0	0.0116	0.8471
4.0	0.0160	0.0940		16.5	0.0110	0.8581
4.5	0.0170	0.1110		17.0	0.0105	0.8686

Table 4.35: Regional Storm Hyetograph Values for Climate Region 2: Central Basin (continued)

Time (hours)	Incremental Rainfall	Cumulative Rainfall		Time (hours)	Incremental Rainfall	Cumulative Rainfall
5.0	0.0187	0.1297		17.5	0.0103	0.8789
5.5	0.0228	0.1525		18.0	0.0103	0.8892
6.0	0.0283	0.1808		18.5	0.0104	0.8996
6.5	0.0305	0.2113		19.0	0.0105	0.9100
7.0	0.0335	0.2448		19.5	0.0105	0.9205
7.5	0.0365	0.2813		20.0	0.0104	0.9309
8.0	0.0484	0.3297		20.5	0.0102	0.9412
8.5	0.0622	0.3919		21.0	0.0100	0.9512
9.0	0.0933	0.4852		21.5	0.0097	0.9609
9.5	0.0527	0.5380		22.0	0.0093	0.9702
10.0	0.0402	0.5782		22.5	0.0087	0.9789
10.5	0.0372	0.6154		23.0	0.0083	0.9872
11.0	0.0348	0.6502		23.5	0.0078	0.9950
11.5	0.0331	0.6833		24.0	0.0050	1.0000
12.0	0.0289	0.7122				

4.D.7 Climate Region 3: Okanogan, Spokane, Palouse

Use the 24-hour precipitation value times 1.06 to determine the long-duration storm total precipitation amount.

Table 4.36: Regional Storm Hyetograph Values for Climate Region 3: Okanogan, Spokane, Palouse

Time (hours)	Incremental Rainfall	Cumulative Rainfall		Time (hours)	Incremental Rainfall	Cumulative Rainfall
0.0	0.0000	0.0000		15.5	0.0158	0.6759
0.5	0.0017	0.0017		16.0	0.0156	0.6915
1.0	0.0030	0.0047		16.5	0.0154	0.7069
1.5	0.0041	0.0088		17.0	0.0152	0.7221
2.0	0.0053	0.0141		17.5	0.0150	0.7372

Table 4.36: Regional Storm Hyetograph Values for Climate Region 3: Okanogan, Spokane, Palouse (continued)

Time (hours)	Incremental Rainfall	Cumulative Rainfall		Time (hours)	Incremental Rainfall	Cumulative Rainfall
2.5	0.0068	0.0209		18.0	0.0148	0.7519
3.0	0.0092	0.0301		18.5	0.0145	0.7664
3.5	0.0108	0.0409		19.0	0.0142	0.7806
4.0	0.0126	0.0535		19.5	0.0139	0.7945
4.5	0.0132	0.0667		20.0	0.0136	0.8081
5.0	0.0139	0.0806		20.5	0.0133	0.8215
5.5	0.0147	0.0952		21.0	0.0131	0.8346
6.0	0.0154	0.1106		21.5	0.0130	0.8475
6.5	0.0162	0.1268		22.0	0.0128	0.8603
7.0	0.0169	0.1437		22.5	0.0126	0.8729
7.5	0.0177	0.1614		23.0	0.0123	0.8852
8.0	0.0184	0.1798		23.5	0.0120	0.8972
8.5	0.0192	0.1990		24.0	0.0116	0.9088
9.0	0.0228	0.2219		24.5	0.0112	0.9200
9.5	0.0238	0.2457		25.0	0.0108	0.9308
10.0	0.0260	0.2717		25.5	0.0104	0.9412
10.5	0.0282	0.2999		26.0	0.0100	0.9512
11.0	0.0395	0.3394		26.5	0.0096	0.9607
11.5	0.0564	0.3958		27.0	0.0092	0.9699
12.0	0.0855	0.4813		27.5	0.0086	0.9785
12.5	0.0451	0.5265		28.0	0.0074	0.9859
13.0	0.0348	0.5612		28.5	0.0054	0.9913
13.5	0.0335	0.5948		29.0	0.0040	0.9953
14.0	0.0276	0.6223		29.5	0.0030	0.9983
14.5	0.0199	0.6422		30.0	0.0017	1.0000
15.0	0.0179	0.6601				

4.D.8 Climate Region 4: Eastern Mountains

Use the 24-hour precipitation value times 1.07 to determine the long-duration storm total precipitation amount.

Table 4.37: Regional Storm Hyetograph Values for Climate Region 4: Eastern Mountains

Time (hours)	Incremental Rainfall	Cumulative Rainfall		Time (hours)	Incremental Rainfall	Cumulative Rainfall
0.0	0.0000	0.0000		15.5	0.0155	0.6606
0.5	0.0015	0.0015		16.0	0.0153	0.6759
1.0	0.0031	0.0046		16.5	0.0151	0.6910
1.5	0.0047	0.0094		17.0	0.0149	0.7059
2.0	0.0064	0.0158		17.5	0.0148	0.7207
2.5	0.0082	0.0239		18.0	0.0146	0.7353
3.0	0.0104	0.0343		18.5	0.0144	0.7496
3.5	0.0115	0.0458		19.0	0.0142	0.7639
4.0	0.0123	0.0581		19.5	0.0140	0.7779
4.5	0.0130	0.0711		20.0	0.0137	0.7915
5.0	0.0137	0.0848		20.5	0.0134	0.8049
5.5	0.0145	0.0993		21.0	0.0132	0.8181
6.0	0.0152	0.1145		21.5	0.0131	0.8312
6.5	0.0160	0.1305		22.0	0.0129	0.8441
7.0	0.0167	0.1472		22.5	0.0129	0.8570
7.5	0.0174	0.1646		23.0	0.0128	0.8697
8.0	0.0182	0.1828		23.5	0.0127	0.8825
8.5	0.0190	0.2019		24.0	0.0127	0.8951
9.0	0.0207	0.2226		24.5	0.0126	0.9077
9.5	0.0232	0.2458		25.0	0.0124	0.9201
10.0	0.0260	0.2717		25.5	0.0121	0.9322
10.5	0.0278	0.2996		26.0	0.0116	0.9438
11.0	0.0399	0.3394		26.5	0.0109	0.9547
11.5	0.0531	0.3925		27.0	0.0101	0.9647

Table 4.37: Regional Storm Hyetograph Values for Climate Region 4: Eastern Mountains (continued)

Time (hours)	Incremental Rainfall	Cumulative Rainfall		Time (hours)	Incremental Rainfall	Cumulative Rainfall
12.0	0.0796	0.4722		27.5	0.0090	0.9738
12.5	0.0441	0.5162		28.0	0.0077	0.9814
13.0	0.0329	0.5492		28.5	0.0061	0.9875
13.5	0.0303	0.5795		29.0	0.0051	0.9926
14.0	0.0291	0.6086		29.5	0.0045	0.9971
14.5	0.0199	0.6284		30.0	0.0029	1.0000
15.0	0.0166	0.6451				

Appendix 4-E: Example SBUH Runoff Hydrograph

Existing Site Conditions

CLIMATE REGION 2, 25-YEAR REGIONAL STORM

Givens:

- Total area (acres) = **5.0**
- w = routing constant = $d_t/(2T_c + d_t)$ = **0.2727**
- P_t (inches) = **1.6**
- d_t (minutes) = **30**
- T_c (minutes) = **40**
- Pervious Area = **5.0 acres**, CN = 65, S = (1000/CN) - 10 = 5.38, 0.2S = 1.08
- Impervious Area = **0.0 acres**, CN = 98, S = (1000/CN) - 10 = 0.20, 0.2S = 0.04

Table 4.38: SBUH Runoff Hydrograph Values for the Existing Site Conditions

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
1	0	0.00000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0	0.00
2	30	0.00000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0	0.00
3	60	0.00000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0	0.00
…											
90	2670	0.06220	0.100	0.934	0.000	0.000	0.495	0.089	0.000	0.0	0.00
91	2700	0.09330	0.149	1.083	0.000	0.000	0.632	0.137	0.000	0.0	0.00
92	2730	0.05275	0.084	1.167	0.001	0.001	0.711	0.079	0.001	0.0	0.00
93	2760	0.04025	0.064	1.232	0.004	0.003	0.772	0.061	0.003	0.0	0.01
94	2790	0.03717	0.059	1.291	0.008	0.004	0.828	0.056	0.004	0.0	0.02
95	2820	0.03483	0.056	1.347	0.013	0.005	0.881	0.053	0.005	0.0	0.03
96	2850	0.03307	0.053	1.400	0.018	0.005	0.931	0.051	0.005	0.1	0.04
97	2880	0.02893	0.046	1.446	0.024	0.005	0.976	0.044	0.005	0.1	0.05
98	2910	0.02519	0.040	1.486	0.029	0.005	1.015	0.039	0.005	0.1	0.05
99	2940	0.02189	0.035	1.521	0.034	0.005	1.048	0.034	0.005	0.0	0.05
100	2970	0.01906	0.030	1.552	0.039	0.005	1.078	0.029	0.005	0.0	0.05

Table 4.38: SBUH Runoff Hydrograph Values for the Existing Site Conditions (continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
101	3000	0.01670	0.027	1.579	0.043	0.004	1.103	0.026	0.004	0.0	0.05
102	3030	0.01480	0.024	1.602	0.047	0.004	1.126	0.023	0.004	0.0	0.04
103	3060	0.01336	0.021	1.624	0.050	0.004	1.147	0.021	0.004	0.0	0.04
104	3090	0.01234	0.020	1.643	0.054	0.004	1.166	0.019	0.004	0.0	0.04
105	3120	0.01156	0.018	1.662	0.057	0.003	1.184	0.018	0.003	0.0	0.04
106	3150	0.01096	0.018	1.679	0.061	0.003	1.201	0.017	0.003	0.0	0.04
107	3180	0.01054	0.017	1.696	0.064	0.003	1.217	0.016	0.003	0.0	0.03
108	3210	0.01032	0.017	1.713	0.067	0.003	1.233	0.016	0.003	0.0	0.03
109	3240	0.01028	0.016	1.729	0.070	0.003	1.249	0.016	0.003	0.0	0.03
110	3270	0.01038	0.017	1.746	0.074	0.003	1.265	0.016	0.003	0.0	0.03
111	3300	0.01046	0.017	1.763	0.077	0.004	1.282	0.016	0.004	0.0	0.03
112	3330	0.01046	0.017	1.779	0.081	0.004	1.298	0.016	0.004	0.0	0.04
113	3360	0.01040	0.017	1.796	0.085	0.004	1.314	0.016	0.004	0.0	0.04
114	3390	0.01025	0.016	1.812	0.088	0.004	1.330	0.016	0.004	0.0	0.04
115	3420	0.01004	0.016	1.828	0.092	0.004	1.346	0.016	0.004	0.0	0.04
116	3450	0.00974	0.016	1.844	0.096	0.004	1.361	0.015	0.004	0.0	0.04
117	3480	0.00926	0.015	1.859	0.099	0.003	1.375	0.014	0.003	0.0	0.04
118	3510	0.00868	0.014	1.873	0.102	0.003	1.389	0.014	0.003	0.0	0.04
119	3540	0.00832	0.013	1.886	0.106	0.003	1.402	0.013	0.003	0.0	0.03
120	3570	0.00781	0.012	1.899	0.109	0.003	1.414	0.012	0.003	0.0	0.03
121	3600	0.00500	0.008	1.907	0.111	0.002	1.422	0.008	0.002	0.0	0.03
122	3630	0.00000	0.000	1.907	0.111	0.000	1.422	0.000	0.000	0.0	0.02
123	3660	0.00000	0.000	1.907	0.111	0.000	1.422	0.000	0.000	0.0	0.01
124	3690	0.00000	0.000	1.907	0.111	0.000	1.422	0.000	0.000	0.0	0.00
125	3720	0.00000	0.000	1.907	0.111	0.000	1.422	0.000	0.000	0.0	0.00
…											
145	4320	0.00000	0.000	1.907	0.111	0.000	1.422	0.000	0.000	0.0	0.00

Column descriptions:

- Column (1) = Time increment
- Column (2) = Time (minutes)

Table 4.38: SBUH Runoff Hydrograph Values for the Existing Site Conditions (continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)

- Column (3) = Rainfall distribution (fraction)
- Column (4) = Incremental rainfall (inches) = Column (3) x P_t
- Column (5) = Accumulated rainfall (inches) = P = Accumulated sum of Column (4)
- Column (6) = Accumulated runoff from the pervious area (inches) = (If P ≤ 0.2S) = 0; (If P > 0.2S) = [(Column (5) – 0.2S)^2/(Column (5) + 0.8S)] where pervious area S value is used
- Column (7) = Incremental runoff from the pervious area (inches) = Column (6) of present step – Column (6) of previous step
- Column (8) = Accumulated runoff from the impervious area (inches) = (If P ≤ 0.2S) = 0; (If P > 0.2S) = [(Column (5) – 0.2S)^2/(Column (5) + 0.8S)] where impervious area S value is used
- Column (9) = Incremental runoff from the impervious area (inches) = Column (8) of present step – Column (8) of previous step
- Column (10) = Total runoff (inches) =[(PERVIOUS AREA/TOTAL AREA) * Column (7)] + [(IMPERVIOUS AREA/TOTAL AREA) x Column (9)]
- Column (11) = Instantaneous flow rate (cfs) = (60.5 x Column (10) x TOTAL AREA)/d_t
- Column (12) = Design flow rate = Column (12) of previous time + w[(Column (11) of previous time step + Column (11) of present time step) – (2 x Column (12) of previous time step)] where w = d_t /(2T_c+ d_t)

Proposed Site Conditions

CLIMATE REGION 2, 25-YEAR REGIONAL STORM

Givens:

- Total area (acres) = **5.0**
- w = routing constant = d_t/(2T_c + d_t) = **0.750**
- P_t (inches) = **1.6**
- d_t (minutes) = **30**
- T_c (minutes) = **5**
- Pervious Area = **0.5 acres**, CN = 65, S = (1000/CN) - 10 = 5.38, 0.2S = 1.08
- Impervious Area = **4.5 acres**, CN = 98, S = (1000/CN) - 10 = 0.20, 0.2S = 0.04

Table 4.39: SBUH Runoff Hydrograph Values for the Proposed Site Conditions

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
1	0	0.00000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0	0.00
2	30	0.00000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0	0.00
3	60	0.00000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0	0.00
…											
22	630	0.01669	0.027	0.046	0.000	0.000	0.000	0.000	0.000	0.0	0.00
23	660	0.02831	0.045	0.092	0.000	0.000	0.010	0.010	0.009	0.1	0.07
24	690	0.04680	0.075	0.167	0.000	0.000	0.048	0.038	0.034	0.3	0.29
25	720	0.03120	0.050	0.217	0.000	0.000	0.081	0.033	0.030	0.3	0.34
26	750	0.02549	0.041	0.257	0.000	0.000	0.111	0.030	0.027	0.3	0.26
27	780	0.01451	0.023	0.281	0.000	0.000	0.129	0.018	0.016	0.2	0.20
28	810	0.00445	0.007	0.288	0.000	0.000	0.135	0.006	0.005	0.1	0.06
29	840	0.00202	0.003	0.291	0.000	0.000	0.138	0.003	0.002	0.0	0.02
30	870	0.00192	0.003	0.294	0.000	0.000	0.140	0.002	0.002	0.0	0.02
31	900	0.00172	0.003	0.297	0.000	0.000	0.142	0.002	0.002	0.0	0.02
32	930	0.00152	0.002	0.299	0.000	0.000	0.144	0.002	0.002	0.0	0.02
33	960	0.00132	0.002	0.301	0.000	0.000	0.146	0.002	0.002	0.0	0.02
34	990	0.00112	0.002	0.303	0.000	0.000	0.147	0.001	0.001	0.0	0.01
35	1020	0.00092	0.001	0.305	0.000	0.000	0.149	0.001	0.001	0.0	0.01
36	1050	0.00072	0.001	0.306	0.000	0.000	0.150	0.001	0.001	0.0	0.01
37	1080	0.00052	0.001	0.307	0.000	0.000	0.150	0.001	0.001	0.0	0.01
38	1110	0.00000	0.000	0.307	0.000	0.000	0.150	0.000	0.000	0.0	0.00
39	1140	0.00000	0.000	0.307	0.000	0.000	0.150	0.000	0.000	0.0	0.00
…											
72	2130	0.00000	0.000	0.307	0.000	0.000	0.150	0.000	0.000	0.0	0.00
73	2160	0.00000	0.000	0.307	0.000	0.000	0.150	0.000	0.000	0.0	0.00
74	2190	0.00544	0.009	0.315	0.000	0.000	0.157	0.007	0.006	0.1	0.05
75	2220	0.00856	0.014	0.329	0.000	0.000	0.169	0.011	0.010	0.1	0.10
76	2250	0.01000	0.016	0.345	0.000	0.000	0.182	0.013	0.012	0.1	0.12
77	2280	0.01200	0.019	0.364	0.000	0.000	0.198	0.016	0.015	0.1	0.14
78	2310	0.01300	0.021	0.385	0.000	0.000	0.216	0.018	0.016	0.2	0.16

Table 4.39: SBUH Runoff Hydrograph Values for the Proposed Site Conditions (continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
79	2340	0.01400	0.022	0.407	0.000	0.000	0.235	0.019	0.017	0.2	0.17
80	2370	0.01500	0.024	0.431	0.000	0.000	0.256	0.021	0.019	0.2	0.19
81	2400	0.01600	0.026	0.457	0.000	0.000	0.279	0.023	0.020	0.2	0.20
82	2430	0.01700	0.027	0.484	0.000	0.000	0.304	0.024	0.022	0.2	0.22
83	2460	0.01869	0.030	0.514	0.000	0.000	0.331	0.027	0.024	0.2	0.24
84	2490	0.02281	0.036	0.551	0.000	0.000	0.364	0.033	0.030	0.3	0.29
85	2520	0.02832	0.045	0.596	0.000	0.000	0.406	0.042	0.038	0.4	0.37
86	2550	0.03050	0.049	0.645	0.000	0.000	0.451	0.045	0.041	0.4	0.41
87	2580	0.03350	0.054	0.698	0.000	0.000	0.502	0.050	0.045	0.5	0.45
88	2610	0.03650	0.058	0.757	0.000	0.000	0.557	0.055	0.050	0.5	0.50
89	2640	0.04842	0.077	0.834	0.000	0.000	0.631	0.074	0.067	0.7	0.63
90	2670	0.06220	0.100	0.934	0.000	0.000	0.727	0.096	0.086	0.9	0.84
91	2700	0.09330	0.149	1.083	0.000	0.000	0.871	0.145	0.130	1.3	1.22
92	2730	0.05275	0.084	1.167	0.001	0.001	0.954	0.082	0.074	0.7	0.94
93	2760	0.04025	0.064	1.232	0.004	0.003	1.017	0.063	0.057	0.6	0.52
94	2790	0.03717	0.059	1.291	0.008	0.004	1.075	0.058	0.053	0.5	0.57
95	2820	0.03483	0.056	1.347	0.013	0.005	1.130	0.055	0.050	0.5	0.49
96	2850	0.03307	0.053	1.400	0.018	0.005	1.182	0.052	0.047	0.5	0.49
97	2880	0.02893	0.046	1.446	0.024	0.005	1.227	0.046	0.042	0.4	0.43
98	2910	0.02519	0.040	1.486	0.029	0.005	1.267	0.040	0.036	0.4	0.37
99	2940	0.02189	0.035	1.521	0.034	0.005	1.301	0.034	0.032	0.3	0.33
100	2970	0.01906	0.030	1.552	0.039	0.005	1.331	0.030	0.028	0.3	0.28
101	3000	0.01670	0.027	1.579	0.043	0.004	1.358	0.026	0.024	0.2	0.25
102	3030	0.01480	0.024	1.602	0.047	0.004	1.381	0.023	0.021	0.2	0.22
103	3060	0.01336	0.021	1.624	0.050	0.004	1.402	0.021	0.019	0.2	0.20
104	3090	0.01234	0.020	1.643	0.054	0.004	1.422	0.019	0.018	0.2	0.18
105	3120	0.01156	0.018	1.662	0.057	0.003	1.440	0.018	0.017	0.2	0.17
106	3150	0.01096	0.018	1.679	0.061	0.003	1.457	0.017	0.016	0.2	0.16
107	3180	0.01054	0.017	1.696	0.064	0.003	1.474	0.017	0.015	0.2	0.16
108	3210	0.01032	0.017	1.713	0.067	0.003	1.490	0.016	0.015	0.2	0.15

Table 4.39: SBUH Runoff Hydrograph Values for the Proposed Site Conditions (continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
109	3240	0.01028	0.016	1.729	0.070	0.003	1.506	0.016	0.015	0.2	0.15
110	3270	0.01038	0.017	1.746	0.074	0.003	1.523	0.016	0.015	0.2	0.15
111	3300	0.01046	0.017	1.763	0.077	0.004	1.539	0.017	0.015	0.2	0.15
112	3330	0.01046	0.017	1.779	0.081	0.004	1.556	0.017	0.015	0.2	0.15
113	3360	0.01040	0.017	1.796	0.085	0.004	1.572	0.016	0.015	0.2	0.15
114	3390	0.01025	0.016	1.812	0.088	0.004	1.589	0.016	0.015	0.2	0.15
115	3420	0.01004	0.016	1.828	0.092	0.004	1.604	0.016	0.015	0.1	0.15
116	3450	0.00974	0.016	1.844	0.096	0.004	1.620	0.015	0.014	0.1	0.14
117	3480	0.00926	0.015	1.859	0.099	0.003	1.635	0.015	0.014	0.1	0.14
118	3510	0.00868	0.014	1.873	0.102	0.003	1.648	0.014	0.013	0.1	0.13
119	3540	0.00832	0.013	1.886	0.106	0.003	1.662	0.013	0.012	0.1	0.12
120	3570	0.00781	0.012	1.899	0.109	0.003	1.674	0.012	0.011	0.1	0.12
121	3600	0.00500	0.008	1.907	0.111	0.002	1.682	0.008	0.007	0.1	0.08
122	3630	0.00000	0.000	1.907	0.111	0.000	1.682	0.000	0.000	0.0	0.01
123	3660	0.00000	0.000	1.907	0.111	0.000	1.682	0.000	0.000	0.0	0.00
124	3690	0.00000	0.000	1.907	0.111	0.000	1.682	0.000	0.000	0.0	0.00
…											
144	4290	0.00000	0.000	1.907	0.111	0.000	1.682	0.000	0.000	0.0	0.00
145	4320	0.00000	0.000	1.907	0.111	0.000	1.682	0.000	0.000	0.0	0.00

Column descriptions:

- Column (1) = Time increment
- Column (2) = Time (minutes)
- Column (3) = Rainfall distribution (fraction)
- Column (4) = Incremental rainfall (inches) = Column (3) x P_t
- Column (5) = Accumulated rainfall (inches) = P = Accumulated sum of Column (4)
- Column (6) = Accumulated runoff from the pervious area (inches) = (If P ≤ 0.2S) = 0; (If P > 0.2S) = [(Column (5) – 0.2S)^2/(Column (5) + 0.8S)] where pervious area S value is used
- Column (7) = Incremental runoff from the pervious area (inches) = Column (6) of present step – Column (6) of previous step

Table 4.39: SBUH Runoff Hydrograph Values for the Proposed Site Conditions (continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)

- Column (8) = Accumulated runoff from the impervious area (inches) = (If P ≤ 0.2S) = 0; (If P > 0.2S) = [(Column (5) – 0.2S)^2/(Column (5) + 0.8S)] where impervious area S value is used
- Column (9) = Incremental runoff from the impervious area (inches) = Column (8) of present step – Column (8) of previous step
- Column (10) = Total runoff (inches) =[(PERVIOUS AREA/TOTAL AREA) * Column (7)] + [(IMPERVIOUS AREA/TOTAL AREA) x Column (9)]
- Column (11) = Instantaneous flow rate (cfs) = (60.5 x Column (10) x TOTAL AREA)/d_t
- Column (12) = Design flow rate = Column (12) of previous time + w[(Column (11) of previous time step + Column (11) of present time step) – (2 x Column (12) of previous time step)] where w = d_t /(2T_c+ d_t)

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Chapter 5 - UIC Program Guidelines

5.1 Introduction to UIC Wells

Chapter 5 - UIC Program Guidelines defines site suitability, treatment requirements, and design criteria for discharges of stormwater to Underground Injection Control (UIC) wells. The requirements of this chapter may be superseded by the Industrial Stormwater General Permit for those permitted sites. See the Glossary and 1.2.8 Underground Injection Control (UIC) Program for the UIC well definition and a list of examples.

All UIC wells receiving stormwater, except those located on tribal lands and UIC wells at single-family homes receiving only residential roof runoff or used to control basement flooding, must be registered with the state of Washington. The majority of UIC wells receiving stormwater runoff can be authorized by the UIC Program without requiring individual permits, provided the nonendangerment standard is met by fulfilling the requirements detailed throughout Chapter 5 - UIC Program Guidelines. Subsurface infiltration (UIC wells) may be used to provide flow control for stormwater runoff under any of the following conditions:

- Pollutant concentrations expected to reach groundwater will meet Washington State groundwater quality standards.
- Stormwater is treated according to the requirements of this section prior to reaching the aquifer.
- Flows are greater than the water quality design storm (see Chapter 4 - Hydrologic Analysis and Design).

The unsaturated geologic material between the bottom of the UIC well and the top of an unconfined aquifer, herein called the vadose zone, usually provides some level of treatment by removing contaminants by filtration, adsorption, and/or degradation. In some cases, the treatment provided by the vadose zone is suitable for protecting groundwater quality from contamination by stormwater runoff. In other cases, additional treatment may be required to protect groundwater quality. 5.16 Determining Runoff Treatment Requirements for UIC Wells and 5.17 Classification of Vadose Zone Treatment Capacity for UIC Wells describe these assessments and their application.

Chapter 5 - UIC Program Guidelines does not address the following:

- UIC wells that receive fluids other than stormwater (precluding accidental spills and illicit discharges, which are addressed in Chapter 8 - Source Control)
- The infiltration capacity of the vadose zone below the UIC well
- The ability of the UIC well to meet local operational requirements to infiltrate a certain volume of water in a given amount of time (see 2.4.6 CE6: Flow Control for more detail on flow control)

The UIC rule, WAC 173 218, requires a well assessment (see 5.5 UIC Well Assessment) for UIC wells that were constructed prior to February 3, 2006. The rule refers to these UIC wells as "existing" UIC wells.

The UIC Program considers an infiltration trench where the design includes perforated pipe to be classified as a UIC well. Registration requirements do not apply to infiltration trenches without perforated pipes. Infiltration trenches designed, constructed, operated, and maintained according to the specifications in BMP F6.22: Infiltration Trenches and a UIC registration with Ecology can be rule-authorized by the presumptive approach (see 5.8 The Presumptive Approach for UIC Wells).

5.2 Rule-Authorization or Permit

UIC wells must either be rule-authorized or covered by a state waste discharge permit to operate. If a UIC well is rule-authorized, an individual permit is not required. Rule-authorization can be rescinded if a UIC well no longer meets the nonendangerment standard, i.e. the discharge does not meet groundwater quality standards.

A UIC well may be rule-authorized when both of the following required actions are completed:

- Submit a registration form to Ecology (unless the UIC well is on tribal land, then registration is through U.S. Environmental Protection Agency (U.S. EPA), Region 10).
- Protects groundwater quality. The discharge from the UIC well must meet the nonendangerment standard.

5.3 UIC Well Registration

Register UIC wells using Ecology's online registration process. See the following website for details:

https://ecology.wa.gov/Regulations-Permits/Guidance-technical-assistance/Underground-injection-control-program/Register-UIC-wells-online

All UIC wells must be registered except:

- UIC wells at single-family homes (or duplexes) receiving only stormwater runoff from residential roofs.
- Non UIC wells, such as: infiltration ponds, dispersion systems, or infiltration trenches that do not contain perforated pipe.
- Storm drain components that contain perforated pipe BUT are intended to convey stormwater to a surface water body. This configuration is not a UIC well.
- UIC wells used only to control basement flooding.

Registering New UIC Wells

Ecology considers UIC wells constructed on or after February 3, 2006, to be new wells. The registration provides Ecology with information to determine if the new UIC well meets the conditions to be rule-authorized:

- Applicants must submit the registration form 60 days prior to construction to allow for a full review of the application by Ecology and other interested stakeholders.
- The UIC well must meet the nonendangerment standard, i.e. it complies with all of the siting, design, and treatment requirements through either the presumptive approach (5.8 The Presumptive Approach for UIC Wells) or the demonstrative approach (5.9 The Demonstrative Approach for UIC Wells).

Registering Existing UIC Wells

The UIC rule considers UIC wells constructed prior to February 3, 2006, as “existing.” Existing wells used to manage stormwater runoff do not have to meet the new UIC well treatment requirements; however, registration is required if the UIC well is not already registered, and the owner must also complete a well assessment (5.5 UIC Well Assessment) to determine if an existing UIC well is a high threat to groundwater. See WAC 173 218 090(2) and Ecology’s UIC web page at the following address:

https://ecology.wa.gov/Regulations-Permits/Guidance-technical-assistance/Underground-injection-control-program/Register-UIC-wells-online

5.4 Meeting the Nonendangerment Standard

According to WAC 173-218-080(3), UIC wells must be constructed, operated, and maintained in a manner that protects water quality.

New UIC Wells

Ecology determines if a new UIC well is either rule-authorized or needs a state waste discharge permit based on whether the UIC well meets the nonendangerment standard.

Designers may use either the presumptive or the demonstrative approach described in 5.8 The Presumptive Approach for UIC Wells and 5.9 The Demonstrative Approach for UIC Wells to meet the nonendangerment standard. UIC wells installed according to the specifications throughout Chapter 5 - UIC Program Guidelines are not considered a high threat to groundwater.

Existing UIC Wells

To determine compliance with the UIC rule, owners of existing UIC wells must complete a UIC well assessment to determine if an existing UIC well is a high threat to groundwater (see 5.5 UIC Well Assessment). The owner of a UIC well that is a high threat to groundwater must retrofit the well to protect groundwater quality.

Requirements for Municipal UIC Wells

The UIC Program rule is the regulatory authority for UIC wells in Washington. The UIC Program rule applies to Class V wells that receive stormwater regardless of whether a UIC well is located in a municipality permitted under a Phase I or Phase II Municipal Stormwater Permit (MS4 Permit).

The MS4 Permit does not authorize stormwater discharges to/from UIC wells unless the overflow or discharge from a UIC well drains to a NPDES municipal separate storm sewer system (MS4).

In those cases, the MS4 Permit does authorize the discharge and the conditions of the MS4 Permit directly apply. For example, if a UIC well is designed to infiltrate the 10-year storm and the excess stormwater from larger storms is routed to the MS4, then the requirements of the MS4 Permit apply to the UIC well excess. In both cases, the UIC wells must be registered, and rule authorized or have a state waste discharge permit.

To prevent redundancy between the NPDES and the UIC programs, the UIC Program rule allows permitted MS4s that also own or operate Class V UIC wells to satisfy the UIC rule by the presumptive approach (5.8 The Presumptive Approach for UIC Wells). MS4 permittees have the option of applying the Stormwater Management Programs (SWMPs) that comply with the MS4 Permit to the areas served by their municipal UIC wells pursuant to WAC 173-218-090 (1)(c)(C) in the manner described below. Municipalities not covered by the MS4 Permit may follow a similar approach. Note that the MS4 Permit does not require jurisdictions to fulfill all the requirements of the UIC Program.

Municipalities may fulfill the source control and operation and maintenance requirements for new and existing municipal UIC wells under the following conditions:

- All areas served by municipally owned and operated UIC wells must be included in a Stormwater Management Program (SWMP) that ensures appropriate siting, treatment, design, operation, and maintenance of new municipal UIC wells as well as source control activities (including targeted education and outreach) that are well-suited for the land uses in these areas.
    - MS4 permittees may have a combined SWMP that addresses UIC and NPDES permit requirements together, or they may have two separate SWMPs for the areas served respectively by their municipal UIC wells and by their MS4.
    - In areas not covered by the MS4 permit, municipalities may create a SWMP specifically for the areas served by municipal UIC wells.
- To comply with the UIC rule, jurisdictions must implement all of the following activities and include them in their SWMP:
    - Register all UIC wells, including existing and new wells.
    - Design, construct, operate, and maintain new UIC wells according to the specific-ations throughout Chapter 5 - UIC Program Guidelines.
    - Operate and maintain existing wells according to the specifications throughout Chapter 5 - UIC Program Guidelines.

Municipalities choosing not to develop and implement a SWMP in areas served by existing Class V UIC wells must:

- Conduct a well assessment (5.5 UIC Well Assessment) for each existing UIC well, and
- Create a Stormwater Site Plan (SSP) for the area served by each existing municipal UIC well. The SSP will include source control best management practices applicable to the activities present in the area and describe operation and maintenance procedures to keep the UIC well functioning properly to provide necessary treatment to protect groundwater.

All new municipal UIC wells must be sited, designed, constructed, managed, operated, and maintained according to the requirements throughout Chapter 5 - UIC Program Guidelines.

5.5 UIC Well Assessment

The assessment of an existing UIC well evaluates the potential risks to groundwater from the use of the UIC well and includes information such as:

- The land use and activities around the well (which affect the quality of the discharge),
- The local geology,
- Depth of the groundwater table in relation to the UIC well, and
- Whether the UIC well is located within a groundwater protection area.

Use this information to assess whether the well is a high threat to groundwater quality, by applying the information in 5.16 Determining Runoff Treatment Requirements for UIC Wells and 5.17 Classification of Vadose Zone Treatment Capacity for UIC Wells. If an existing UIC well is located in a groundwater protection area and the assessment determines that sufficient best management practices are not provided under the current conditions, retrofitting is required to protect groundwater quality. Existing UIC wells in groundwater protection areas that receive prohibited discharges (5.12 Prohibited Activities for UIC Wells) must either be decommissioned or the activities must be moved and isolated from the areas served by the existing UIC well. Only stormwater that has not mixed with prohibited discharge is allowed to be discharged to a UIC well.

A UIC well that was in use prior to the project is considered an existing well only if it remains in place. The well may be retrofitted or reconstructed in place without being considered a new well. Otherwise, if an existing well is moved, it is considered a new well, and the UIC requirements pertaining to new UIC wells apply. The owner must register the UIC well prior to construction to be considered an existing well.

Evaluating High Threat to Groundwater

For existing UIC wells, Ecology considers any of the following a high threat to groundwater for which the UIC well must be retrofitted.

- Existing UIC wells receiving prohibited discharges (5.12 Prohibited Activities for UIC Wells); these wells also require a separate groundwater discharge permit.
- Existing UIC wells receiving a high pollutant load where the vadose zone between the bottom of the UIC well and the top of the groundwater has no treatment capacity or the vadose zone conditions are unknown; retrofits must provide treatment prior to the discharge to the well.
- Existing UIC well structures completed below the groundwater table; retrofits must provide a minimum vertical separation and, if needed, treatment (see (5.16 Determining Runoff Treatment Requirements for UIC Wells and 5.17 Classification of Vadose Zone Treatment Capacity for UIC Wells). If a UIC well has standing water when it has not received recent stormwater inflows, it is likely completed below the groundwater table. See WAC 173-218-090(1)(b) for vertical separation requirements between the bottom of the UIC well and the

top of the groundwater table. The bottom most layer of the UIC well is the base elevation of the UIC well for regulatory and construction considerations.

- Site-specific information indicates that a groundwater quality problem exists in the vicinity of the existing UIC well.

A UIC well retrofit means to reduce the pollutant load from a UIC well to meet the nonendangerment standard by applying source control activity and/or structural controls such as a treatment BMP or create separation between the base of the well and the top of the groundwater table, WAC 173-218-030.

5.6 UIC Well Preservation and Maintenance Projects

A preservation or maintenance project is defined as preserving/protecting infrastructure by rehabilitating or replacing existing structures to maintain operational and structural integrity, and for the safe and efficient operation of the UIC well. Maintenance projects do not increase the traffic capacity of a roadway or parking area.

A UIC well that was in use prior to a preservation or maintenance project is considered an existing well only if it remains in place. The well may be retrofitted or reconstructed in place without being considered a new well. Otherwise, if an existing UIC well is moved, it is considered a new well and the UIC requirements pertaining to new UIC wells apply.

5.7 Using UIC Wells for Emergency Situations

In emergency situations, such as roadway flooding, a jurisdiction may install a UIC well that does not meet the requirements in this manual on a temporary basis. When weather permits, and within a year of the event, the jurisdiction must either fully decommission the well or ensure that the UIC well meets the requirements of the rule. Regardless of the duration of use, the jurisdiction must register the UIC well even if the registration is after the emergency situation subsides and the emergency well has been decommissioned. If the jurisdiction does not decommission the UIC well, they must also perform a well assessment (see 5.5 UIC Well Assessment).

For example, excessive winter rainfall overwhelms the capacity of the existing drainage system along a road. The water drains onto the road and turns to ice. The jurisdiction installs a new UIC well to fix the immediate problem and, once the weather permits, implements the required Runoff Treatment BMPs.

5.8 The Presumptive Approach for UIC Wells

New UIC wells that meet all of the requirements detailed throughout Chapter 5 - UIC Program Guidelines meet the presumptive approach to comply with the nonendangerment standard. Otherwise, the demonstrative approach (5.9 The Demonstrative Approach for UIC Wells) is required.

The presumptive approach requires the implementation of BMPs in Chapter 6 - Runoff Treatment, Flow Control, and LID BMP Library and/or Chapter 8 - Source Control of this manual or an equivalent manual, adopted at the time of construction. The manual addresses the following issues:

- The potential pollutant loading expected in the stormwater runoff for the planned land use (s) (see 5.17 Classification of Vadose Zone Treatment Capacity for UIC Wells)
- Source control of pollutants, especially those that are difficult to remove from stormwater by filtration, settlement, or other treatment technologies (see Chapter 8 - Source Control)
- Known treatment methods (see other sections of Chapter 6 - Runoff Treatment, Flow Control, and LID BMP Library)
- The potential treatment capacity of the vadose zone (see 5.16 Determining Runoff Treatment Requirements for UIC Wells)
- Siting (see the Site Suitability Criteria [SSC] in 6.5.6 Site Suitability Criteria (SSC))
- Design (see 5.10 Siting and Design of New UIC Wells or 6.5 Infiltration BMPs)
- Operation and maintenance (O&M) (see Appendix 6-A: BMP Maintenance Tables)

5.10 Siting and Design of New UIC Wells details the siting and design criteria to meet the presumptive approach for drywells designed to meet runoff treatment. 6.5 Infiltration BMPs details the design requirements for infiltration trenches and drywells.

The presumptive approach may not be used when none of the source control or treatment BMPs in the manual are expected to eliminate or reduce concentrations of the pollutant(s) of concern (WAC 173-218-090(1)(i)(D)) to meet the nonendangerment standard.

5.9 The Demonstrative Approach for UIC Wells

The demonstrative approach must show, with UIC well-specific emphasis, how the proposed Runoff Treatment BMPs will be protective of the groundwater quality and meet the nonendangerment standard. The UIC registration application submittal plans, technical reports, maps and diagrams, and analysis narratives must be sufficiently detailed to validate how the selected BMPs will currently, and into the future, provide for groundwater protection and help the UIC well comply with the nonendangerment standard (WAC 173-218-080).

New UIC wells must meet the demonstrative approach to meet the nonendangerment standard if the presumptive approach is not completely followed, or if for any reason a project proponent chooses not to directly apply all of the requirements of this manual (or an equivalent manual).

The documentation for the demonstrative approach is a site-specific analysis that demonstrates that the proposed discharge will comply with groundwater quality standards.

To be eligible for rule-authorization using the demonstrative approach, the following topic areas must be addressed and documented with the UIC well registration:

- Site-specific analysis of pollutant loading, including a risk assessment of downgradient and adjacent drinking water sources
- Site-specific analysis of the treatment capacity of the vadose zone, if used for treatment
- BMP selection process used
- Pollutant removal expected from the selected BMPs

- Technical basis supporting the performance claims for the selected BMPs
- Assessment of how the selected BMPs will comply with state groundwater quality standards and satisfy state all known, available, and reasonable methods of prevention, control, and treatment (AKART) requirements

5.10 Siting and Design of New UIC Wells

The requirements in this section apply to UIC wells built on or after February 3, 2006.

Minimum Siting Requirements for Rule-Authorization of New UIC Wells

The following Site Suitability Criteria (SSC) from 6.5.6 Site Suitability Criteria (SSC) apply to all UIC wells:

- SSC-1 Setback Criteria
- SSC-2 Groundwater Protection Areas
- SSC-3 High Vehicle Traffic Areas
- SSC-5 Depth to Bedrock, Water Table, or Impermeable Layer
- SSC-7 Seepage Analysis and Control
- SSC-8 Cold Climate and Impact of Roadway Deicing Chemicals
- SSC-9 Previously Contaminated Soils or Unstable Soils

UIC wells may be used to provide Flow Control for stormwater runoff where pollutant concentrations that reach groundwater will meet the Washington State groundwater quality standards (WAC 173-200) in the following situations:

- For flows greater than the water quality design storm (see Chapter 4 - Hydrologic Analysis and Design); or
- Where stormwater is treated prior to discharge into the UIC well according to the requirements in 5.16 Determining Runoff Treatment Requirements for UIC Wells.

Furthermore, If SSC-4 Soil Infiltration Rate/Drawdown Time and SSC-6 Soil Physical and Chemical Suitability for Treatment are met, the site is considered to have a high treatment capacity, and the existing site soils may be used to provide runoff treatment for flows through the UIC well (see 5.13 Source Control and Runoff Treatment Requirements for UIC Wells).

Restrictions on Siting UIC Wells

- Prohibited areas: Owners/operators may not site UIC wells in prohibited areas. See 5.12 Prohibited Activities for UIC Wells for the list of areas where stormwater discharges to UIC wells are prohibited.

- Soil contamination: Owners/operators may not site UIC wells where there are soil contaminants that could be transported to groundwater unless the site soil and groundwater is remediated and has been documented to comply with applicable state and federal cleanup standards prior to construction.

Siting UIC Wells Near Drinking Water Wells

Because a UIC well could be a potential source of contamination, it must be sited ≥ 100 feet from a drinking water well, outside of the sanitary control area of a public drinking water system, and ≥ 200 feet from a spring used for drinking water supplies. The design must consider the distance between the UIC well and a drinking water well based on the direction and rate of groundwater flow, and the vulnerability of the drinking water supply well to potential contamination, which is influenced by the following documented factors:

- Depth/distance from the bottom of the UIC well to the drinking water well screened interval (s), and
- Presence or lack of confining layer(s) between the bottom of the UIC well and the aquifer interval(s) used as the water supply, and
- Characteristics of the geologic material between the bottom of the UIC well and the aquifer.

Groundwater Protection Areas

At a minimum, basic treatment to remove solids prior to discharge to the UIC well is required for UIC wells located:

- In a wellhead protection area where the drinking water well is categorized with a high-susceptibility rating by the Washington State Department of Health, and/or
- Where a confining layer is not present between the base of the UIC well and the top of the aquifer used as a drinking water source, except when a UIC well receives insignificant and or low pollutant load from stormwater (see Table 5.4: Pollutant Loading Classifications for Solids, Metals, and Oil in Stormwater Runoff Directed to UIC Wells (continued)).

Local jurisdictions may have ordinances that apply to development within groundwater protection areas, such as sole source aquifers, groundwater management areas, wellhead protection areas, and areas designated as Critical Aquifer Recharge Areas. To locate the wellhead protection areas and the associated water districts in each county, see the Washington State Department of Health (DOH) Source Water Assessment Program maps at the following web address:

https://fortress.wa.gov/doh/swap/

Consult with the local jurisdiction for information on groundwater protection areas.

Design and Construction Requirements for Rule-Authorization of New UIC Wells

In order to be rule-authorized under the presumptive approach, UIC wells must be designed and installed in accordance with this manual or an equivalent manual adopted at the time of construction. The following subsections include additional requirements for design and construction of UIC wells.

Prevention of Clogging During Construction

In order to prevent clogging, UIC wells must be protected from sediment in runoff generated during construction. See Chapter 7 - Construction Stormwater Pollution Prevention for construction BMPs to prevent other pollutants from entering the UIC well during the construction phase of a project.

Stormwater Infiltration Rate/Drawdown Time

In most cases, UIC wells are designed to completely drain ponded runoff within 48 to 72 hours after flow to the UIC well has stopped. If the UIC well is designed to meet a runoff treatment requirement, the long-term infiltration rate (see 6.5.4 Determining the Design Infiltration Rate of the Native Soils) must be sufficient to accommodate the water quality design storm (see Chapter 4 - Hydrologic Analysis and Design).

Vertical Separation for Rule-Authorization Using the Presumptive Approach

WAC 173-218-090 requires that new Class V UIC wells used for stormwater management must not directly discharge into groundwater. A 5-foot separation between the bottom of the well and the top of the groundwater is required, unless a demonstrative approach confirms that a separation of 3 feet will meet the nonendangerment standard.

The required depth to groundwater/vertical separation between the base of the UIC well and the top of the groundwater table for rule-authorization using the presumptive approach depends on the treatment capacity of the unsaturated zone. 5.16 Determining Runoff Treatment Requirements for UIC Wells and 5.17 Classification of Vadose Zone Treatment Capacity for UIC Wells provide a method for determining the treatment requirements based on the treatment capacity of the vadose zone and the pollutant loading classification of the stormwater runoff directed to the UIC wells.

The minimum vertical separation is 5 feet between the base of a UIC well and the highest elevation between the seasonal high groundwater table, bedrock, hardpan, or other low-permeability layer.

Vertical Separation When 5-Foot Minimum Separation Cannot Be Met

If the vertical separation required for the presumptive approach cannot be met:

- Rule-authorization can be obtained using the demonstrative approach (see 5.9 The Demonstrative Approach for UIC Wells), or
- A reduction in separation to as little as 3 feet can be considered under the presumptive approach provided:
    - The treatment requirements are otherwise met (see 5.16 Determining Runoff Treatment Requirements for UIC Wells and 5.17 Classification of Vadose Zone Treatment Capacity for UIC Wells), and:

    - The groundwater mounding analysis, the volumetric water holding capacity of the zone receiving the water, and the design of the overflow and/or bypass structures are evaluated by the design professional and deemed adequate to prevent overtopping and to meet the SSC specified in this section.

5.11 Operation and Maintenance of UIC Wells

The UIC rule requires that wells are operated and maintained to protect groundwater quality. Maintenance of UIC wells prevents clogging and contamination from materials that collect in the well over time. The following required preventive maintenance activities will help maintain UIC function:

- Treatment for solids removal or a catch basin with a down-turned elbow upstream of discharge to the UIC well to promote the long-term infiltration capacity and reduce the need for maintaining the UIC wells, as well as reduce the long-term accumulation of contaminants in the vadose zone
- Frequent inspections and regular maintenance to improve the long-term performance of UIC wells
- Periodic removal of debris and sediment from the drywell to reduce or eliminate the buildup of materials that could inhibit infiltration
- Checking for structural damage and repair as needed

See Appendix 6-A: BMP Maintenance Tables for recommended maintenance criteria and inspection frequencies.

5.12 Prohibited Activities for UIC Wells

UIC wells may not receive stormwater from the activities and conditions listed below:

- Vehicle maintenance, repair, and service
- Commercial or fleet vehicle washing
- Airport/airplane deicing
- Storage of treated lumber
- Storage or handling of hazardous materials
- Generation, storage, transfer, treatment, or disposal of hazardous wastes
- Handling of radioactive materials
- Solid waste handling facilities, including compost and biosolid facilities, except for those that recycle only glass, paper, plastic, or cardboard
- Concrete recycling facilities that generate, store, or handle crushed concrete
- Asphalt recycling facilities that generate, store, or handle crushed asphalt

- Fire fighting training facilities
- Industrial areas where mechanical maintenance activities occur
- Industrial or commercial areas that have outdoor processing, handling, or storage of raw solid materials or finished products unless the facility has specific management plans for proper storage and spill prevention, control, and containment appropriate to the types of materials handled at the facility (see Chapter 8 - Source Control for information on stormwater pollution prevention plans and source control)
- Contaminated sites when the stormwater would increase the mobility of the contaminants at the site. For example, a drywell could not be used upgradient of or over the contaminant plume at a leaking underground storage tank site. The stormwater could increase the movement of the contaminants.
- Process water from the production area of an animal feeding operation.
- Land use, activity, or infiltration determined to be a significant contributor of pollutants to waters of the State or a site release of hazardous substances from historical or current activities resulting in contamination of soil, groundwater, surface water, if the groundwater is in direct communication with surface water, or sediment, which is prohibited under the Model Toxics Control Act (Chapter 173-340 WAC) and Sediment Management Standards (Chapter 173-204 WAC).

Because of the potential to contaminate groundwater, a UIC well must be individually authorized under a waste discharge permit to receive stormwater from any areas subject to the activities listed above. Ecology does not consider conventional runoff treatment to be protective of groundwater in these situations. Stormwater from areas subject to the activities listed above must be handled on-site with a closed-loop system or discharged to the sanitary sewer, if allowed by the local jurisdiction.

However, careful design of these project sites may allow UIC wells to handle some of the stormwater runoff that will be generated. Stormwater from any portions of the site or facility that do not come in contact with these activities (or the areas of the facility associated with these activities) are allowed to be discharged to a UIC well following the presumptive approach.

See WAC 173-218-040(5)(b) for a list of examples of other prohibited UIC wells.

5.13 Source Control and Runoff Treatment Requirements for UIC Wells

The UIC rule bases source control and runoff treatment requirements on the types and quantities of pollutants expected from the proposed land use contributing storm runoff to the UIC well.

The rule presumes a UIC well meets the nonendangerment standard and is rule-authorized if the designer follows the guidelines in this section based on the following:

- Application of source control BMPs to control loading of pollutants that are difficult to remove from stormwater by filtration, settlement, or other treatment technologies, and

- Appropriate treatment of runoff to remove pollutants, which may be achieved by either or both:
    - Application of treatment to remove pollutants before discharging stormwater into the UIC well
    - Availability of appropriate vadose zone treatment capacity to remove the solid phase of pollutants in stormwater by filtration and adsorption (see 5.16 Determining Runoff Treatment Requirements for UIC Wells and 5.17 Classification of Vadose Zone Treatment Capacity for UIC Wells)

Source Control

Source control is necessary to protect groundwater from pathogens, pesticides, nitrates, road salts and other anti-icing and deicing chemicals, fuel additives, and many other pollutants in urban runoff, as well as accidental spills.

The operational and structural source control BMPs that are also required to meet the nonendangerment standard for various land uses are described in Chapter 8 - Source Control or other equivalent manuals. Targeted education and outreach may also be a necessary source control measure.

Source control BMPs can significantly reduce clogging and pollutants, especially solids, and must be used at all project sites. Protect UIC wells during the construction phase to prevent sediment from entering the UIC well. Implement the BMPs in Chapter 7 - Construction Stormwater Pollution Prevention or in an equivalent manual. Where there are no existing runoff treatment BMPs to practically address a pollutant issue and where filtration by the vadose zone cannot provide adequate removal of pollutants, owners are required to use source control BMPs to meet the nonendangerment standard. Otherwise, the discharge to the UIC well is prohibited (WAC 173-218-090(1)(c)(i)(D)). See 5.12 Prohibited Activities for UIC Wells for prohibited discharges.

Wherever practicable, reduce the exposure of stormwater to these contaminants by one or more of the following:

- Careful attention to the product label application rates
- Targeted product use to avoid contamination of stormwater runoff
- Careful management of the storage and use of products
- Separation of areas where products are used from contributing areas that discharges to a UIC well
- Spill response planning

Contact the local jurisdiction to determine whether specific source control requirements apply to your project in addition to those methods described in this manual for the proposed land use.

Runoff Treatment

The BMPs chosen for the site must remove or reduce the target pollutants to levels that will comply with State groundwater quality standards when the discharge reaches the groundwater table or first comes into contact with an aquifer (see Chapter 173-200 WAC). Each BMP is designed to reduce or eliminate certain pollutants. See other sections in Chapter 6 - Runoff Treatment, Flow Control, and LID BMP Library for specific Runoff Treatment BMP design criteria.

Removing solids from stormwater runoff before it is discharged to a UIC well helps preserve infiltration rates over the long term. UIC wells used for flow control are required to have solids removed prior to discharge. Treatment for solids removal (basic treatment, see the Glossary for definition) must be designed, constructed, operated and maintained in accordance with this manual or an equivalent manual.

Designers may alternatively use the demonstrative approach (5.9 The Demonstrative Approach for UIC Wells) should they wish to install a BMP that is not included in this manual.

Some pollutants may require additional treatment beyond that provided by the approved BMPs described in other sections in Chapter 6 - Runoff Treatment, Flow Control, and LID BMP Library. The text below discusses these pollutants.

Bacteria

Fecal coliform bacteria and other pathogens in stormwater come from many sources. Examples are manure fertilizers, pet waste, and animal feeding operations.

Runoff treatment BMPs are unreliable in removing fecal coliform bacteria and other pathogens from runoff. Because of this, UIC wells shall not receive direct stormwater discharges from areas or sites that generate high loadings of fecal coliform bacteria, such as animal feeding operations.

Alternatively, runoff from sites generating high loadings of bacteria and pathogens may be:

- Discharged to the sanitary sewer, if allowed by the local jurisdiction; or
- Used for crop irrigation, as long as other applicable requirements are met; or
- Directed to a bioretention or biofiltration BMP after the nutrient loading is addressed; or
- Diverted through stormwater treatment wetlands (BMP T5.73: Stormwater Treatment Wetlands) prior to discharge to a UIC well.

Municipal UIC well owners must implement appropriate source control, targeted education and outreach, and illicit discharge detection and elimination programs in areas served by their UIC wells to prevent pet wastes from contaminating stormwater and to control other sources of pathogens.

UIC wells in the vicinity of land application areas (i.e., along adjacent roadways) must be protected by appropriate buffers and berms to prevent manure-contaminated runoff from entering the UIC well. Best practices for setbacks, nutrient loading, and timing of application must also be implemented.

Private UIC well owners must ensure that their UIC wells are appropriately protected from sources of bacterial contamination.

Soluble Pollutants, Pesticides, Fertilizer, and Nutrients

Many soluble pollutants that are commonly found in stormwater (including pesticides, fertilizers, road salts, and other chemical pollutants) are very difficult to remove from stormwater. Source controls applicable to the land use and activities at the site are required to reduce the contamination of stormwater from these chemicals.

Areas such as parks, playgrounds, golf courses, public ball fields, cemeteries, and urban landscape typically use pesticides and fertilizers for landscape management. Examples of other activities that generate high nutrient loads include commercial composting, commercial animal handling areas, nurseries, and land application areas.

Pesticides include a host of chemicals with varying chemical fate and transport characteristics. Some pesticides travel to groundwater more readily because they are more water soluble and less likely to "stick" or sorb to soil particles. These pesticides need treatment by a biological treatment method, such as a biofiltration swale or constructed wetland. UIC wells that receive stormwater with pesticides that use one of these biological treatment methods are rule-authorized when they are registered, providing this technical guidance is followed.

If UIC owners wish to use a different treatment method for pesticides, they may apply to the department for rule-authorization using the demonstrative approach outlined in 5.9 The Demonstrative Approach for UIC Wells. Nonbiological treatment systems are ineffective at removing these pollutants from runoff. Instead, runoff from these types of landscaped areas should be directed to bioretention, biofiltration, or constructed wetland BMPs prior to discharge to UIC wells. Stormwater with fertilizer or nutrients may be used to irrigate crops and/or landscaped areas in accordance with other applicable requirements.

Ecology encourages use of the following practices:

- Limited use of applied chemicals
- Site design to minimize runoff from the landscaped surface
- Development of a pesticide management plan

UIC wells in the vicinity of land application areas (i.e. along adjacent roadways) must be protected by appropriate buffers and berms to prevent manure-contaminated runoff from entering the UIC well. Best practices for setbacks, nutrient loading, and timing of application must also be implemented.

Industrial Activities with Requirements to Monitor for Nitrate, Nitrite, Ammonia, or Phosphorus

The U.S. EPA lists industrial activities that have monitoring requirements for nitrate, nitrite, ammonia, or phosphorus. Runoff from sites where nitrate, nitrite, ammonia, or phosphorus come into contact with stormwater must be directed to one of the following:

- Bioretention or biofiltration BMPs
- Constructed wetlands prior to discharge

- Sanitary sewer, if allowed by the local jurisdiction
- Municipal drainage system that discharges to surface water, if allowed by the local jurisdiction and following treatment for removal of solids

Facilities may complete a no exposure certification as part of Ecology's UIC well registration process for exemption from these requirements. In order to qualify, no outdoor processing, handling, or storage of raw solid materials or finished products may take place at the facility. Industrial facilities that qualify for no-exposure certification may use the tables in 5.17 Classification of Vadose Zone Treatment Capacity for UIC Wells to determine treatment requirements.

Commercial Site Roofs With Ventilation for Commercial Indoor Pollutants

Roof runoff from commercial businesses with ventilation systems specifically designed to remove commercial indoor pollutants must be evaluated on a case-by-case basis to identify the pollutants of concern and the appropriate treatment requirements.

In general, this runoff may be classified as a "medium" pollutant loading source (see Table 5.4: Pollutant Loading Classifications for Solids, Metals, and Oil in Stormwater Runoff Directed to UIC Wells (continued)), and the requirements of this section may be applied to discharges from these areas to UIC wells.

Commercial Site Outdoor Handling or Storage

Treatment for solids removal (basic treatment) is required at commercial sites with outdoor handling or storage of raw solid materials. Examples include gravel, sands, logs, salts, and compost.

Industrial Site Roofs

Roof runoff from industrial facilities must be evaluated on a case-by-case basis and should be treated according to the other Best Management Practice requirements for the facility.

Industrial Sites Outdoor Handling or Storage

Owners at industrial sites where outdoor processing, handling, or storage of raw solid materials or finished products, including outdoor loading areas for these materials or products, takes place must provide solids removal (basic treatment). These are sites defined by the U.S. EPA (40 CFR 122.26(b)(14)).

5.14 Spills and Illicit Discharges to UIC Wells

Appropriate spill control, prevention, and response measures for various land uses are described in Chapter 8 - Source Control. The spill control requirements in Chapter 8 - Source Control apply to all stormwater discharges to UIC wells. Any spills that pose a threat to groundwater quality should be reported to Ecology. Petroleum spills that enter a UIC well must be reported to Ecology. Report a spill immediately to both:

- 1-800-258-5990 (Washington Emergency Management Division)
- 1-800-424-8802 (National Response Center)

There are no penalties for reporting a spill unnecessarily, but there may be significant penalties for not reporting one.

5.15 Deep UIC Wells

General Guidance for Deep UIC Wells

UIC wells that extend below an upper confining layer and discharge into the underlying vadose zone are designated by Ecology as deep UIC wells. This includes drywells where drilling extends through a surficial till layer into the vadose zone below. Local jurisdictions may impose additional limits on the total depth of these UIC wells based on specific hydrologic conditions and other considerations.

Ecology recommends that project proponents explore alternative approaches to stormwater management before deciding to use a deep UIC well. Projects using deep UIC wells must provide the following:

- A hydrogeologic study, performed by a licensed hydrogeologist, that details the following, to determine if contamination could occur:
    - Consideration of potential changes to the aquifer.
    - Infiltration testing to determine mounding affects.
    - Identification of the direction and rate of groundwater flow.
    - Evaluation of the treatment capacity of the vadose zone (see 5.16 Determining Runoff Treatment Requirements for UIC Wells and 5.17 Classification of Vadose Zone Treatment Capacity for UIC Wells).
    - Determination as to whether the proposed deep UIC well is located within a groundwater protection area (GWPA) such as a wellhead protection area.
    - If a deep UIC well is located within a GWPA, assessment of the vulnerability of the drinking water supply source as follows:
        - Evaluate whether the introduction of stormwater will affect the quality of the groundwater at the water supply well.
        - Describe the following hydrogeologic factors that may influence the vulnerability of a groundwater supply source:
            - Depth of the drinking water well screened interval in relation to the deep UIC well infiltration depth, and
            - Presence or lack of a confining layer between the land surface and the aquifer interval, and

    - Type of material between the land surface and the aquifer, and between the bottom of the deep UIC well and the aquifer.

- An operation and maintenance manual for the deep UIC wells and treatment structures that includes a schedule for their implementation.
- A list of source control BMPs that will be implemented to minimize solids entering the deep UIC well.
- Description of any additional special runoff treatment needs and site operation requirements.
- A minimum of basic treatment for all discharges to drywells to remove suspended sediments, and to prevent sediment entering the well structure and vadose zone.
- A minimum 15-foot separation between the base of the drywell and the surface of the seasonal high groundwater table.
- Stabilization of the site prior to the drywells going on line to prevent sediment entering the drywells.
- A landscape management plan.
- Sealing of any impermeable layers that are penetrated during drilling, to prevent aquifer interconnection if a perched aquifer or other saturated stratum is penetrated.

A surface seal should also be included in the final completion of a deep drywell.

Ecology recommends hiring a Washington licensed well driller for construction of deep UICs. However, most UIC wells are not regulated by the Well Construction Act.

All deep UIC wells must meet the following conditions:

- Documentation of notification and summary of discussion with downgradient and adjacent drinking water well owners
- Recommend Use of Licensed Driller
- Minimum 15-foot vertical separation from saturated zone
- Operational Maintenance Manual
- A list of source control BMPs that will be implemented to minimize solids entering the deep UIC well
- Additional special runoff & enhanced treatment needs
- Sealing of any impermeable layers that are penetrated during drilling
- A surface seal for final completion of a deep drywell

Deep UIC Wells within Sensitive Groundwater Areas

Groundwater protection areas are by or close by a surrounding community and non-transient noncommunity water system, that uses groundwater as a source of drinking water (40 C.F.R. 144.87) and other sensitive groundwater areas critical to protecting underground sources of drinking water from contamination; such as sole source aquifers, highly productive aquifers supplying private wells, critical aquifer recharge areas and/or other state and local areas determined by state and local governments. Deep UIC wells that extend below an upper confining layer and discharge into the underlying vadose zone may require greater protection from potential pollution sources considered to be a high threat to groundwater (WAC 173-218-030) due to the absence of a confining layer between the UIC well and drinking water supplies.

Requirements for Deep UIC Wells in Wellhead Protection Areas

Within wellhead protection areas (WHPAs), enhanced measures and procedures are necessary to protect groundwater supplies by limiting or prohibiting certain activities. Each WHPA is divided into wellhead protection zones (WHPZs) which may be characterized as a minimum distance or as a groundwater time of travel (TOT).

Prior to submitting an application to Ecology, the proponent for deep UIC well(s) must notify downgradient and adjacent drinking water well owner(s), water purveyor(s), and water district(s) (Owners) of the proposal to install a deep UIC well within the drinking water WHPA. The notification must include the proposed well depth, land use information, and any proposed treatment of the fluids to the UIC well. Documentation of notification and a summary of discussion between the proponent and the Owner(s) must be included in the application for review by Ecology. UIC applications for deep UIC wells are not considered complete until such notification and summary are submitted.

Deep UIC Well Rule Authorizations Within WHPZs

Table 5.1: Prohibitions and Additional Conditions for Facilities and Activities Within the Area(s) Draining to a Deep UIC Well (continued) describes where deep UIC wells are prohibited or where additional conditions are required for rule-authorization. Depending on which WHPZ the facility or activity is located in, some UIC wells may be prohibited or may be required to meet one or more additional conditions (a, b, c, d, and e, as listed in the table).

In addition to the facilities and activities listed in Table 5.1: Prohibitions and Additional Conditions for Facilities and Activities Within the Area(s) Draining to a Deep UIC Well (continued), other land use, activity, or infiltration determined to be a significant contributor to pollution may also be prohibited or require further conditions for rule-authorization.

<u>**Sanitary Control Areas**</u>

All UIC wells, including deep UIC wells, are prohibited within the sanitary control area (100 feet from the wellhead). These areas are vulnerable to spills and other human activities and are critical to the protection and quality of drinking water wells and the groundwater within this WHPZ. Therefore, the most effective protective measure is a moratorium on stormwater injection activities within this zone.

Six-Month Time of Travel WHPZ

Within the six-month TOT WHPZs, only runoff from residential roofs are appropriate for non-restricted stormwater discharge to the subsurface. In some circumstances, Ecology may consider conditionally approved discharges to deep UIC wells for parks and some commercial roofs.

One-Year Time of Travel WHPZ

Allowed activities in the area that drains to a deep UIC well located within the one-year TOT WHPZ include those allowed in the six-month TOT WHPZ in addition to conditionally-approved residential driveways and small light-use parking lots.

Five-Year Time of Travel WHPZ

The five-year TOT WHPZ, with its larger volume and potential for longer residency times, can provide greater treatment opportunities for stormwater moving through soils. These natural treatment conditions, in conjunction with enhanced filtration technologies, provide greater treatment efficiencies for a wider variety of stormwater disposal activities. In addition to all the allowed activities identified in the six-month TOT WHPZ, UIC registrations for commercial roofs susceptible to industrial emissions may be considered for conditional rule-authorization.

Ten-Year Time of Travel WHPZ

Within the ten-year TOT WHPZ, all allowed activities in the five-year TOT WHPZ may be rule-authorized. Additionally, commercial roof runoff and residential driveways may be rule authorized through the presumptive approach without conditional approval. Stormwater injections from parking lots that meet the definition of "high-use site" may be considered in the WHPZ when they are conditionally rule-authorized. Stormwater from non-commercial airports, automobile refueling stations, and industrial roof runoff may be conditionally rule-authorized when paired with an individual state waste discharge permit.

Table 5.1: Prohibitions and Additional Conditions for Facilities and Activities Within the Area(s) Draining to a Deep UIC Well

Type of Activity Draining to the Deep UIC Well	UIC well location within 100 feet	UIC well location within 6-month time of travel	UIC well location within 1-year time of travel	UIC well location within 5-year time of travel	UIC well location within 10-year time of travel
Multi-unit residential roof runoff	Prohibited	a	a	a	a
Commercial/Municipal roof runoff (no emissions)	Prohibited	a,b	a,b,d	a,b,d	a,b,d
Commercial/ Municipal	Prohibited	Prohibited	Prohibited	a,b,c,d	a,b,c,d

Table 5.1: Prohibitions and Additional Conditions for Facilities and Activities Within the Area(s) Draining to a Deep UIC Well (continued)

Type of Activity Draining to the Deep UIC Well	UIC well location within 100 feet	UIC well location within 6-month time of travel	UIC well location within 1-year time of travel	UIC well location within 5-year time of travel	UIC well location within 10-year time of travel
roof runoff (with emissions)					
Residential driveways	Prohibited	Prohibited	a,b	a,b	a,b
Vegetated areas (parks, school fields, etc.)	Prohibited	a,b,c,d	a,b,c,d	a,b,c,d	a,b,c,d
Parking lots	Prohibited	Prohibited	a,b,c,d	a,b,c,d	a,b,c,d
Parking lots that meet the definition of "high-use site"	Prohibited	Prohibited	Prohibited	Prohibited	a,b,c,d
Non-commercial airports (FBO - On fuel pad only-No mobile fueling)	Prohibited	Prohibited	Prohibited	Prohibited	a,b,c,d,e
Automotive refueling stations (only stormwater separated from fuel pad)	Prohibited	Prohibited	Prohibited	Prohibited	a,b,c,d,e
Industrial roof runoff	Prohibited	Prohibited	Prohibited	Prohibited	a,b,c,d,e
Fire fighting training facilities	Prohibited	Prohibited	Prohibited	Prohibited	Prohibited
Train terminals and train yards	Prohibited	Prohibited	Prohibited	Prohibited	Prohibited
Recycling facilities	Prohibited	Prohibited	Prohibited	Prohibited	Prohibited
Treated Lumber Manufacturing Facilities	Prohibited	Prohibited	Prohibited	Prohibited	Prohibited
Fuel refinery	Prohibited	Prohibited	Prohibited	Prohibited	Prohibited
Fuel depot	Prohibited	Prohibited	Prohibited	Prohibited	Prohibited
Vehicle maintenance, repair and service	Prohibited	Prohibited	Prohibited	Prohibited	Prohibited

Table 5.1: Prohibitions and Additional Conditions for Facilities and Activities Within the Area(s) Draining to a Deep UIC Well (continued)

Type of Activity Draining to the Deep UIC Well	UIC well location within 100 feet	UIC well location within 6-month time of travel	UIC well location within 1-year time of travel	UIC well location within 5-year time of travel	UIC well location within 10-year time of travel
Commercial or fleet vehicle washing	Prohibited	Prohibited	Prohibited	Prohibited	Prohibited
Airport de-icing activities	Prohibited	Prohibited	Prohibited	Prohibited	Prohibited
Storage of treated lumber	Prohibited	Prohibited	Prohibited	Prohibited	Prohibited
Storage or handling of hazardous materials	Prohibited	Prohibited	Prohibited	Prohibited	Prohibited
Generation, storage, transfer, treatment, disposal of hazardous wastes	Prohibited	Prohibited	Prohibited	Prohibited	Prohibited
Handling of radioactive materials	Prohibited	Prohibited	Prohibited	Prohibited	Prohibited
Solid waste handling facilities	Prohibited	Prohibited	Prohibited	Prohibited	Prohibited
Concrete recycling facilities	Prohibited	Prohibited	Prohibited	Prohibited	Prohibited
Asphalt recycling facilities	Prohibited	Prohibited	Prohibited	Prohibited	Prohibited
Contaminated sites	Prohibited	Prohibited	Prohibited	Prohibited	Prohibited
Concentrated Animal Feeding Operation (CAFO)	Prohibited	Prohibited	Prohibited	Prohibited	Prohibited
a. Hydrogeologic Study b. Site-specific analysis that demonstrates the proposed discharge will comply with groundwater quality standards c. Stormwater Pollution Prevention Plan d. Integrated landscape management plan e. Must apply for, and be issued, a state waste discharge permit					

5.16 Determining Runoff Treatment Requirements for UIC Wells

For all stormwater discharges to UIC wells, some form of treatment is required. Treatment may be provided by the vadose zone or by structural treatment BMPs, and depends on the geologic conditions, the land use, and activities at the project site.

Designers intending to use the presumptive approach can use the tables in 5.17 Classification of Vadose Zone Treatment Capacity for UIC Wells to identify the necessary level of Runoff Treatment prior to discharge to the UIC well.

Designers for industrial sites with no outdoor processing, storage, or handling of raw or finished products may use the tables in 5.17 Classification of Vadose Zone Treatment Capacity for UIC Wells. Designers may not use the tables in 5.17 Classification of Vadose Zone Treatment Capacity for UIC Wells for stormwater runoff from industrial activities, outdoor processing, storage, or handling of raw or finished products; or areas where stormwater runoff comes into contact with leachate or other prohibited discharges.

Where on-site or nearby geologic and groundwater depth information is available, designers can use the tables in 5.17 Classification of Vadose Zone Treatment Capacity for UIC Wells to evaluate whether the presumption that a stormwater discharge from a road, commercial site, or residential site to a UIC well meets the nonendangerment standard for solids, metals, oil, grease, and polycyclic aromatic hydrocarbons (PAHs).

Used together, the tables in 5.17 Classification of Vadose Zone Treatment Capacity for UIC Wells identify Ecology's presumption about the extent to which the vadose zone provides sufficient treatment for a given pollutant loading classification and whether additional treatment is necessary to meet the groundwater quality standards for these pollutants.

Depending on conditions, treatment may be as simple as a catch basin with a downturned elbow, or as complex as an oil and water separator followed by basic and/or metals removal. See Table 5.5: Treatment Required for Solids, Oil, and Metals (continued) for treatment requirements as a function of pollutant loading classification and vadose zone treatment capacity.

Exceptions Based on Site-Specific or Local Studies

Exceptions to the tables in 5.17 Classification of Vadose Zone Treatment Capacity for UIC Wells may be made under any of the following circumstances:

- Local planning efforts have generated an alternative method that meets the nonendangerment standard based on local conditions. For example, local jurisdictions may choose to allow changes in the pollutant loading categories in Table 5.4: Pollutant Loading Classifications for Solids, Metals, and Oil in Stormwater Runoff Directed to UIC Wells (continued) based on source control BMPs implemented at a site.

- More detailed site-specific data are gathered by the project proponent and local permission is granted under a locally developed stormwater management program.

- The required thicknesses of the vadose zone treatment layer listed in Table 5.3: Vadose Zone Treatment Capacity (continued) may be as little as 3 feet for a high-capacity treatment matrix and 6 feet for a medium-capacity treatment matrix when all of the following requirements are met:
  - The UIC well is regulated under a local stormwater management program that satisfies the requirements in 5.4 Meeting the Nonendangerment Standard, and local jurisdiction approves the change in minimum thicknesses.
  - The pollutant loadings are insignificant or low.
  - Reliable on-site information is available. Designers may use borehole logs within 0.25 miles of the proposed UIC well if geologic conditions are consistent.
  - Site-specific, long-term water level data history justifies the minimal separation from the groundwater table in cases where the 3 feet of high-capacity treatment matrix provides the entire separation between the bottom of the structure and the seasonal high groundwater table.
  - Potential mounding of infiltrating stormwater above the groundwater table is likely. Additional separation or treatment may be required.

Vadose Zone Treatment Capacity

In general, the vadose zone may provide adequate filtration, adsorption, and other pollutant reduction capacity to meet the nonendangerment standard for solids, metals, oil, grease, and PAHs. Designers may use the tables in 5.17 Classification of Vadose Zone Treatment Capacity for UIC Wells to evaluate the use of the vadose zone for treatment and to determine treatment requirements to reduce concentrations of these pollutants prior to discharge to the UIC well.

Studies of stormwater pollutant concentrations in water through and below infiltration systems show mixed results in the effectiveness of vadose zone filtration in protecting groundwater quality (USEPA, 1999), (Pitt et al., 1999), (Mason et al., 1999), and (Appleyard, 1993).

Designers can eliminate many of the problems documented in these studies by proper siting, design, maintenance, and use of the UIC well. Additional actions to offset problems are enhanced source control, spill prevention and response plans, and additional treatment prior to discharge to the UIC well, or prohibition of the discharge.

Studies of subsurface infiltration systems also indicate that filtered and adsorbed pollutants accumulate in the vadose zone at depths of less than a few feet below the UIC well at concentrations that may require soil cleanup activities upon decommissioning of a UIC well (Mikkelsen et al., 1996a), (Mikkelsen et al., 1996b), and (Appleyard, 1993).

Because contaminated soil removal and disposal costs can be considerable, project proponents may wish to consider including pretreatment BMPs to remove solids from stormwater runoff and avoid potential cleanup requirements following long-term use of the UIC well.

5.17 Classification of Vadose Zone Treatment Capacity for UIC Wells

The treatment capacity of the vadose zone is classified as high, medium, low, or none. Ecology bases these classifications on minimum thickness and the characteristics of the geologic materials that make up the proposed treatment layer.

The tables include several different ways of describing the geologic materials: grain-size distribution, sand-to-fines ratio, well log lithology, geologic names, and infiltration rate, as defined in Table 5.2: Examples of Geologic Material Descriptions.

Table 5.2: Examples of Geologic Material Descriptions

Geologic Material Description Method	Example
Grain size characteristics	Materials with median grain size < 0.125 mm
Sand-to-fines ratio	Having a sand to silt/clay ratio of < 1:1 and sand plus gravel < 50%
Well log lithology	Sandy or silty clay Silt Clayey or sandy silt Sandy loam or loamy sand Silt/clay with interbedded sand
Geologic name	This category includes geologic terms that indicate provenance, including till, hardpan, caliche, and loess
Infiltration rate	Infiltration rate of ≥ 12 in/hr

The ability of geologic materials to filter or adsorb pollutants such as solids, oils, and metals is related to grain size, the amount of organic matter, and the presence of clays, among other factors. Native organic matter improves adsorption and filtration (Ingloria et al., 1997) but is rarely found at depths below UIC wells.

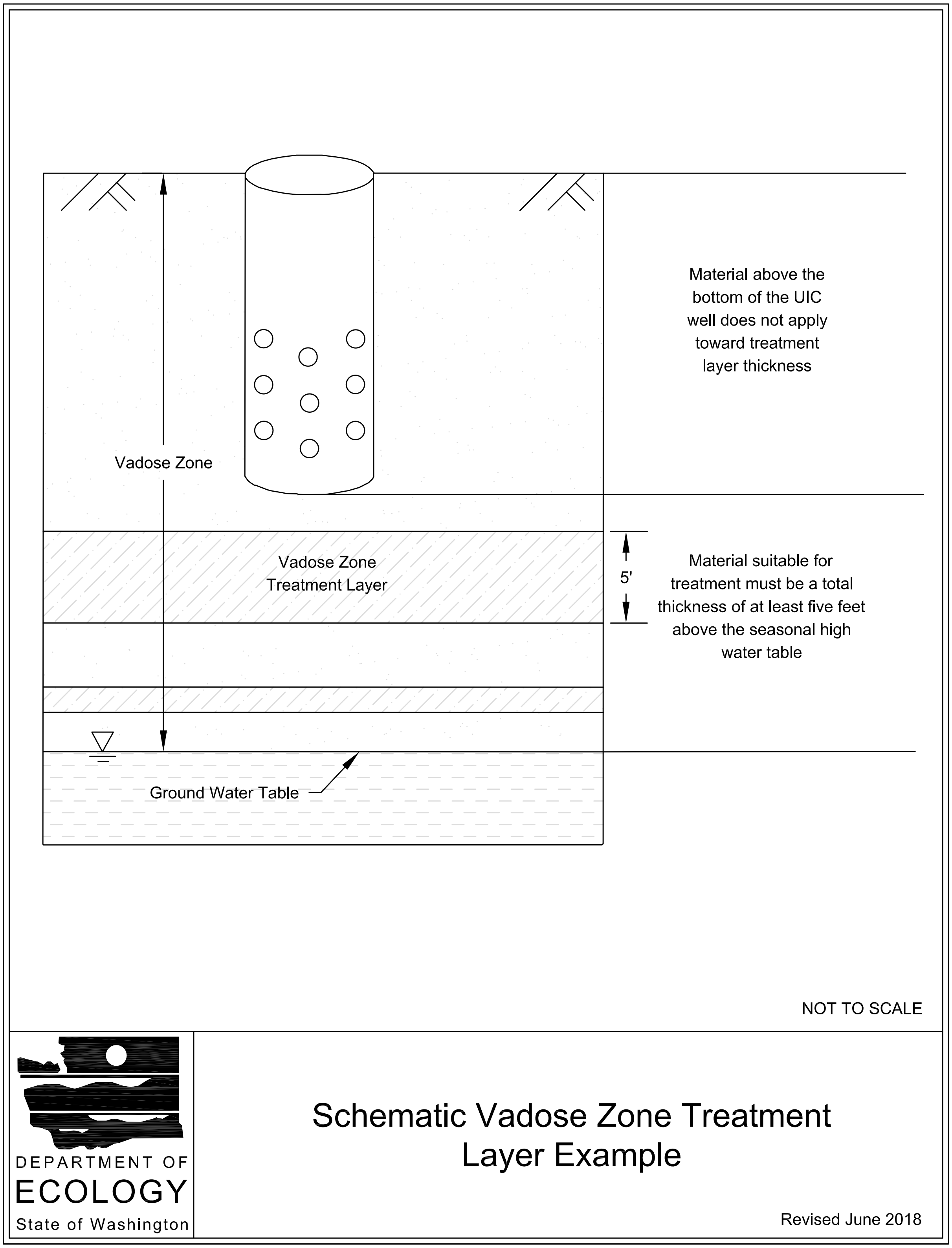
Geologic materials classified as having a high treatment capacity are fine-grained with a greater capacity to filter discharges. These materials also tend to remove pollutants by chemical reactions such as cation exchange capacity (CEC) and sorption. These may be mixtures of materials where silt and clay fill the void spaces in the matrix of the coarser materials. More compaction results in better filtration. High-capacity treatment layers must total a minimum of 5 feet between the bottom of the UIC well and the seasonal high groundwater table to provide an adequate level of treatment (see Figure 5.1: Schematic Vadose Zone Treatment Layer Example).

Geologic materials classified as having a medium treatment capacity provide moderate to high filtration and have minor or no chemically reactive characteristics. Medium-capacity treatment layers must total a minimum of 10 feet to provide an adequate level of treatment.

Geologic materials that have a low treatment capacity provide some minimal filtration. Although the sand and gravel mixtures in this category may provide some filtration when the UIC well is initially installed, preferential flow paths develop that contribute to relatively rapid reduction in treatment capacity. Low-capacity treatment layers must total a minimum of 25 feet between the bottom of the UIC well and the seasonal high groundwater table to provide an adequate level of treatment.

Geologic materials that are classified as having no treatment capacity do not provide filtration to remove pollutants. Since this type of material does not have treatment capacity, basic treatment of stormwater (Removal of Solids) is always required prior to discharge to the UIC well, except for sites that are classified as having an insignificant pollutant load in Table 5.4: Pollutant Loading Classifications for Solids, Metals, and Oil in Stormwater Runoff Directed to UIC Wells (continued).

Figure 5.1: Schematic Vadose Zone Treatment Layer Example



Classification of Vadose Zone Treatment Capacity

Site exploration or information from the site or, a site nearby, is required to obtain sufficient data to classify the treatment capacity of the vadose zone materials using Table 5.3: Vadose Zone Treatment Capacity (continued).

In some cases, geologic information may be available from regional geology maps in publications from the Washington State Department of Natural Resources or the U.S. Geological Survey, from a well borehole log(s) in the same quarter-section on Ecology's well log web page (https://ecology.wa.gov/Regulations-Permits/Guidance-technical-assistance/Well-report-gateway), or from local jurisdictions.

The following should be kept in mind when using these sources.

- Surface soil maps generally do not provide adequate information although the parent material information provided may be helpful in some locations.
- Verify well borehole log locations because electronic databases contain many errors of this type.
- When using borehole logs, a "nearby" site is generally defined as being within a quarter of a mile, but preferably within 50 to 500 feet of the project site, depending on the heterogeneity of the region.
- Subsurface geology can vary considerably in a very short horizontal distance in many areas of the state. Use professional judgment to determine whether the available data are adequate or site exploration is necessary.
- Alternatively, for small projects where site exploration is not cost-effective, a design professional may apply a conservative design approach, subject to the approval of the local jurisdiction.

The treatment capacity classifications in Table 5.3: Vadose Zone Treatment Capacity (continued) apply to the vadose zone between the bottom of the UIC well and the top of the highest known seasonal groundwater table. Designers should use Table 5.3: Vadose Zone Treatment Capacity (continued) to assist in the determination of treatment requirements when using Table 5.5: Treatment Required for Solids, Oil, and Metals (continued). If vadose zone conditions are unknown, use "none" for treatment capacity. If thicknesses are less than the listed minimums, use "none" for treatment capacity or consider using the demonstrative approach (see 5.9 The Demonstrative Approach for UIC Wells). Separation between the bottom of the UIC well and the top of the groundwater table is still required, see WAC 173-218-090(1)(b).

Depth to Groundwater

The minimum required separation between the bottom of the UIC well and the highest seasonal groundwater table depends on the characteristics of the vadose zone, the potential for mounding of infiltrating stormwater above the groundwater table, and the degree of certainty of available data as to the seasonal high groundwater table elevation.

Knowledge of the seasonal high groundwater table is especially important for siting UIC wells in areas with seasonal high groundwater table less than 15 feet below the bottom of the UIC well.

Significant mounding of infiltrating stormwater can occur above the groundwater table (Appleyard, 1993) and UIC wells must not discharge stormwater directly into groundwater at any time. This applies even if the groundwater level is rising in response to the UIC discharge.

In most cases, one depth to water measurement, such as water level data associated with a single borehole log, is not sufficient to determine the depth/elevation of the seasonal high groundwater table. This is especially true if drilling was conducted outside of the period of seasonal high groundwater levels or following a period of lower than normal precipitation. Seasonal high groundwater tables generally occur during late winter through mid-spring in most of Washington State. In heavily irrigated areas, the seasonal high groundwater table elevation may occur in late summer. The elevation of the seasonal high groundwater table is best determined through installation and periodic monitoring of one or more groundwater monitoring wells at the infiltration BMP location.

In portions of eastern Washington, groundwater table elevations can fluctuate by tens of feet seasonally. At sites where the fluctuation of the seasonal groundwater table is large (several feet) or unknown, designers should err on the side of caution. As described above and reinforced here, UIC wells must not discharge stormwater directly into groundwater.

Table 5.3: Vadose Zone Treatment Capacity

Treatment Capacity Classification and Required Minimum Thickness	Description of Vadose Zone Layer[c,d]

HIGH
 	
A minimum thickness of 5 feet
	Meets all of the following characteristics:
	• Materials with median grain size < 0.125 mm
	• Having a sand to silt/clay ratio of < 1:1 and sand plus gravel < 50%
	• Field-tested saturated hydraulic conductivity below 2.4 in/hr at the bottom elevation of the proposed BMP
	• Materials with CEC of ≥ 5 milliequivalents CEC/100 g dry soils, and a minimum of 1% organic content, ≥ 18-inch minimum thickness
	• Typical geotechnical descriptive words for appropriate soils:
	    ○ Lean, fat, or elastic clay
	    ○ Sandy or silty clay
	    ○ Silt
	    ○ Clayey or sandy silt
	    ○ Sandy loam or loamy sand
	    ○ Silt/clay with interbedded sand
	    ○ Well-compacted, poorly sorted materials

Table 5.3: Vadose Zone Treatment Capacity (continued)

Treatment Capacity Classification and Required Minimum Thickness	Description of Vadose Zone Layer[c,d]
	This category generally includes till, hardpan, caliche, and loess.

MEDIUM
 	
A minimum thickness of 10 feet
	Meets all of the following characteristics:
	• Materials with average grain size 0.125 to 4 mm
	• Having a sand to silt/clay ratio from 1:1 and 9:1 and percent sand > percent gravel
	• Field-tested saturated hydraulic conductivity between 2.4 in/hr and 6 in/hr at the bottom elevation of the proposed BMP
	• Materials between 2 and 5 milliequivalents CEC/100 g dry soils, and a minimum of 0.5% to 1% organic content,
	• Typical geotechnical descriptive words for appropriate soils:
	    ○ Fine, medium, or coarse sand
	    ○ Sand with interbedded clay and/or silt
	    ○ Poorly compacted, poorly sorted materials
	This category includes some alluvium and outwash deposits.

LOW
 	
A minimum thickness of 25 feet
	Meets all of the following characteristics:
	• Materials with median grain size > 4 mm to 64 mm
	• Having a sand to silt/clay ratio > 9:1 and percent sand less than percent gravel
	• Field-tested saturated hydraulic conductivity between 6 in/hr and 12 in/hr at the bottom elevation of the proposed BMP
	• Materials with CEC of ≤ 2 milliequivalents CEC/100 g dry soils and a minimum of < 0.5% organic content
	• Typical geotechnical descriptive words for appropriate soils:
	    ○ Poorly sorted, silty, or muddy gravel
	    ○ Sandy gravel, gravelly sand, or sand and gravel
	This category includes some alluvium and outwash deposits.

NONE	Meets any of the following characteristics:

Table 5.3: Vadose Zone Treatment Capacity (continued)

Treatment Capacity Classification and Required Minimum Thickness	Description of Vadose Zone Layer[c,d]

Minimum thickness not applicable	• Vadose zone conditions are unknown; or
	• Vadose zone conditions are known and are characterized in any of the following ways:
	    ◦ Sedimentary materials with median grain size > 64 mm
	    ◦ Total fines (sand and mud) < 5%
	    ◦ Field-tested saturated hydraulic conductivity > 12 in/hr at the bottom elevation of the proposed BMP
	    ◦ Materials with no measurable CEC or organic content
	    ◦ Typical geotechnical descriptive words for appropriate soils:
	        ▪ Well-sorted or clean gravel
	        ▪ Boulders and/or cobbles
	        ▪ Fractured rock
	This category generally includes vadose zones with conditions that are unknown or vadose zones that are known to be composed of fractured basalt, other fractured bedrock, and cavernous limestone.

a. This table is applicable to designers intending to use the presumptive approach to identify the necessary level of stormwater treatment prior to discharge to a UIC well. Designers for industrial sites with no outdoor processing, storage, or handling of raw or finished products may also use these tables.

b. This table is not applicable to stormwater runoff from industrial activities, outdoor processing, storage, or handling of raw or finished products; or areas where stormwater runoff comes into contact with leachate or other prohibited discharges.

c. If vadose zone conditions are unknown or if the vadose zone thicknesses are less than those listed, use “none” for the treatment capacity.

d. Separation between the bottom of the UIC well and the top of the groundwater table is required, see WAC 173-218-090(1)(b).

Table 5.4: Pollutant Loading Classifications for Solids, Metals, and Oil in Stormwater Runoff Directed to UIC Wells

Classification	Areas Contributing Runoff to the UIC Well
Insignificant	• Impervious surfaces not subject to motorized vehicle traffic or application of sand or deicing chemicals • Unmaintained open space

Low	• Parking areas with < 40 total trip ends per 1,000 square feet (sf) of gross building area or < 100 total trip ends (if you exceed either threshold, move to the Medium Classification)
	• Other land uses with similar traffic/use characteristics (e.g., most residential parking and employee-only parking areas for small office parks or other commercial buildings)
	• **Inside Urban Growth Management Areas**
	    ○ Fully controlled and partially controlled limited access highways with ADT < 15,000
	    ○ Other roads with ADT < 7,500 vehicles
	• **Outside Urban Growth Management Areas**
	    ○ All roads with ADT < 15,000 vehicles

Medium	• Parking areas with between 40 and 100 trip ends per 1,000 sf of gross building area or between 100 and 300 total trip ends (if you exceed either threshold, move to the High Classification)
	• Primary access points for high-density residential apartments
	• Intersections controlled by traffic signals that do not meet the definition of a high-density intersection (see the Glossary)
	• Transit center bus stops
	• **Inside Urban Growth Management Areas**
	    ○ Fully controlled and partially controlled limited access highways with ADT between 15,000 and 30,000 vehicles
	    ○ Other roads with ADT between 7,500 and 30,000 vehicles
	• **Outside Urban Growth Management Areas**
	    ○ All roads with ADT between 15,000 and 30,000 vehicles

High	• High-use sites ○ Includes roads with ADT > 30,000 vehicles • On-street parking areas of municipal streets in commercial and industrial areas

Table 5.4: Pollutant Loading Classifications for Solids, Metals, and Oil in Stormwater Runoff Directed to UIC Wells (continued)

Classification	Areas Contributing Runoff to the UIC Well
	• Highway rest areas • Other land uses with similar traffic/use characteristics (e.g., commercial buildings with a frequent turnover of visitors, such as grocery stores, shopping malls, restaurants, drive-through services, etc.)

Notes:

a. This table is applicable to designers intending to use the presumptive approach to identify the necessary level of treatment upstream of a UIC well. Designers for industrial sites with no outdoor processing, storage, or handling of raw or finished products may also use these tables.

b. This table is not applicable to stormwater runoff from industrial activities, outdoor processing, storage, or handling of raw or finished products; or areas where stormwater runoff comes into contact with leachate or other prohibited discharges.

Use the treatment capacity classification from Table 5.3: Vadose Zone Treatment Capacity (continued) and the pollutant loading classification from Table 5.4: Pollutant Loading Classifications for Solids, Metals, and Oil in Stormwater Runoff Directed to UIC Wells (continued) to determine the appropriate level of treatment for solids, oil, and metals in Table 5.5: Treatment Required for Solids, Oil, and Metals (continued).

Designers may use UIC wells to provide flow control of excess stormwater runoff for flows greater than the water quality design storm where pollutant concentrations that reach groundwater will meet Washington State groundwater quality standards; or where stormwater is adequately treated prior to discharge.

Table 5.5: Treatment Required for Solids, Oil, and Metals

Pollutant Loading	Treatment Capacity			
	High	Medium	Low	None
Insignificant	Two-stage drywell[a]	Two-stage drywell[a]	Two-stage drywell[a]	Two-stage drywell[a]
Low	Two-stage drywell[a]	Pretreatment[b]	Pretreatment[b]	Remove solids[c]
Medium	Pretreatment[b]	Remove solids[c]	Remove solids[c]	Remove solids[c]
High	Remove oil[d]	Remove oil[d]	Remove oil and solids[c,d]	Remove oil and solids[c,d]

Notes:

a. A two-stage drywell has a catch basin or other presettling device that traps small quantities of oils and solids. Regularly inspect and maintain the catch basin or other presettling device.

Table 5.5: Treatment Required for Solids, Oil, and Metals (continued)

Pollutant Loading	Treatment Capacity			
	High	Medium	Low	None
b. Pretreatment removes solids, but at a level less than basic treatment. Ecology's definition for pretreatment is 50% removal. See the definition for pretreatment in the Glossary. c. Treatment to remove solids means basic treatment. See the definition of basic treatment in the Glossary. Removal of solids removes a large portion of the total metals in most stormwater runoff. Any special treatment requirements in this chapter still apply. Owners may use appropriate source control BMPs for low-pollutant-loading sites, in lieu of structural treatment BMPs. d. Treatment to remove oil is to be accomplished by applying one of the oil control BMPs identified in this manual. See BMP T5.100: API (Baffle type) Separator and BMP T5.110: Coalescing Plate (CP) Separator. • At high-density intersections and at commercial or industrial sites subject to an expected average daily traffic (ADT) count of 100 vehicles/1,000 sf gross building area, sufficient quantities of oil may be generated to justify operation of a separator BMP. • At other high-use sites, project proponents may select a basic treatment BMP that also provides adsorptive capacity, such as a biofiltration swale, a filter, or other adsorptive technology, in lieu of a separator BMP. A catch basin with a turned down elbow is not adequate for oil control in this case. • For roads in eastern Washington with ADT >30K, basic treatment with sorptive characteristics (i.e., swale or sand filter) is required, and suffices for the oil treatment requirement. • The requirement to apply a basic treatment BMP with adsorptive characteristics also applies to commercial parking and to streets with ADT > 7,500.				

Chapter 6 - Runoff Treatment, Flow Control, and LID BMP Library

6.1 General BMP Design

6.1.1 What Are Runoff Treatment BMPs?

Best Management Practices (BMPs) are schedules of activities, prohibitions of practices, maintenance procedures, managerial practices, or structural features that prevent or reduce adverse impacts on waters of Washington State. BMPs for long-term management of stormwater at developed sites can be divided into three main categories:

- BMPs addressing the volume and timing of stormwater flows (Flow Control BMPs)
- BMPs addressing prevention of pollution from potential sources (Source Control BMPs)
- BMPs addressing treatment of runoff to remove sediment and other pollutants (Runoff Treatment BMPs)

This section of the *Stormwater Management Manual for Eastern Washington* (manual) focuses on the third category, treatment of runoff to remove sediment and other pollutants at developed sites. The purpose of this section is to provide guidance for selection, design, and maintenance of permanent Runoff Treatment BMPs.

Runoff Treatment BMPs are designed to remove pollutants contained in stormwater runoff. The pollutants of concern include sand, silt, and other suspended solids; metals such as copper, lead, and zinc; nutrients (e.g., nitrogen and phosphorus); certain bacteria and viruses; and organics such as petroleum hydrocarbons and pesticides. Methods of pollutant removal include sedimentation/settling, filtration, plant uptake, ion exchange, adsorption, and bacterial decomposition. Floatable pollutants such as oil, debris, and scum can be removed with separator structures.

6.1.2 Choosing Your Runoff Treatment BMPs

Use the step-by-step process outlined below to determine the type of Runoff Treatment BMPs applicable to the project.

Runoff Treatment BMPs might apply to the project if directed by 2.3 Applicability of the Core Elements and/or 2.4.5 CE5: Runoff Treatment, or if the project is using an infiltration BMP per 6.5 Infiltration BMPs.

This section may also be referred to as directed by Chapter 5 - UIC Program Guidelines to determine acceptable Runoff Treatment BMPs prior to UIC wells.

The step-by-step process should be used in conjunction with Figure 6.1: Runoff Treatment BMP Selection Flow Chart and Figure 6.2: Runoff Treatment BMP Selection Flow Chart for Discharges to Subsurface Infiltration Systems (UIC Wells).

Figure 6.1: Runoff Treatment BMP Selection Flow Chart

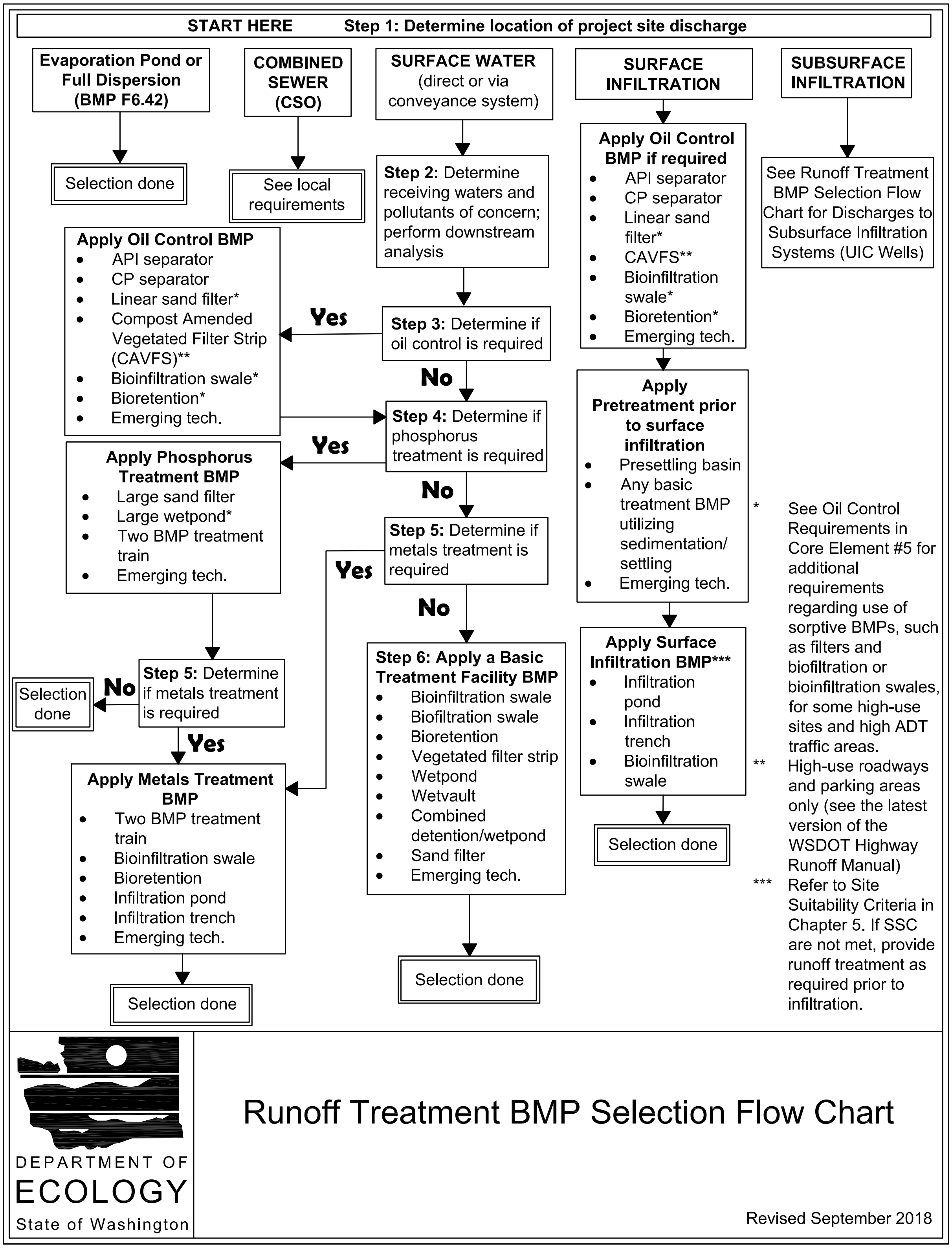
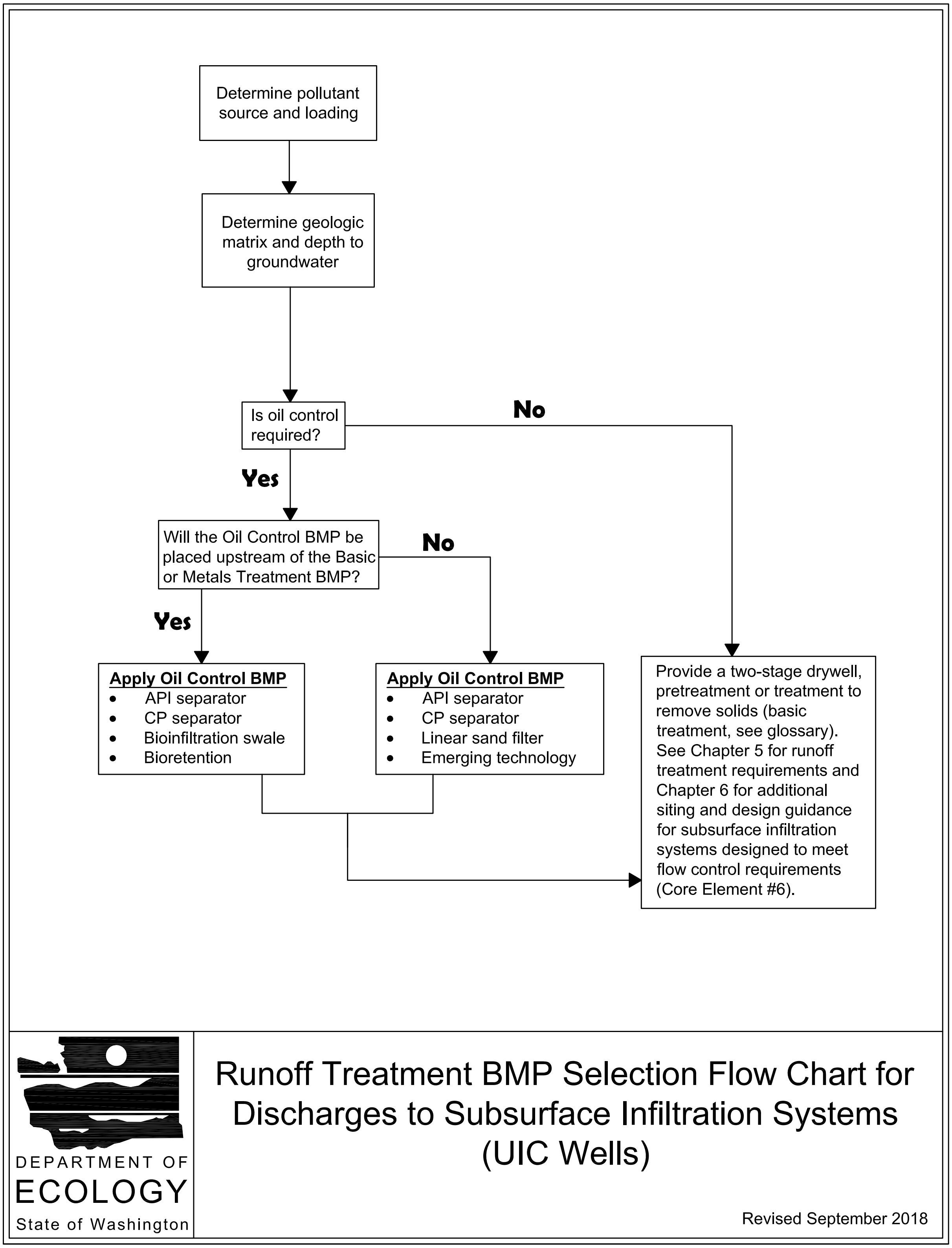


Figure 6.2: Runoff Treatment BMP Selection Flow Chart for Discharges to Subsurface Infiltration Systems (UIC Wells)



Step 1: Determine the Receiving Waters and Pollutants of Concern Based on Off-Site Analysis

Step 1a: Determine the Location of Project Site Discharge

First, determine which of the following describes the location of the project site discharge:

A. Evaporation or Full Dispersion (BMP F6.42: Full Dispersion) *(no additional treatment required)*

B. Combined sanitary sewer *(no additional treatment required except as determined by local requirements)*

C. Surface waters *(proceed to Step 2)*

D. Surface infiltration *(proceed further with Step 1)*

E. Subsurface infiltration *(proceed further with Step 1)*

For discharges to surface infiltration or subsurface infiltration systems, see the infiltration treatment design criteria in 6.5 Infiltration BMPs.

Infiltration can be effective at treating stormwater runoff, but soil properties must be appropriate to achieve effective Runoff Treatment while not adversely impacting groundwater resources. The location and depth to bedrock, the water table, or impermeable layers, and the proximity to wells, foundations, septic tank drain fields, and unstable slopes can preclude the use of infiltration.

For discharges to subsurface infiltration BMPs, such as underground injection control (UIC) wells, see Figure 6.2: Runoff Treatment BMP Selection Flow Chart for Discharges to Subsurface Infiltration Systems (UIC Wells) for the BMP selection process. One of the initial steps is to determine pollutant source and loading. The geologic matrix and depth to groundwater should be determined using the criteria and guidance in Chapter 5 - UIC Program Guidelines. Using Table 5.5: Treatment Required for Solids, Oil, and Metals (continued), a determination is then made whether treatment is required prior to discharge. If treatment is required, appropriate controls are then selected, such as oil control, and/or other runoff treatment BMPs as applicable. See 6.5 Infiltration BMPs for subsurface infiltration system siting and design guidance.

The local jurisdiction should verify whether any type of groundwater quality management plans and/or local ordinances or regulations have been established such as groundwater management plans or wellhead protection plans that identify required actions for stormwater discharges to protect groundwater quality and/or quantity.

Step 1b: Determine the Receiving Waters and Pollutants of Concern

To obtain a more complete determination of the potential impacts of a stormwater discharge, Ecology encourages local jurisdictions to require an off-site analysis similar to that in Chapter 3 - Preparation of Stormwater Site Plans. The off-site analysis must include both surface and groundwater paths. Ensure that the analysis looks at down gradient aquifers as well as downstream surface waters when performing the off-site analysis.

Even without an off-site analysis requirement, the project proponent must determine the natural receiving water for the stormwater drainage from the project site (e.g. groundwater, wetland, lake, or stream). This is necessary to determine the level of Runoff Treatment applicable to your site. The identification of the receiving water should be verified by the local jurisdiction with review responsibility. If the discharge is to the local municipal storm drainage system, the receiving water for the drainage system must be determined.

The local jurisdiction should verify whether any type of water quality management plans and/or local ordinances, regulations, or plans have established specific requirements, recommendations, or policies for the receiving water(s). The project proponent needs to check all other agencies for requirements. Examples of plans to be aware of include:

- Watershed or basin plans: These can be developed to cover a wide variety of geographic scales (e.g., Water Resource Inventory Areas or subbasins of a few square miles), and can be focused solely on establishing stormwater requirements (e.g. “stormwater basin plans”) or can address a number of pollution and water quantity issues, including urban stormwater.
- Water cleanup plans: These plans are written to establish a Total Maximum Daily Load (TMDL) of a pollutant or pollutants in a specific receiving water or basin, and identify actions necessary to remain below that maximum loading. The plans may identify discharge limitations or management limitations (e.g. use of specific treatment BMPs) for stormwater discharges from new and redevelopment projects.
- Lake management plans: These plans are developed to protect lakes from eutrophication due to inputs of phosphorus and other nutrients from the drainage basin. Control of phosphorus and/or other nutrients from new development is a likely requirement in a lake management plan.
- Other similar locally-adopted plans that contain requirements, recommendations, or policies for a particular receiving water.

An analysis of the proposed land use(s) of the project should also be used to determine the stormwater pollutants of concern. Table 6.4: Typical Sources of Pollutants of Concern in Stormwater (continued) lists the pollutants of concern from various land uses. Table 6.5: Ability of Runoff Treatment BMPs to Remove Key Pollutants (continued) indicates the ability of treatment BMPs to remove key pollutants. See Table 6.4: Typical Sources of Pollutants of Concern in Stormwater (continued) and Table 6.5: Ability of Runoff Treatment BMPs to Remove Key Pollutants (continued) for examples of treatment options after determining whether oil control, phosphorus treatment, metals treatment, or basic treatment applies to the project. Those decisions are made in the following steps.

Step 2: Determine if an Oil Control BMP is Required

The use of Oil Control BMPs is dependent upon the specific land use proposed for development.

When a Level 1 Oil Control BMP is required, it is in addition to Runoff Treatment BMPs required to meet other applicable Runoff Treatment Performance Goals (Basic, Metals, and/or Phosphorus).

When a Level 2 Oil Control BMP is required, the Level 2 Oil Control BMP may serve to fulfill both the Oil Control requirement as well as the Basic, Metals, and/or Phosphorus BMP requirements (so long as the chosen BMP is on the list of accepted BMPs for Basic, Metals, and/or Phosphorus).

If an Oil Control BMP is required, select and apply an appropriate Oil Control BMP from the options below. After selecting an Oil Control BMP, proceed to Step 3.

If an Oil Control BMP is not required, proceed directly to Step 3.

The Oil Control Performance Goal

Oil Control is intended to achieve the goals of no ongoing or recurring visible sheen, and to have a 24-hour average Total Petroleum Hydrocarbon (TPH) concentration no greater than 10 mg/l, and a maximum of 15 mg/l for a discrete sample (grab sample).

Note: Use the method for NWTPH-Dx in *Analytical Methods for Petroleum Hydrocarbons* (Ecology, 1997). If the concentration of gasoline is of interest, the method for NWTPH-Gx should be used to analyze grab samples.

When is Oil Control Required?

Level 1 Oil Control BMPs are required for areas that typically generate high concentrations of oil due to high traffic turnover or the frequent transfer of oil. These types of areas include:

- 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, or 300 total trip ends per day. Gasoline stations, with or without small food stores, will likely exceed this threshold.
- 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. This petroleum storage and transfer criterion is intended to address regular transfer operations such as gasoline service stations, not occasional filling of heating oil tanks.
- 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.). In general, all-day parking areas are not intended to require Level 1 Oil Control BMPs.
- 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. The traffic count can be estimated using information from *Trip Generation Manual* (ITE, 2012), or from a traffic study prepared by a professional engineer or transportation specialist with experience in traffic estimation.

The following land uses may have areas that require Level 1 Oil Control BMPs. Further, these sites require special attention to the Oil Control BMP selected.

- Industrial machinery and equipment, and railroad equipment maintenance areas
- Log storage and sorting yards
- Aircraft maintenance areas
- Railroad yards
- Fueling stations
- Vehicle maintenance and repair sites
- Junkyards and areas with vehicle recycling operations
- Construction businesses (paving, heavy equipment storage and maintenance, storage of petroleum products.)

Some land use types require the use of a spill control (SC-type) oil/water separator. Those situations are described in Chapter 8 - Source Control and are separate from this Runoff Treatment requirement.

The text in this box originates from one or more of the following Permits:
Appendix 1 of the Phase I / Phase II Municipal Stormwater Permits
Construction Stormwater General Permit

Level 2 Oil Control BMPs are required for areas that generate sufficient quantities of oil to threaten water quality, but the quantities of oil generated may be insufficient for Level 1 Oil Control BMPs to be effective. These types of areas include:

- Any road with average daily traffic (ADT) > 30,000 vehicles
- Commercial on-street parking areas on streets with an expected total ADT of ≥ 7,500

Some land use types require the use of a spill control (SC-type) oil/water separator. Those situations are described in Chapter 8 - Source Control and are separate from this Runoff Treatment requirement.

The text in this box originates from one or more of the following Permits:
Appendix 1 of the Phase I / Phase II Municipal Stormwater Permits
Construction Stormwater General Permit

How Do I Apply Oil Control to My Project Site?

Place Oil Control BMPs upstream of other BMPs, as close to the source of oil generation as practical.

For sites that require oil control located within a large commercial center, Oil Control BMPs are only required for the impervious surface(s) subject to the activities listed above. If common parking for multiple businesses is provided, Oil Control BMPs shall be applied to the number of parking stalls required for the business that requires oil control. However, if the runoff contributing to the Oil Control BMP includes runoff from other areas, the Oil Control BMP must be sized to treat all water passing through it.

Roadway intersections that trigger the above thresholds shall provide oil control for lanes where vehicles accumulate during the signal cycle, including left and right turn lanes and through lanes, from the beginning of the left turn pocket. If no left turn pocket exists, the area treated shall begin at a distance equal to three car lengths from the stop line. If runoff from the intersection drains to more than two collection areas that do not combine within the intersection, oil control treatment may be limited to any two of the collection areas where the cars stop.

Level 1 Oil Control BMP Options

Ecology currently recognizes the following BMPs as providing Runoff Treatment that meets the Oil Control Performance Goal, for use when Level 1 Oil Control BMPs are required:

- BMP T5.100: API (Baffle type) Separator
- BMP T5.110: Coalescing Plate (CP) Separator
- BMP T5.83: Linear Sand Filter

  Note: BMP T5.83: Linear Sand Filter may also be used to meet the Basic, Metals, or Phosphorus Treatment performance goals. If used to satisfy one of those performance goals, the same BMP shall not also be used to satisfy the oil control requirement unless increased maintenance is assured. 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. Quarterly cleaning is required unless specified otherwise by the designer.

Level 2 Oil Control BMP Options

Level 2 Oil Control BMPs include treatment methods with sorptive properties (due to their ability to better control smaller quantities of oil), or other oil removal techniques.

Ecology currently recognizes the following BMPs as providing Runoff Treatment that meets the Oil Control Performance Goal, for use when Level 2 Oil Control BMPs are required:

- BMP T5.83: Linear Sand Filter
- BMP T5.60: Compost-Amended Vegetated Filter Strips (CAVFS)
- BMP T5.21: Infiltration Swales
- BMP F6.23: Bioretention
- BMP T5.40: Basic Biofiltration Swale

Step 3: Determine if it is Practicable to Provide Runoff Treatment by Infiltrating into the Native Soil

Due to the hydrologic benefits of infiltration, Ecology recommends evaluating whether it is practicable to provide Runoff Treatment by infiltrating into the site's native soils before considering other Runoff Treatment BMPs. If Runoff Treatment by infiltrating into the native soil is practicable, it has the advantage that it is presumed to meet the Phosphorus, Metals, and Basic Treatment Performance Goals.

The guidance in 6.5 Infiltration BMPs must be followed for designing infiltration BMPs. 6.5.6 Site Suitability Criteria (SSC) details the site conditions that must be met for infiltration to be practicable for the site, and includes conditions specific to using the native soil for Runoff Treatment. Runoff Treatment may be provided by infiltrating into the native soil if the conditions below the infiltration BMP meet the criteria for Runoff Treatment per 6.5.6 Site Suitability Criteria (SSC).

Most infiltration BMPs should be preceded by a pretreatment BMP to reduce the occurrence of plugging. Some infiltration BMPs have pretreatment integrated into the BMP, such as BMP F6.24: Permeable Pavement and BMP F6.23: Bioretention, and therefore it is not necessary to provide additional pretreatment prior to infiltration. Any Basic Treatment BMPs, or detention ponds, vaults, or tanks designed to meet Flow Control requirements, can also be used for pre-treatment. If an oil/water separator is necessary for oil control, it could also function as the pre-settling basin as long as the influent suspended solids concentrations are not high. However, frequent inspections are necessary to determine when accumulated solids exceed the 6-inch depth at which clean-out is recommended (See Appendix 6-A: BMP Maintenance Tables).

If infiltration is planned, also refer to the guidance in 6.5.3 General Design Criteria for Infiltration BMPs and Appendix 6-A: BMP Maintenance Tables. This guidance may affect the design and placement of infiltration BMPs on the site.

Infiltration through soils that do not meet the criteria for Runoff Treatment per 6.5.6 Site Suitability Criteria (SSC) is allowable as a Flow Control BMP only. Use of infiltration through such soils is acceptable provided the appropriate type of Runoff Treatment BMP (Metals, Phosphorus, or Basic) is provided as directed in the steps below.

If it is practicable to provide Runoff Treatment by infiltrating into the native soil, select and apply a Pretreatment BMP and an infiltration BMP. You have completed the Runoff Treatment selection process.

If it is not practicable to provide Runoff Treatment by infiltrating into the native soil, proceed to Step 4.

Step 4: Determine if a Phosphorus Treatment BMP is Required

The use of Phosphorus Treatment BMPs is dependent upon the location of the site proposed for development. Note that when a Phosphorus Treatment BMP is required, a separate Basic Treatment BMP is not also required. Phosphorus Treatment BMPs meet both the Phosphorus Treatment Performance Goal as well as the Basic Treatment Performance Goal.

The plans, ordinances, and regulations identified in Step 1 are a good reference to help determine if the subject site is in an area where a Phosphorus Treatment BMP is required.

If a Phosphorus Treatment BMP is required, select and apply an appropriate Phosphorus Treatment BMP from the options below. After selecting a Phosphorus Treatment BMP, proceed to Step 5.

If a Phosphorus Treatment BMP is not required, proceed directly to Step 5.

The Phosphorus Treatment Performance Goal

Phosphorus Treatment is intended to achieve a goal of 50% total phosphorus removal for a range of influent concentrations of 0.1 to 0.5 mg/l total phosphorus. In addition, Phosphorus Treatment BMPs are also intended to achieve the Basic Treatment Performance Goal.

The Phosphorus Treatment Performance Goal applies to the water quality design volume or flow rate, whichever is applicable, on an annual average basis. The incremental portion of runoff in excess of the water quality design volume or flow rate can be routed around the BMP (creating an off-line Runoff Treatment BMP), or can be passed through the BMP (creating an on-line Runoff Treatment BMP) provided a net pollutant reduction is maintained. Ecology encourages the design and operation of Runoff Treatment BMPs that engage a bypass at flow rates higher than the water quality design flow rate. However, this is only acceptable provided that the overall reduction in phosphorus loading (treated plus bypassed) is at least equal to that achieved with initiating bypass at the water quality design flow rate.

When is Phosphorus Treatment Required?

Phosphorus Treatment BMPs are required for projects (or portions of projects) within watersheds that have been determined by the local jurisdiction (e.g. through a lake management plan), Ecology (e.g. through a TMDL waste load allocation), or the USEPA to be sensitive to phosphorus and are being managed to control phosphorus. The following are examples of sources that the local jurisdiction can use for determining whether a water body is sensitive to phosphorus:

- Those waterbodies reported under section 303(d) of the Clean Water Act, where designated uses are not supported due to phosphorous or other water quality criteria related to excessive phosphorus. This information can be viewed on Ecology's Water Quality Atlas at the following web address:

  https://apps.ecology.wa.gov/waterqualityatlas/wqa/map

- Those listed in Washington State's Nonpoint Source Assessment required under section 319(a) of the Clean Water Act due to nutrients.
- A locally-adopted plan that contains requirements, recommendations, or policies indicating that a particular receiving water is sensitive to phosphorus

The text in this box originates from one or more of the following Permits:
Appendix 1 of the Phase I / Phase II Municipal Stormwater Permits
Construction Stormwater General Permit

How Do I Apply Phosphorus Treatment to My Project Site?

If Phosphorus Treatment BMPs are required, select and apply a Phosphorous Treatment BMP from the options listed below. Select an option from the list after reviewing the BMP design guidance of each for compatibility with the site.

After you have selected a Phosphorus Treatment BMP, also refer to the guidance in 6.1 General BMP Design and Appendix 6-A: BMP Maintenance Tables. This guidance may affect the design and placement of BMPs on the site.

Phosphorus Treatment BMP Options

Ecology currently recognizes the following BMPs as providing Runoff Treatment that meets the Phosphorus Treatment Performance Goal:

- Infiltration (see 6.5 Infiltration BMPs) through soils that meet the criteria for Runoff Treatment per 6.5.6 Site Suitability Criteria (SSC)

  Pretreatment must precede infiltration through soils that meet the criteria for Runoff Treatment per 6.5.6 Site Suitability Criteria (SSC). A presettling basin or a Basic Treatment BMP can serve for pretreatment.

- Infiltration (see 6.5 Infiltration BMPs) through soils that do NOT meet the criteria for Runoff Treatment per 6.5.6 Site Suitability Criteria (SSC), paired with:
  - a Basic Treatment BMP, AND
  - a minimum distance of 1/4 mile between the infiltration location and the phosphorus sensitive receiving water (or tributary to that water)
- BMP F6.23: Bioretention - BSM options for Phosphorus Treatment are:
  - HPBSM Type 2
  - HPBSM Type 3
- BMP T5.81: Large Sand Filter Basin
- Large Wetpond - see BMP T10.10: Wetponds - Basic and Large
- BMP T10.40: Combined Detention and Wetpool Facilities
- BMP F6.24: Permeable Pavement - designed with the native soils below the permeable pavement to meet the criteria for Runoff Treatment per 6.5.6 Site Suitability Criteria (SSC)
- BMP T5.21: Infiltration Swales - either vegetated or rock-lined, so long as the treatment soil depth is 18 inches or greater
- Manufactured Treatment Devices approved for phosphorus treatment - See 6.11.4 Which Manufactured Treatment Devices Have Ecology Approval?
- Two-Facility Treatment Trains – See Table 6.1: Treatment Trains for Phosphorus Treatment

Table 6.1: Treatment Trains for Phosphorus Treatment

First Basic Treatment BMP	Second Treatment BMP
BMP T5.40: Basic Biofiltration Swale or BMP T9.20: Wet Biofiltration Swale or BMP T9.30: Continuous Inflow Biofiltration Swale or Basic Wetpond - see BMP T10.10: Wetponds - Basic and Large or BMP T5.72: Wetvaults or BMP T5.73: Stormwater Treatment Wetlands or BMP T10.40: Combined Detention and Wetpool Facilities (Basic)	BMP T5.80: Basic Sand Filter Basin or BMP T5.82: Sand Filter Vault
BMP T5.50: Vegetated Filter Strip	BMP T5.83: Linear Sand Filter (no presettling needed)
BMP T5.83: Linear Sand Filter Note that the concentrated flow from the linear sand filter will need to be converted to sheet flow prior to entering the vegetated filter strip. See 6.1.10.2 Flow Spreaders.	BMP T5.50: Vegetated Filter Strip

Step 5: Determine if a Metals Treatment BMP is Required

The use of Metals Treatment BMPs is dependent upon the specific land use proposed for development. Note that when a Metals Treatment BMP is required, a separate Basic Treatment BMP is not also required. Metals Treatment BMPs meet both the Metals Treatment Performance Goal as well as the Basic Treatment Performance Goal.

If a Phosphorus Treatment BMP is required (per Step 4 above), and a Metals Treatment BMP is also required, note that some BMPs can provide both Metals Treatment and Phosphorus Treatment. If a BMP is listed in both the Phosphorus Treatment BMP options list and the Metals Treatment BMP options list, then that BMP may be used to provide both Phosphorus Treatment and Metals Treatment (as well as Basic Treatment). If a site that requires both Phosphorus Treatment BMPs and Metals Treatment BMPs selects a Metals Treatment BMP that is not also on the Phosphorus Treatment BMP options list, then a separate Phosphorus Treatment BMP must also be provided.

If a Metals Treatment BMP is required, select and apply an appropriate Metals Treatment BMP from the options below. You have completed the Runoff Treatment selection process.

If a Metals Treatment BMP is not required, but a Phosphorus Treatment BMP was required, selected, and applied per Step 4 above, you have completed the Runoff Treatment selection process.

If neither a Metals Treatment or Phosphorus Treatment BMP is required, proceed to Step 6.

The Metals Treatment Performance Goal

Metals Treatment BMPs are intended to provide a higher rate of removal of dissolved metals than Basic Treatment BMPs. Based on a review of dissolved metals removal from Basic Treatment BMPs, a “higher rate of removal” is currently defined as greater than 30% dissolved copper removal (assuming a dissolved copper influent range of 0.005 to 0.02 mg/l), and greater than 60% dissolved zinc removal (assuming a dissolved zinc influent range of 0.02 to 0.3 mg/l). In addition, Metals Treatment BMPs are also intended to achieve the Basic Treatment Performance Goal.

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

When is Metals Treatment Required?

Metals Treatment BMPs are required for the types of project sites listed below that:

a. discharge directly to fresh waters designated for aquatic life use or that have an existing aquatic life use; or

b. discharge to conveyance systems that are tributary to fresh waters designated for aquatic life use or that have an existing aquatic life use; or

c. infiltrate stormwater within ¼ mile of a fresh water designated for aquatic life use or that has an existing aquatic life use.

The types of project sites are:

- Sites subject to industrial activities,
- Commercial project sites,
- Multifamily residential project sites, and

- High ADT roads as follows:
    - Within Urban Growth Areas:
        - Roads with an ADT of 7,500 or greater.
    - Outside of Urban Growth Areas:
        - Roads with an ADT of 15,000 or greater
- Light rail elevated and non-elevated guideways/tracks
- Other project sites that are anticipated to generate a high pollutant loading, including:
    - Parking areas as follows:
        - Commercial or industrial areas: All on-street parking areas.
        - Areas other than commercial or industrial areas: On-street parking areas on streets with an expected total ADT of ≥ 7,500.
        - Parking areas with an expected trip end count ≥ 40 vehicles per 1,000 sf of gross building area.
        - Parking areas with ≥ 100 expected trip ends per day.
    - Fueling stations
    - Transit center bus stops

The following areas of the above-listed project sites do not require Metals Treatment BMPs:

- Areas that discharge directly, or indirectly through a municipal separate storm sewer system, to a water listed in Appendix 2-B: Basic Treatment Receiving Waters.
- Landscaped areas of industrial, commercial, and multi-family project sites that do not involve any other pollution-generating sources (e.g. industrial activities, customer parking, storage of erodible or leachable material, wastes, or chemicals).
- Parking lots of industrial and commercial project sites, dedicated solely to parking of employees' private vehicles that do not involve any other pollution-generating sources (e.g. industrial activities, customer parking, storage of erodible or leachable material, wastes, or chemicals).

For project sites with a mix of land use types, Metals Treatment BMPs are required when the runoff from the areas subject to the Metals Treatment Performance Goal comprises 50% or more of the total runoff from the project site.

The text in this box originates from one or more of the following Permits:
Appendix 1 of the Phase I / Phase II Municipal Stormwater Permits
Construction Stormwater General Permit

Exemptions from metals treatment requirements for rural roads or small isolated commercial projects located outside Urban Growth Area (UGA) boundaries may be considered on a case-by-case basis. Some receiving waters will have sufficient capacity to dilute the metals concentration from the cumulative stormwater discharges so water quality standards are not violated. Other water bodies will not have sufficient mixing and dilution capacity. In making a determination, the local jurisdiction or other agency reviewing the project should consider:

- The average lowest monthly flow in the water body
- The existing and expected metals contributions from the surrounding area based on the zoning
- Probable future land use
- Whether a water quality violation is likely to occur during a thunderstorm following an extended period of dry weather

How Do I Apply Metals Treatment to My Project Site?

If Metals Treatment BMPs are required, select and apply a Metals Treatment BMP from the options listed below. Select an option from the list after reviewing the BMP design guidance of each for compatibility with the site.

After you have selected a Metals Treatment BMP, also refer to the guidance in 6.1 General BMP Design and Appendix 6-A: BMP Maintenance Tables. This guidance may affect the design and placement of BMPs on the site.

Metals Treatment BMP Options

Ecology currently recognizes the following BMPs as providing Runoff Treatment that meets the Metals Treatment Performance Goal:

- Infiltration (see 6.5 Infiltration BMPs) through soils that meet the criteria for Runoff Treatment per 6.5.6 Site Suitability Criteria (SSC)

  Pretreatment must precede infiltration through soils that meet the criteria for Runoff Treatment per 6.5.6 Site Suitability Criteria (SSC). A presettling basin or a Basic Treatment BMP can serve for pretreatment.
- BMP F6.42: Full Dispersion
- BMP T5.81: Large Sand Filter Basin
- BMP T5.73: Stormwater Treatment Wetlands
- BMP T5.60: Compost-Amended Vegetated Filter Strips (CAVFS)
- BMP F6.23: Bioretention - BSM options for Metals Treatment are:
  - Default BSM
  - Custom BSM

    - HPBSM Type 1
    - HPBSM Type 2
    - HPBSM Type 3

  Note: Stormwater runoff that filters through the bioretention soil mix will receive Metals Treatment.

- BMP T5.84: Media Filter Drain
- BMP F6.24: Permeable Pavement - designed with either:
    - The native soils below the permeable pavement meet the criteria for Runoff Treatment per 6.5.6 Site Suitability Criteria (SSC), or
    - The permeable pavement design includes a 12" layer of sand that meets the size gradation (by weight) given in Table 6.30: Sand Medium Specification.
- BMP T5.21: Infiltration Swales - either vegetated or rock-lined, so long as the treatment soil depth is 18 inches or greater
- Manufactured Treatment Devices approved for Metals Treatment - See 6.11.4 Which Manufactured Treatment Devices Have Ecology Approval?
- Two Facility Treatment Trains - See Table 6.2: Treatment Trains for Metals Treatment (continued)

Table 6.2: Treatment Trains for Metals Treatment

First Runoff Treatment BMP	Second Runoff Treatment BMP
BMP T5.40: Basic Biofiltration Swale or BMP T9.20: Wet Biofiltration Swale or BMP T9.30: Continuous Inflow Biofiltration Swale or Basic Wetpond - see BMP T10.10: Wetponds - Basic and Large or BMP T5.72: Wetvaults or BMP T10.40: Combined Detention and Wetpool Facilities (Basic)	BMP T5.80: Basic Sand Filter Basin or BMP T5.82: Sand Filter Vault or Manufactured Treatment Devices - See 6.11.4 Which Manufactured Treatment Devices Have Ecology Approval?. The Manufactured Treatment Device must be a type approved for Basic or Metals Treatment use by Ecology.

Table 6.2: Treatment Trains for Metals Treatment (continued)

First Runoff Treatment BMP	Second Runoff Treatment BMP
BMP T5.50: Vegetated Filter Strip	BMP T5.83: Linear Sand Filter (no pre-settling cell needed)
BMP T5.83: Linear Sand Filter Note that the concentrated flow from the linear sand filter will need to be converted to sheet flow prior to entering the vegetated filter strip. See 6.1.10.2 Flow Spreaders.	BMP T5.50: Vegetated Filter Strip
BMP T5.80: Basic Sand Filter Basin or BMP T5.82: Sand Filter Vault **These options must include a presettling cell if the filter isn't preceded by a detention BMP	Manufactured Treatment Devices - See 6.11.4 Which Manufactured Treatment Devices Have Ecology Approval?. The Manufactured Treatment Device must be a type approved for Basic or Metals Treatment use by Ecology.

Step 6: Select a Basic Treatment BMP

Note that if a MetalsTreatment BMP or a Phosphorus Treatment BMP has been applied, an additional Basic Treatment BMP is not required. Phosphorus Treatment and Metals Treatment BMPs meet both the Basic Treatment Performance Goal as well as their own respective Performance Goals.

The Basic Treatment Performance Goal

Basic Treatment BMPs are intended to achieve 80% removal of total suspended solids for influent concentrations that are 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 intended to achieve an effluent goal of 20 mg/l total suspended solids.

The Basic Treatment Performance Goal applies to the water quality design volume or flow rate, whichever is applicable. The incremental portion of runoff in excess of the water quality design volume or flow rate can be routed around the BMP (creating an off-line Runoff Treatment BMP), or can be passed through the BMP (creating an on-line Runoff Treatment BMP) provided a net TSS reduction is maintained. Ecology encourages the design and operation of Runoff Treatment BMPs that engage a bypass at flow rates higher than the water quality design flow rate as long as the reduction in TSS loading exceeds that achieved with initiating bypass at the water quality design flow rate. The Basic Treatment Performance Goal assumes that the BMP is treating stormwater with a typical particle size distribution. For a description of a typical particle size distribution, please refer to Ecology's *Technical Guidance Manual for Evaluating Emerging Stormwater Treatment Technologies*(Ecology, 2011b).

When is Basic Treatment Required?

> Areas that must provide Phosphorus Treatment BMPs or Metals Treatment BMPs do NOT have to provide additional Basic Treatment BMPs to meet the Basic Treatment Performance Goal.
>
> If Phosphorus Treatment BMPs or Metals Treatment BMPs are not provided, Basic Treatment BMPs are required.
>
> ***The text in this box originates from one or more of the following Permits:***
> *Appendix 1 of the Phase I / Phase II Municipal Stormwater Permits*
> *Construction Stormwater General Permit*

How Do I Apply Basic Treatment to My Project Site?

If Basic Treatment BMPs are required, select and apply a Basic Treatment BMP from the options listed below. Select an option from the list after reviewing the BMP design guidance of each for compatibility with your site.

After selecting a Basic Treatment BMP, also refer to the guidance in 6.1 General BMP Design and Appendix 6-A: BMP Maintenance Tables. This guidance may affect the design and placement of BMPs on the site.

Basic Treatment BMP Options

Ecology currently recognizes the following BMPs as providing Runoff Treatment that meets the Basic Treatment Performance Goal:

- Infiltration (see 6.5 Infiltration BMPs) into soils that meet the criteria for Runoff Treatment per 6.5.6 Site Suitability Criteria (SSC).

  Pretreatment must precede infiltration through soils that meet the criteria for Runoff Treatment per 6.5.6 Site Suitability Criteria (SSC). A presettling basin or a Basic Treatment BMP can serve for pretreatment.

- BMP F6.42: Full Dispersion
- BMP T5.80: Basic Sand Filter Basin
- BMP T5.81: Large Sand Filter Basin
- BMP T5.82: Sand Filter Vault
- BMP T5.83: Linear Sand Filter
- BMP T5.84: Media Filter Drain
- BMP T5.40: Basic Biofiltration Swale
- BMP T9.20: Wet Biofiltration Swale

- BMP T9.30: Continuous Inflow Biofiltration Swale
- BMP T5.50: Vegetated Filter Strip
- BMP T5.60: Compost-Amended Vegetated Filter Strips (CAVFS)
- Basic Wetpond - see BMP T10.10: Wetponds - Basic and Large
- Large Wetpond - see BMP T10.10: Wetponds - Basic and Large
- BMP T5.72: Wetvaults

  Note: A wetvault may be used for commercial, industrial, or road projects if there are space limitations. Ecology discourages the use of wetvaults for residential projects.
- BMP T5.73: Stormwater Treatment Wetlands
- BMP T10.40: Combined Detention and Wetpool Facilities
- BMP F6.23: Bioretention - BSM options for Basic Treatment are:
  - Default BSM
  - Custom BSM
  - HPBSM Type 1
  - HPBSM Type 2
  - HPBSM Type 3
- BMP F6.24: Permeable Pavement - designed with either:
  - The native soils below the permeable pavement meet the criteria for Runoff Treatment per 6.5.6 Site Suitability Criteria (SSC), or
  - The permeable pavement design includes a 6" layer of sand that meets the size gradation (by weight) given in Table 6.30: Sand Medium Specification.
- BMP T5.21: Infiltration Swales - options as follows:
  - vegetated, so long as the treatment soil depth is 6 inches or greater
  - rock-lined, so long as the treatment soil depth is 18 inches or greater
- Manufactured Treatment Devices approved for Basic, Phosphorus, or Metals Treatment - See 6.11.4 Which Manufactured Treatment Devices Have Ecology Approval?

Congratulations! You have completed Ecology's Runoff Treatment BMP selection process.

Other Runoff Treatment BMP Selection Factors

The selection of a Runoff Treatment BMP should be based on site physical factors and pollutants of concern. The requirements for use of Metals Treatment BMPs or Phosphorus Treatment BMPs represents BMP selection based on pollutants of concern. Even if the site is not subject to those requirements, try to choose a BMP that is likely to remove the types of pollutants generated on the site.

Site Context

Consider the location and surrounding site context to determine whether Runoff Treatment BMP design criteria and local jurisdiction requirements can be met. For instance, Runoff Treatment BMPs located in tight roadway right-of-way areas may have very different siting constraints than BMPs located in relatively open parking lots.

High Sediment Input

High TSS loads can clog infiltration soil, sand filters, and coalescing plate oil & water separators. Pretreatment with a presettling basin, wet vault, or another Basic Treatment BMP would typically be necessary.

Soil Type

The permeability of the soil underlying a Runoff Treatment BMP has a profound influence on its effectiveness. This is particularly true for infiltration BMPs that are typically best sited in sandy to loamy sand soils. They are not generally appropriate for sites that have a design infiltration rate less than 0.3 inches per hour. Wetpool BMPs situated on coarser soils will need a synthetic liner or the soils amended to reduce the infiltration rate and provide treatment. Maintaining a permanent pool in the first cell is necessary to avoid resuspension of settled solids. Biofiltration swales in coarse soils can also be amended to reduce the infiltration rate.

See the Site Suitability Criteria (SSC) in 6.5.6 Site Suitability Criteria (SSC) for soil criteria that must be considered for siting infiltration BMPs and check with the local jurisdiction for other possible requirements specific to local conditions. Table 6.3: Screening Runoff Treatment BMPs Based on Soil Type (continued) presents a screening-level summary of appropriate runoff treatment BMP types based on soils underlying proposed BMP locations.

Table 6.3: Screening Runoff Treatment BMPs Based on Soil Type

Soil Type	Infiltration/ Bioretention	Wetpond[a]	Biofiltration[a] (e.g. Swale or Filter Strip)
Coarse Sand or Cobbles	–	–	–
Sand	+	–	–
Loamy Sand	+	–	+

Table 6.3: Screening Runoff Treatment BMPs Based on Soil Type (continued)

Soil Type	Infiltration/ Bioretention	Wetpond[a]	Biofiltration[a] (e.g. Swale or Filter Strip)
Sandy Loam	+	–	+
Loam	–	–	+
Silt Loam	–	–	+
Sandy Clay Loam	–	+	+
Silty Clay Loam	–	+	–
Sandy Clay	–	+	–
Silty Clay	–	+	–
Clay	–	+	–

Notes:

- Sand filtration is not listed because its feasibility is not dependent on soil type.
- **+** Indicates that use of the technology is generally appropriate for this soil type.
- – Indicates that use of the technology is generally not appropriate for this soil type.
- [a]Coarser soils may be used for these BMPs if a liner is installed to prevent infiltration, or if the soils are amended to reduce the infiltration rate.

Other Physical Factors

- ***Slope:*** Steep slopes restrict the use of several BMPs. A geotechnical/hydrologic evaluation should be done for sites on steeper slopes. See specific guidance for each BMP.
- ***High Water Table:*** Unless there is sufficient horizontal hydraulic receptor capacity, the water table acts as an effective barrier to exfiltration and can sharply reduce the efficiency of an infiltration system. If the high water table extends to within five feet of the bottom of an infiltration BMP, the site is seldom suitable.
- ***Depth to Bedrock/Hardpan/Till:*** The downward exfiltration of stormwater is also impeded if a bedrock or till layer lies too close to the surface. If the impervious layer lies within five feet below the bottom of the infiltration BMP, the site is not suitable. Similarly, pond BMPs are often not feasible if bedrock lies within the area that must be excavated.
- ***Proximity to Foundations and Wells:*** Since infiltration BMPs convey runoff back into the soil, some sites may experience problems with local seepage. This can be a real problem if the BMP is located too close to a building foundation. Another risk is groundwater pollution;

hence, the requirement to site infiltration systems more than 100 feet away from drinking water wells and outside the sanitary control area of public drinking water wells.

Pollutants of Concern

Table 6.4: Typical Sources of Pollutants of Concern in Stormwater (continued) summarizes the pollutants of concern and those land uses that are likely to generate pollutants. Table 6.5: Ability of Runoff Treatment BMPs to Remove Key Pollutants (continued) suggests treatment options for each pollutant. For example, oil and grease are the expected pollutants from an uncovered fueling station. Using Table 6.4: Typical Sources of Pollutants of Concern in Stormwater (continued), a combination of an oil and water separator and a biofiltration BMP could be considered as the basic treatment for runoff from uncovered fueling stations. Table 6.5: Ability of Runoff Treatment BMPs to Remove Key Pollutants (continued) provides a general indication of the relative effectiveness of classes of treatment BMPs in removing key stormwater pollutants.

Table 6.4: Typical Sources of Pollutants of Concern in Stormwater

Typical Sources of Pollutants of Concern in Stormwater	Typical Pollutants of Concern in Stormwater
Roofs	
Uncoated metal	Zn
Vents and emissions[a]	O&G, TSS, organics
Parking Lot/Driveway	
>High-use site	High O&G, TSS, Cu, Zn, PAHs
<High-use site	O&G, TSS
Streets/Highways	
Arterials/highways	O&G, TSS, Cu, Zn, PAHs
Residential collectors	Low O&G, TSS, Cu, Zn
High-use site intersections	High O&G, TSS, Cu, Zn, PAHs
Other Sources	
Industrial/commercial development	O&G, TSS, Cu, Zn
Residential development	TSS, pesticides/herbicides, nutrients
Uncovered fueling stations	High O&G
Industrial yards	High O&G, TSS, metals, PAHs

Notes:

- Application of effective source control measures is the preferred approach for pollutant reduction. Where source control measures are not used, or where they are ineffective, stormwater treatment is necessary.
- Cu = copper

Table 6.4: Typical Sources of Pollutants of Concern in Stormwater (continued)

Typical Sources of Pollutants of Concern in Stormwater	Typical Pollutants of Concern in Stormwater
• O&G = oil and grease • PAH = polycyclic aromatic hydrocarbons • TSS = total suspended solids • Zn = zinc • [a]Manufacturing and food production.	

Table 6.5: Ability of Runoff Treatment BMPs to Remove Key Pollutants

BMP	TSS	Dissolved Metals (e.g., Cu, Zn)	Total Phosphorus	Pesticides/ Fungicides	Hydro-carbons (e.g., O&G, PAHs)
Wetpond	++	+	+		+
Wetvault	++				
Biofiltration	++	+	+	+	+
Sand Filter	++	+	+		+
Constructed Wetland	++	++	+	++	++
Leaf Compost Filters	++	+		++	++
Infiltration[a]	++	+		+	+
Oil and Water Separator					++

Table 6.5: Ability of Runoff Treatment BMPs to Remove Key Pollutants (continued)

BMP	TSS	Dissolved Metals (e.g., Cu, Zn)	Total Phosphorus	Pesticides/ Fungicides	Hydro-carbons (e.g., O&G, PAHs)
Bioretention	++	++	++		++

Notes:

- A blank cell indicates that the treatment BMP is not particularly effective at treating the identified pollutant.
- **++** Indicates a significant process
- + Indicates a lesser process
- Cu = copper
- O&G = oil and grease
- PAH = polycyclic aromatic hydrocarbons
- TSS = total suspended solids
- Zn = zinc
- [a]Assumes loamy sand, sandy loam, or loam soils.

Source: Adapted from (Kulzer, 1997). Additional BMPs with metals treatment benefits that are not included in the table are amended sand filters and two-BMP treatment trains; additional BMPs for phosphorus treatment are large sand filters, two-BMP treatment trains, and amended sand filters.

Climate Type

Arid regions have annual rainfall < 16 inches and semiarid regions have annual rainfall from 16 to 35 inches. The amount of annual rainfall affects the effectiveness of BMPs that rely on vegetation for filter material or a pool of water for treatment. Table 6.6: Recommended Stormwater Treatment BMPs Based on Climate Type (continued) identifies the preferred BMPs and the limitations to use in the arid and semiarid climates found in most of eastern Washington.

Table 6.6: Recommended Stormwater Treatment BMPs Based on Climate Type

Stormwater BMP	Arid Climates < 16 Inches Annual Rainfall	Semiarid Climates 16 to 35 Inches Annual Rainfall
Sand filters	Preferred: • Requires greater pretreatment	Preferred

Table 6.6: Recommended Stormwater Treatment BMPs Based on Climate Type (continued)

Stormwater BMP	Arid Climates < 16 Inches Annual Rainfall	Semiarid Climates 16 to 35 Inches Annual Rainfall
	• Sensitive to sediment loadings	
Infiltration swales (vegetated)	Acceptable with Limitations: • Use dryland grass	Preferred: • Use dryland or irrigated grass
Bioretention	Acceptable with Limitations: • Use dryland grass	Preferred: • Use dryland or irrigated grass
Large extended detention dry ponds	Preferred: • Multiple storm extended detention • Stable pilot channels • Dry forebay	Acceptable: • Dry or wet forebay needed
Infiltration	Acceptable with Limitations: • See Table 5.5: Treatment Required for Solids, Oil, and Metals (continued) • Minimize erodible soils that reduce infiltration • Pretreatment • Soil limitations	Acceptable with Limitations: • See Table 5.5: Treatment Required for Solids, Oil, and Metals (continued) • Minimize erodible soils that reduce infiltration • Pretreatment
Wetponds	Not Recommended: • Evaporation rates are too high to maintain a normal pond without extensive use of scarce water	Limited Use: • Liners to prevent water loss require water balance analysis design for a variable rather than permanent normal pool • Use water sources such as air conditioner condensate for pool • Aeration unit to prevent stagnation
Stormwater wetlands	Not Recommended: • Evaporation rates too great to maintain wetlands plants	Limited Use: • Require supplemental water • Submerged gravel wetlands can help reduce water loss

Table 6.6: Recommended Stormwater Treatment BMPs Based on Climate Type (continued)

Stormwater BMP	Arid Climates < 16 Inches Annual Rainfall	Semiarid Climates 16 to 35 Inches Annual Rainfall
Biofiltration swales	Not Recommended: • Not recommended for pollutant removal, but rock berms and grade control needed for open channels to prevent channel erosion	Limited Use: • Use dryland or irrigated grass • Rock berms and grade control essential to prevent erosion in open channels
Source: Adapted from (Caraco, 2000).		

6.1.3 Choosing Your Flow Control BMPs

Use this section to determine the type of Flow Control BMPs most appropriate for the project.

Flow Control BMPs might apply to the project if directed by 2.3 Applicability of the Core Elements, 2.4.6 CE6: Flow Control, and/or 2.4.8 CE8: Wetlands Protection.

Step 1: Determine Whether the Site is Suitable for Infiltration

Due to the multiple hydrologic benefits of infiltration, Ecology recommends first evaluating whether infiltration is practicable to provide Flow Control.

The guidance in 6.5 Infiltration BMPs must be followed for designing infiltration BMPs. 6.5.6 Site Suitability Criteria (SSC) details the site conditions that must be met for infiltration to be practicable for the site, and includes conditions specific to using the native soil for Runoff Treatment.

Infiltration through soils that do not meet the criteria for Runoff Treatment per 6.5.6 Site Suitability Criteria (SSC) is allowable as a Flow Control BMP only. Use of infiltration through such soils is acceptable provided the appropriate type of Runoff Treatment BMP (Metals, Phosphorus, Oil, and/or Basic) is provided as directed in 6.1.2 Choosing Your Runoff Treatment BMPs.

Infiltration BMPs must be preceded by a pretreatment BMP, such as a presettling basin, manufactured treatment device, or vault, to reduce the occurrence of plugging. Any Basic Treatment BMPs, or detention ponds, vaults, or tanks designed to meet Flow Control requirements, can also be used for pre-treatment. If an oil/water separator is necessary for oil control, it could also function as the pre-settling basin as long as the influent suspended solids concentrations are not high. However, frequent inspections are necessary to determine when accumulated solids exceed the 6-inch depth at which clean-out is recommended (See Appendix 6-A: BMP Maintenance Tables).

If infiltration is planned, also refer to the guidance in 6.1 General BMP Design and Appendix 6-A: BMP Maintenance Tables. This guidance may affect the design and placement of infiltration BMPs on the site.

If it is practicable to provide Flow Control by infiltration, use the guidance provided in [6.5 Infiltration BMPs] to size the infiltration BMP to meet the applicable Flow Control based performance standard(s).

If it is not practicable to provide Flow Control by infiltration, proceed to Step 2.

Step 2: Choose a Detention BMP to Provide Flow Control

Use the guidance provided in 6.13 Detention BMPs to size a detention BMP to meet the applicable Flow Control based performance standard(s).

6.1.4 Review and Document Your BMP Choices

The list of BMPs chosen for the site should be reviewed. The site designer may want to re-evaluate site layout to reduce the need for construction of BMPs. The site designer may be able to reduce the size of the BMPs by reducing the amount of impervious surfaces created, providing more LID BMPs, and/or decreasing the areas disturbed.

The design and location of the BMPs on the site must be determined using the detailed guidance in Chapters 6, 7, and 8.

The site designer must document the site's BMP selection and design decisions and calculations. Types of documentation for Stormwater BMPs include:

- Stormwater Site Plans, as required per 2.4.1 CE1: Preparation of a Stormwater Site Plan and as described in Chapter 3 - Preparation of Stormwater Site Plans.
- Construction Stormwater Pollution Prevention Plans, as required per 2.4.2 CE2: Construction Stormwater Pollution Prevention Plan (SWPPP) and as described in 7.3 Construction Stormwater Pollution Prevention Plans (Construction SWPPPs)
- Operation and Maintenance Manuals, as required per 2.4.7 CE7: Operation and Maintenance

6.1.5 Sizing Your Runoff Treatment BMPs

Size Runoff Treatment BMPs for the entire area that drains to them, even if some of those areas are not pollution-generating.

Runoff Treatment BMPs are sized by using either a volume (the Water Quality Design Volume) or a flow rate (the Water Quality Design Flow Rate), depending on the Runoff Treatment BMP selected. Refer to the selected Runoff Treatment BMP to determine whether the BMP is sized based on a volume or a flow rate. See below for details about the Water Quality Design Volume and the Water Quality Design Flow Rate used to size Runoff Treatment BMPs.

Water Quality Design Volume

The Water Quality Design Volume is the same whether the Runoff Treatment BMP is located upstream or downstream of Detention BMPs.

Each agency or local jurisdiction should specify which of the following methods will be used in their jurisdiction to determine the Water Quality Design Volume. If the jurisdiction has not identified a preferred method, the default method shall be Method 1 in Climate Regions 1 and 4, and Method 2 in Climate Regions 2 and 3 (see Figure 4.1: Average Annual Precipitation and Climate Regions).

- **Method 1:** The volume of runoff predicted for the proposed development condition from the regional storm (72-hour) with a 6-month return frequency. An alternative to this method is the modified Type IA storm with a 6-month return frequency described in Chapter 4 - Hydrologic Analysis and Design. Designers may use this alternative method on small projects where the designer's software does not accept storms longer than 24 hours.
- **Method 2:** The volume of runoff predicted for the proposed development condition from the SCS Type IA 24-hour storm with a 6-month return frequency.
- **Method 3:** In Climate Regions 2 and 3, volume-based Runoff Treatment BMPs may be sized for 0.5-inch predicted runoff produced for the proposed development condition from all impervious surface areas that contribute flow to the Runoff Treatment BMP. This method is modified for design of BMP T5.21: Infiltration Swales.
- **Method 4:** The volume of runoff predicted for the proposed development condition from the SCS Type II 24-hour storm with a 6-month return frequency.
- **Method 5:** Another sizing approach and criteria based on peer-reviewed methods and supported by local data that meet the objective of treating at least 90% of the average annual runoff volume from the site.

Snowmelt considerations: Snowmelt should be considered when determining the Water Quality Design Volume. This is especially important in Climate Regions 1 and 4 and also applies to other areas of eastern Washington. Check for local requirements (see 2.5.4 APM3: Local Requirements). A snowmelt factor based on the water content of the average annual daily depth of snow (or based on some other appropriate measurement) should be added to the depth of precipitation when calculating the Water Quality Design Volume, or another method described in 4.3.9 Rain-on-Snow and Snowmelt Design may be used.

Water Quality Design Flow Rate

The Water Quality Design Flow Rate is dependent on the location of the Runoff Treatment BMP relative to Detention BMP(s):

- *Upstream of Detention BMPs or when there are no Detention BMPs:*

  Each agency or local jurisdiction should specify which of the following methods will be used in their jurisdiction to determine the Water Quality Design Flow Rate preceding Detention BMPs. If the jurisdiction has not identified a preferred method, the default method shall be Method 1 in all climate regions. For large Runoff Treatment BMPs receiving inflow from multiple sources, the flow rate generated by the regional or SCS Type IA storm should also be checked.

  - **Method 1:** The runoff flow rate predicted for the proposed development condition from the short-duration (3-hour) storm with a 6-month return frequency. (Use 15 minute time steps, unless otherwise specified in the BMP design guidance.)

  - **Method 2:** The runoff flow rate predicted for the proposed development condition from the SCS Type II 24-hour storm with a 6-month return frequency. (Use 15 minute time steps, unless otherwise specified in the BMP design guidance.)

  - **Method 3:** The runoff flow rate for the proposed development condition calculated by the Rational Method using the 2-year mean recurrence interval (see 4.8.1 Introduction). This method may only be used to design facilities based on instantaneous peak flow rates.

- *Downstream of Detention BMPs:* The Water Quality Design Flow Rate shall be the full 2-year release rate from the Detention BMP.

The text in this box originates from one or more of the following Permits:
Appendix 1 of the Phase I / Phase II Municipal Stormwater Permits
Construction Stormwater General Permit

The Water Quality Design Volume and Water Quality Design Flow Rate are intended to capture and effectively treat at least 90% of the annual runoff volume. BMPs that are designed, operated, and maintained according to the criteria set forth in this manual should also capture and treat nearly all of the first flush events.

Bypass Requirements for Runoff Treatment BMPs

A bypass must be provided for all Runoff Treatment BMPs unless the BMP is able to convey the 25-year short-duration (3-hour) storm without damaging the BMP or dislodging pollutants from within it.

Extreme runoff events may produce high flow velocities through BMPs that can damage and or dislodge pollutants from within the BMP. The designer must check the maximum allowable velocity (typically < 2 feet per second [ft/sec]) or shear stress specified for the BMP and implement a flow bypass as necessary to prevent an exceedance of these velocities.

To design a bypass for a flow-rate-based Runoff Treatment BMP:

1. Determine the maximum allowable velocity that will not result in damage of the BMP or dislodging of pollutants from within it.

2. Size an orifice or weir in a flow splitter manhole, vault, etc., such that the maximum velocity is not exceeded for the 25-year short-duration storm event.
3. Size the overflow (bypass) conveyance system for bypass flows.

To design a bypass for a volume-based Runoff Treatment BMP such as BMP T5.21: Infiltration Swales, maintain an elevated inlet or other overflow structure that bypasses flows above the design volume rather than using a flow-rate-based Runoff Treatment BMP. The bypassed water may discharge to another Runoff Treatment BMP or directly into a drainage system or infiltration BMP.

Bypass is not recommended for wetponds, constructed wetlands, and similar volume-based treatment BMPs. Inlet structures for these BMPs should be designed to dampen velocities. The pond dimensions will further dissipate the energy of the inflows. In these BMPs, larger storms will be retained for a shorter detention time than the shorter storms for which the ponds are designed.

Online Versus Off-Line Runoff Treatment BMPs

Most Runoff Treatment BMPs can be designed as “online” systems with flows above the Water Quality Design Flow Rate simply passing through the BMP with lesser or no pollutant removal. An example of an online system is a biofiltration swale with overflow to a drywell.

However, it is sometimes desirable to control the peak flow rates to the BMPs and bypass the remaining uncontrolled flows around them. These are called “off-line” systems. An example of an off-line system is a biofiltration swale downstream of a flow splitter.

Off-Line Runoff Treatment BMPs

Off-line Runoff Treatment BMPs make use of a flow splitter directly upstream of the Runoff Treatment BMP to regulate the amount of flow entering the BMP. Design the flow splitter to direct flows up to and including the Water Quality Design Flow Rate to the Runoff Treatment BMP. The Runoff Treatment BMP must be sized to treat the Water Quality Design Flow Rate, per the individual BMP's design guidance.

Ecology allows off-line designs in which the flow splitter directs flows higher than the Water Quality Design Flow Rate to the Runoff Treatment BMP. Ecology assumes that these designs will act similarly to an "on-line" Runoff Treatment BMP, where flows higher than the Water Quality Design Flow Rate will not achieve the full performance goal, but will achieve some level of pollutant removal. If you choose this design option, you must document that the higher flows will not damage the BMP, and you may need to consider an increased maintenance frequency to accommodate the increase in pollutant accumulation within the BMP.

On-Line Runoff Treatment BMPs

On-line Runoff Treatment BMPs do not make use of a flow splitter, and receive all of the stormwater runoff from the contributing basin. On-line Runoff Treatment BMPs must be designed using the Water Quality Design Flow Rate. On-line Runoff Treatment BMPs treat flows up to the Water Quality Design Flow Rate to meet the performance goal, and flows higher than the Water Quality Design Flow Rate pass through the BMP at a lower percent removal. Ecology does not give Runoff Treatment credit for the higher flows that pass through the BMP at a lower percent removal.

When designing on-line Runoff Treatment BMPs, you must ensure that the higher flows will not damage the BMPs. If higher flows will damage the proposed Runoff Treatment BMP, you should consider attenuating the flows to the BMP or using an off-line Runoff Treatment BMP.

6.1.6 Sequence of Runoff Treatment and Detention BMPs

In general, Runoff Treatment BMPs may be installed upstream of detention BMPs, although presettling basins are needed for sand filters and infiltration basins. However, not all Runoff Treatment BMPs can function effectively if located downstream of detention BMPs. Those Runoff Treatment BMPs that treat unconcentrated flows, such as filter strips, are usually not practical downstream of detention BMPs. Other types of Runoff Treatment BMPs present special problems that must be considered before placement downstream of detention BMPs.

For instance, prolonged flows discharged from a detention BMP may interfere with the proper functioning of basic biofiltration swales and sand filters. Grasses typically specified in the basic biofiltration swale design may not survive. For sand filters, the prolonged flows from a detention BMP may cause extended saturation periods within the filter and cause the filter to lose function and/or release previously captured phosphorus.

Oil control BMPs must be located upstream of Runoff Treatment BMPs and as close to the source of oil-generating activity as possible. They should also be located upstream of detention facilities, if possible.

Manufactured Treatment Devices may be installed either upstream or downstream of detention BMPs. The location depends on the type of technology and the level of treatment desired.

Table 6.7: Runoff Treatment BMP Placement in Relation to Detention (continued) summarizes placement considerations of Runoff Treatment BMPs in relation to detention.

Table 6.7: Runoff Treatment BMP Placement in Relation to Detention

Runoff Treatment BMP	Preceding Detention	Following Detention
BMP T5.40: Basic Biofiltration Swale	OK	OK. Prolonged flows may reduce grass survival.
BMP T9.20: Wet Biofiltration Swale	OK	OK
BMP T5.50: Vegetated Filter Strip	OK	No - must be installed before flows concentrate.
BMP T10.10:	OK	OK - less water level fluctuation in ponds downstream of

Table 6.7: Runoff Treatment BMP Placement in Relation to Detention (continued)

Runoff Treatment BMP	Preceding Detention	Following Detention
Wetponds - Basic and Large		detention may improve aesthetic qualities and performance.
BMP T5.72: Wetvaults	OK	OK
BMP T5.80: Basic Sand Filter Basin BMP T5.81: Large Sand Filter Basin BMP T5.82: Sand Filter Vault	OK, but presettling and control of floatables needed	OK - sand filters downstream of detention facilities may require field adjustments if prolonged flows cause sand saturation and interfere with phosphorus removal.
BMP T5.73: Stormwater Treatment Wetlands	OK	OK - less water level fluctuation and better plant diversity are possible if the stormwater wetland is located downstream of the detention facility.

6.1.7 Setbacks, Slopes, and Embankments

The following guidelines for setbacks, slopes, and embankments are intended to provide for adequate maintenance accessibility to Runoff Treatment BMPs. Setback requirements are generally required by local regulations, Uniform Building Code requirements, or other state regulations. Local governments should require specific setback, slope and embankment limitations to address public health and safety concerns.

Setbacks

Local governments may require specific setbacks in sites with steep slopes, landslide areas, open water features, springs, wells, and septic tank drain fields. Setbacks from tract lines are necessary for maintenance access and equipment maneuverability. Adequate room for maintenance equipment should be considered during site design.

Examples of text describing commonly used setbacks include the following:

- Stormwater infiltration BMPs shall be set back at least 100 feet from open water features and designated landslide hazard areas; stormwater infiltration BMPs shall be set back 200 feet from springs and flowing artesian wells used for drinking water supply. Infiltration BMPs upgradient of drinking water supplies must comply with Health Department requirements.

- Stormwater infiltration BMPs, and unlined wetponds and detention ponds shall be located at least 100 feet from drinking water wells and septic tanks and drainfields.
- Wetvaults and tanks may be required to be set back from building foundations, structures, property lines, and vegetative buffers. A typical setback requirement is 20 feet, for maintenance access.
- Stormwater infiltration BMPs shall be set back 100-feet from retaining walls to prevent “short circuiting” of stormwater by free-draining rock behind the retaining walls, unless the bottom of the infiltration BMP is greater than 2-feet below the lowest point on the retaining wall.
- All facilities shall be a minimum of 50 feet from any steep (greater than 15%) slope. A geotechnical report must address the potential impact of a wetpond on a steep slope.

Side Slopes and Embankments

Side slopes should preferably not be steeper than a slope of 3H:1V. Moderately undulating slopes are acceptable and can provide a more natural setting for the BMP. In general, gentle side slopes improve the aesthetic attributes of the BMP and enhance safety.

Interior side slopes may be retaining walls, if the design is prepared and stamped by a licensed engineer in the state of Washington. A fence should be provided along the top of the wall for safety for any retaining wall exceeding 4-feet in height or any pond with a design depth greater than 2-feet.

Maintenance access should be provided through an access ramp or other adequate means.

Embankments that impound water must comply with the Washington State Dam Safety Regulations (Chapter 173-175 WAC). If the impoundment has a storage capacity (including both water and sediment storage volumes) greater than 10 acre-feet (435,600 cubic feet or 3.26 million gallons) above natural ground level, then dam safety design and review are required by Ecology. See BMP F6.10: Detention Ponds for additional Dam Safety guidance.

6.1.8 Cold Weather Considerations

This section describes some general cold weather concerns common to most Runoff Treatment BMPs. Cold weather considerations specific to individual BMPs are presented in the design guidance for the individual BMP.

Cold Weather Challenges to BMP Design

Cold climates can present additional challenges to the selection, design, and maintenance of Runoff Treatment BMPs due to one or more of the factors listed in Table 6.8: Cold Weather Challenges to BMP Design. Designers of Runoff Treatment BMPs in cold weather regions should be aware of these challenges and make provisions for them in their final designs.

Regions that have an average daily maximum temperature of greater than 35 degrees Fahrenheit (°F) in January and a growing season less than120 days are especially vulnerable to the effects of cold weather. These cold weather conditions exist in many parts of eastern Washington and are, therefore, an important design concern.

Table 6.8: Cold Weather Challenges to BMP Design

Climatic Conditions	BMP Design Challenge
Cold Temperatures	• Pipe freezing • Permanent pool ice-covered • Reduced biological activity • Reduced oxygen levels during ice cover • Reduced settling velocities • Impacts of road salt/deicing chemicals/chlorides • Winter sanding impacts on BMPs
Deep Frost Line	• Frost heaving • Reduced soil infiltration • Pipe freezing
Short Growing Season	• Short time period to establish vegetation • Tolerance of plant species
Significant Snowfall	• High runoff volumes during snowmelt • High runoff during rain-on-snow • High pollutant loads during spring melt • Other impacts of road salt/deicing chemicals/chlorides • Snow management may affect BMP storage • Winter sanding impacts on BMPs

Much of the following information has been adapted from *Stormwater BMP Design Supplement for Cold Climates* (CWP, 1997).

The recommendations presented in the report were customized in response to regional experiences for eastern Washington. However, since local experiences are often the best measure of BMP performance, designers should consult with the local jurisdiction before making a final decision on the inclusion of cold weather measures. Local jurisdictions should identify BMPs that work best in their areas as well as BMPs that are not allowable due to performance considerations.

For cold weather considerations, several of the most common effects are briefly described below. These discussions are not meant to address every possible design detail that a designer may face when designing a BMP for cold weather. The goal is to identify common BMP concerns such that the designer is aware of factors that might influence their designs.

Pipe Freezing

Many BMPs rely on piping for the inlet, outlet, or underdrain system. Frozen pipes can crack due to ice expansion, creating a maintenance or replacement burden. In addition, pipe freezing reduces the capability of BMPs to treat runoff for water quality and can create the potential for flooding.

Ice Formation on Wetponds

The permanent pool of a wetpond serves several purposes. First, the water in the permanent pool slows down incoming runoff, allowing increased settling. In addition, the biological activity in this pool can act to remove nutrients, as growing algae, plants, and bacteria require these nutrients for growth. In some systems, such as sand filters, a permanent pool acts as a pretreatment measure, settling out larger sediment particles before full treatment by the BMP.

Ice cover on the permanent pool causes two problems. First, the treatment pool’s volume is reduced. Second, because the permanent pool is frozen, it acts as an impermeable surface. Runoff entering the pond will either be forced under the ice, causing scouring of the bottom sediments, or it will flow over the top of the ice, where it receives very little treatment.

Reduced Biological Activity

Many BMPs rely on biological mechanisms to help reduce pollutants, especially nutrients and organic matter. In cold temperatures, microbial activity is sharply reduced when plants are dormant during longer winters, limiting these pollutant removal pathways.

Reduced Oxygen Levels in Bottom Sediments

In cold regions, oxygen exchange between the air-water interface in ponds and lakes is restricted by ice cover. In addition, warmer water sinks to the bottom during ice cover because it is denser than the cooler water near the surface. Although biological activity is limited in cooler temperatures, the decomposition that takes place does so at the bottom of wetponds, sharply reducing oxygen concentrations in bottom sediments. In these anoxic conditions, positive ions retained in sediments can be released from bottom sediments, reducing the BMP's ability to treat these nutrients or metals in runoff.

Reduced Settling Velocities

Settling is the most important removal mechanism in many BMPs. As water becomes cooler, its viscosity increases, reducing the velocity of particle settling. This reduced settling velocity influences pollutant removal in any BMP that relies on settling.

Frost Heave

The primary risk of frost heave is the damage of structures such as pipes or concrete materials to construct BMPs. Another concern is that infiltration BMPs can cause frost heave damage to other structures, particularly roads. The water infiltrated into the soil matrix can flow under a permanent structure and then refreeze. The sudden expansion associated with this freezing can cause damage to aboveground structures.

Reduced Soil Infiltration

The rate of infiltration in frozen soils is limited, especially when ice lenses form. There are two results of this reduced infiltration. First, BMPs that rely on infiltration to function can be ineffective when the soil is frozen. Second, runoff rates from snowmelt are elevated when the ground underneath the snow is frozen.

Short Growing Season

For some BMPs, such as BMP T5.21: Infiltration Swales and BMP T5.40: Basic Biofiltration Swale, vegetation is integral to the proper function of the BMP. When the growing season is shortened, establishing and maintaining this vegetation becomes more difficult. Some plant species go dormant at the onset of colder temperatures, reducing the pollutant removal efficiency in BMPs that rely on actively growing plant life.

High Pollutant Loading During Winter or Spring Thaw Periods

Winter or spring melt events are important because of increased runoff volumes and pollutant loads. The snowpack contains high pollutant concentrations due to the buildup of pollutants over a several-month period. Chloride loadings are highest in snowmelt events because of the use of deicing salts, such as sodium chloride and magnesium chloride. Excessive loadings can kill vegetation in swales and other vegetative BMPs. Research indicates roughly 65% of the annual sediment, organic, nutrient, and lead loads can be attributed to winter and spring melts.

Snow Management – Plowing and Sanding

Snow management can influence water quality and impact the selection of BMPs. Dumping snow into receiving waters is not allowed. Plowing snow onto pervious surfaces can help to decrease peak runoff rates and encourage infiltration. Snow with large amounts of sand, or bare surfaces with accumulated sand, however, can result in smothering or filling the capacity of stormwater BMPs.

BMP Applicability in Cold Regions

Based on climate conditions and design obstacles, a list of BMP applicability in cold regions is presented in Table 6.9: Summary of BMP Applicability in Cold Regions (continued). These recommendations should be used as a rule-of-thumb rather than a hard and fast rule that can be applied in all instances. Also note that in order to meet the goal of treating at least 90% of the annual runoff volume, it may be necessary to oversize BMPs in cold regions.

Table 6.9: Summary of BMP Applicability in Cold Regions

BMP	Applicability (High, Medium, Low)	Notes
BMP F6.21: Infiltration Ponds	Medium	Can be effective but may be restricted by groundwater quality concerns related to infiltration of chlorides. Frozen ground may inhibit the infiltration capacity of ground. Plants for vegetated BMPs should be selected for tolerance to cold and freezing conditions.
BMP F6.22: Infiltration Trenches	Medium	
BMP T5.21: Infiltration Swales	Medium	
BMP T5.21: Infiltration Swales	Medium	
BMP F6.23: Bioretention	Medium	
BMP T5.40: Basic Biofiltration Swale	Medium	Reduced effectiveness in the winter because of dormant vegetation. Very valuable for snow storage and meltwater infiltration.
BMP T5.50: Vegetated Filter Strip	Medium	
Drywell	Medium to high	Infiltration surface below frost line.
Basic Wetpond - see BMP T10.10: Wetponds - Basic and Large	Medium	Can be effective but needs modifications to prevent freezing of outlet pipes. Limited by reduced treatment volume and biological activity during ice cover.
Large Wetpond - see BMP T10.10: Wetponds - Basic and Large	High	Some modifications needed to conveyance structures. Extended detention storage provides treatment during winter season.
BMP T5.72: Wetvaults	High	Design pool elevation below frost line or per manufacturer specs. Some modifications needed to conveyance structures.
BMP T5.73: Stormwater Treatment Wetlands	High	Extended detention storage provides treatment during winter season. Modifications needed to wetland plant species. Some modifications needed to conveyance structures.
BMP T5.80: Basic Sand Filter Basin	Low	Frozen ground considerations, combined with frost heave, make this ineffective in cold climates.
BMP T5.81: Large Sand Filter Basin	Low	
BMP T5.82: Sand Filter Vault	High	Design filter elevation below frost line or per manufacturer specifications.
BMP T5.83: Linear Sand Filter	Low to medium	Design filter elevation below frost line or per manufacturer specifications. Cold conditions may

Table 6.9: Summary of BMP Applicability in Cold Regions (continued)

BMP	Applicability (High, Medium, Low)	Notes
		plug surface inlet and impact performance.
BMP F6.30: Evaporation Ponds	Medium to high	Evaporation not expected to result in significant water losses during cold weather; hence must size to provide adequate storage.
BMP T5.100: API (Baffle type) Separator	Low to medium	Check with the manufacturer for cold weather applicability.
BMP T5.110: Coalescing Plate (CP) Separator	Low to medium	

6.1.9 Liners and Geotextiles

6.1.9.1 General Liner Design

Liners are intended to reduce the likelihood that pollutants in stormwater will reach groundwater when Runoff Treatment BMPs are constructed. In addition to groundwater protection considerations, some BMP types require permanent pools of water for proper functioning. An example is the first cell of a wetpond.

Treatment liners amend the soil with materials that treat stormwater before it reaches more freely draining soils. Treatment liners have slow rates of infiltration, generally less than 2.4 inches per hour (1.7×10^{-3} cm/s), but not as slow as low permeability liners. Treatment liners may use in-place native soils or imported soils.

Low permeability liners reduce infiltration to a very slow rate, generally less than 0.02 inches per hour (1.4×10^{-5} cm/s). These types of liners should be used for industrial or commercial sites with a potential for high pollutant loading in the stormwater runoff. Low permeability liners may be fashioned from earthen materials, geomembrane, or concrete. Earthen liners are preferred because of their general resilience and ease of maintenance.

The following should be considered when a liner is part of your design:

- Table 6.10: Liner Types Recommended for Runoff Treatment BMPs (continued) shows recommendations for the type of liner (either treatment or low permeability) generally best suited for use with various Runoff Treatment BMPs.
- Liners shall be evenly placed over the bottom and/or sides of the treatment area of the BMP as indicated in Table 6.10: Liner Types Recommended for Runoff Treatment BMPs (continued). Areas above the treatment volume required to pass flows greater than the water quality treatment flow (or volume) need not be lined. However, the lining must be extended to the top of the interior side slope and anchored if it cannot be permanently secured by other means.
- For low permeability liners, the following criteria apply:

1. Where the seasonal high groundwater elevation is likely to contact a low permeability liner, liner buoyancy may be a concern. A low permeability liner shall not be used in this situation unless evaluated and recommended by a geotechnical engineer.
2. Where grass must be planted over a low permeability liner per the BMP design, a minimum of 6 inches of topsoil or compost-amended native soil (2 inches compost tilled into 6 inches of native till soil) must be placed over the liner in the area to be planted. Twelve inches of cover is preferred.

- If a treatment liner will be below the seasonal high water level, the pollutant removal performance of the liner must be evaluated by a geotechnical or groundwater specialist and found to be as protective as if the liner were above the level of the groundwater.

See 6.1.9.2 Treatment Liners and 6.1.9.3 Low Permeability Liners for more specific design criteria for treatment liners and low permeability liners.

Table 6.10: Liner Types Recommended for Runoff Treatment BMPs

Runoff Treatment BMP	Area to be Lined	Type of Liner Recommended
BMP T6.10: Presettling Basin	Bottom and sides	Low permeability liner or Treatment liner (If the basin will intercept the seasonal high groundwater table, a treatment liner is recommended.)
BMP T10.10: Wetponds - Basic and Large (first cell)	bottom and sides to WQ design water surface	Low permeability liner or Treatment liner (If the wet pond will intercept the seasonal high groundwater table, a treatment liner is recommended.)
BMP T10.10: Wetponds - Basic and Large (second cell)	bottom and sides to WQ design water surface	Treatment liner
BMP T10.40: Combined Detention and Wetpool Facilities (first cell)	bottom and sides to WQ design water surface	Low permeability liner or Treatment liner (If the facility will intercept the seasonal high groundwater table a treatment liner is recommended.)
BMP T10.40: Combined Detention and Wetpool Facilities (second cell)	bottom and sides to WQ design water surface	Treatment liner
BMP T5.73: Stormwater Treatment Wetlands	Bottom and sides, both cells	Low permeability liner (If the facility will intercept the seasonal high groundwater table, a treatment liner is recommended.)
BMP T5.80: Basic Sand	Basin sides only	Treatment liner

Table 6.10: Liner Types Recommended for Runoff Treatment BMPs (continued)

Runoff Treatment BMP	Area to be Lined	Type of Liner Recommended
Filter Basin or BMP T5.81: Large Sand Filter Basin		
BMP T5.82: Sand Filter Vault	Not applicable	No liner needed
BMP T5.83: Linear Sand Filter (in vault)	Not applicable if in vault	No liner needed
BMP T5.83: Linear Sand Filter (not in vault)	Bottom and sides of presettling cell if not in vault	Low permeability or treatment liner
BMP T5.72: Wetvaults	Not applicable	No liner needed

6.1.9.2 Treatment Liners

Listed below is Ecology's design criteria for treatment liners:

- A two foot thick layer of soil with a minimum organic content of 1.0% AND a minimum cation exchange capacity (CEC) of 5 milliequivalents/100 grams can be used as a treatment liner beneath a Runoff Treatment or Flow Control 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 taken throughout the depth of the treatment liner (usually two to six 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 Runoff Treatment BMP. However, if the treatment liner is an engineered soil or has very low permeability, the potential to bypass the treatment liner through the side walls may be significant. In those cases, the Runoff Treatment BMP side walls must 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.

  Models must be run assuming no infiltration through the sidewalls if one sidewall is impervious.
- 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 local approval authority.

6.1.9.3 Low Permeability Liners

This section contains Ecology's design criteria for the following low permeability liner options:

- earthen liners,
- geomembrane liners, and
- concrete liners.

Earthen Liners

- Soils used for earthen liners should be free from foreign material such as paper, brush, trees, and large rocks.
- All soil liners constructed of compacted material should be at least 24 inches thick, compacted in lifts no greater than 6 inches thick, and compacted to 95 percent of maximum density as determined by the Standard Proctor Density test (WSDOT test method No. 606).
- For in-situ clay soils meeting the soils liner criteria above, a minimum of 6 inches below planned grade should be excavated and re-compacted to assure a uniformly compacted finished surface.
- Soil liners should meet the following particle size gradation and Atterberg limits:
  - Thirty percent or more passing a number 200 mesh sieve.
  - A liquid limit of 30 percent or greater.
  - A plasticity index of 15 or greater.
  - A permeability less than or equal to 1×10^{-7} cm/sec.
- Soil embankment walls should have a top width of at least five feet.
- The interior and exterior slopes of soil embankment walls should be no steeper than one foot vertical to three feet horizontal.
- All soil embankment walls should have a vegetative cover or other stabilizing material to prevent erosion.
- All piping penetrating the embankments should have erosion stops and water seals.

Source: (Ecology, 2019)

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 may be operated over the geomembrane liner.

- Geomembrane liners shall be bedded according to the manufacturer's recommendations.
- Geomembrane liners shall be installed so that they can be covered with 12 inches of top dressing forming the bottom and sides of the Runoff Treatment BMP, except for BMP T5.82: Sand Filter Vault, BMP T5.83: Linear Sand Filter if located in a vault, or BMP T5.72: Wetvaults. Top dressing shall consist of 6 inches of crushed rock covered with 6 inches of native soil. The rock layer is to mark the location of the liner for future maintenance operations. As an alternative to crushed rock, 12 inches of native soil may be used if orange plastic “safety fencing” or another highly visible, continuous marker is embedded 6 inches above the geomembrane liner.
- If possible, geomembrane 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.
- 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 recommendation by a geotechnical engineer that the top dressing will be stable for all site conditions, including maintenance.

Concrete Liners

- Portland cement liners are allowed irrespective of BMP size, and shotcrete may be used on slopes. However, specifications must be developed by a licensed engineer in the state of Washington 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 must be no steeper than 5H:1V to prevent the top dressing material from slipping.

6.1.9.4 Geotextile Specifications

Table 6.11: Geotextile Properties for Underground Drainage

Geotextile Property Requirements[1]			
		Low Survivability	Moderate Survivability
Geotextile Property	Test Method	Woven / Nonwoven	Woven / Nonwoven
Grab Tensile Strength, in machine and x-machine direction	ASTM D4632	180 lbs / 115 lbs min.	250 lbs / 160 lbs min.
Grab Failure Strain, in machine and x-	ASTM	< 50% / >= 50%	< 50% / >=50%

Table 6.11: Geotextile Properties for Underground Drainage (continued)

Geotextile Property Requirements[1]			
		Low Survivability	Moderate Surviv-ability
Geotextile Property	Test Method	Woven / Nonwoven	Woven / Nonwoven
machine direction	D4632		
Seam Breaking Strength (if seams are present) with seam located in the center of 8-inch-long specimen oriented parallel to grip faces	ASTM D4632	160 lbs / 100 lbs min.	220 lbs / 140 lbs min.
Puncture Resistance	ASTM D6241	370 lbs / 220 lbs min.	495 lbs / 310 lbs min.
Tear Strength, in machine and x-machine direction	ASTM D4533	67 lbs / 40 lbs min.	80 lbs / 50 lbs min.
Ultraviolet (UV) Radiation stability	ASTM D4355	50% strength retained min., after 500 hrs. in a xenon arc device	50% strength retained min., after 500 hrs. in a xenon arc device
1. All geotextile properties are minimum average roll values (i.e., the test result for any sampled roll in a lot shall meet or exceed the values shown in the table).			

Table 6.12: Geotextile for Underground Drainage Filtration Properties

Geotextile Property Requirements[1]				
Geotextile Property	Test Method	Class A	Class B	Class C
AOS[2]	ASTM D4751	No. 40 max.	No. 60 max.	No. 80 max.
Water Permittivity	ASTM D4491	0.5/sec min.	0.4/sec min.	0.3/sec min.
1. All geotextile properties are minimum average roll values (i.e., the test result for any sampled roll in a lot shall meet or exceed the values shown in the table). 2. Apparent Opening Size (measure of diameter of the pores in the geotextile)				

Table 6.13: Geotextile Strength Properties for Impermeable Liner Protection

Geotextile Property	Test Method	Geotextile Property Requirements[1]
Grab Tensile Strength, min. in machine and x-machine direction	ASTM D4632	250 lbs min.

Table 6.13: Geotextile Strength Properties for Impermeable Liner Protection (continued)

Geotextile Property	Test Method	Geotextile Property Requirements[1]
Grab Failure Strain, in machine and x-machine direction	ASTM D4632	> 50%
Seam Breaking Strength (if seams are present)	ASTM D4632 and ASTM D4884 (adapted for grab test)	220 lbs min.
Puncture Resistance	ASTM D4833	125 lbs min.
Tear Strength, min. in machine and x-machine direction	ASTM D4533	90 lbs min.
Ultraviolet (UV) Radiation	ASTM D4355	50% strength stability retained min., after 500 hrs. in xenon arc device
1. All geotextile properties are minimum average roll values (i.e., the test result for any sampled roll in a lot shall meet or exceed the values shown in the table).		

Applications

1. For sand filter drain strip between the sand and the drain rock or gravel layers specify Geotextile Properties for Underground Drainage, moderate survivability, Class A, from Table 6.11: Geotextile Properties for Underground Drainage (continued) and Table 6.12: Geotextile for Underground Drainage Filtration Properties.

2. 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 6.13: Geotextile Strength Properties for Impermeable Liner Protection (continued) should be used to specify survivability properties for the liner protection application. Table 6.12: Geotextile for Underground Drainage Filtration Properties, Class C should be used for filtration properties. Only nonwoven geotextiles are appropriate for the liner protection application.

3. For an infiltration drain specify Geotextile for Underground Drainage, low survivability, Class C, from Table 6.11: Geotextile Properties for Underground Drainage (continued) and Table 6.12: Geotextile for Underground Drainage Filtration Properties.

4. For a sand bed cover a geotextile fabric is placed exposed on top of the sand layer to trap debris brought in by the storm water and to protect the sand, facilitating easy cleaning of the surface of the sand layer. However, a geotextile is not the best product for this application. A polyethylene or polypropylene geonet would be better. The geonet material should have high UV resistance (90% or more strength retained after 500 hours in the weatherometer, ASTM D4355), and high permittivity (ASTM D4491, 0.8 sec. -1 or more) and percent open area (CWO-22125, 10% or more). Tensile strength should be on the order of 200 lbs grab (ASTM D4632) or more.

Courtesy of Tony Allen (Allen, 1999).

Reference for Table 6.11: Geotextile Properties for Underground Drainage (continued) and Table 6.12: Geotextile for Underground Drainage Filtration Properties: Section 9-33.2 "Geotextile Properties" from WSDOT's 2012 *Standard Specifications for Road, Bridge, and Municipal Construction* (WSDOT, 2012).

6.1.10 Hydraulic Structures

6.1.10.1 Flow Splitters

Many Runoff Treatment BMPs can be designed as on-line systems with flows above the Water Quality Design Flow Rate or Water Quality Design Volume simply passing through the BMP at a lower pollutant removal efficiency. However, it is sometimes desirable to restrict flows to Runoff Treatment BMPs and bypass the remaining higher flows around them. This turns the BMP into an off-line facility. This can be accomplished by splitting flows in excess of the Water Quality Design Flow Rate upstream of the Runoff Treatment BMP and diverting higher flows to a bypass pipe or channel. The bypass typically enters a detention pond or the downstream receiving drainage system, depending on Flow Control requirements. In most cases, it is the designer's choice whether Runoff Treatment BMPs are designed as on-line or off-line; an exception is oil/water separators, which must be designed as off-line.

A crucial factor in designing flow splitters is to ensure that low flows are delivered to the Runoff Treatment BMP up to the Water Quality Design Flow Rate. Above this rate, additional flows are diverted to the bypass system with minimal increase in head at the flow splitter structure to avoid surcharging the Runoff Treatment BMP under high flow conditions.

Flow splitters are typically manholes or vaults with concrete baffles. In place of baffles, the splitter mechanism may be a half tee section with a solid top and an orifice in the bottom of the tee section. A full tee option may also be used as described below in the "General Design Criteria." We show two possible design options for flow splitters in Figure 6.3: Flow Splitter, Option A and Figure 6.4: Flow Splitter, Option B. Other equivalent designs that achieve the result of splitting low flows and diverting higher flows around the facility are also acceptable.

General Design Criteria

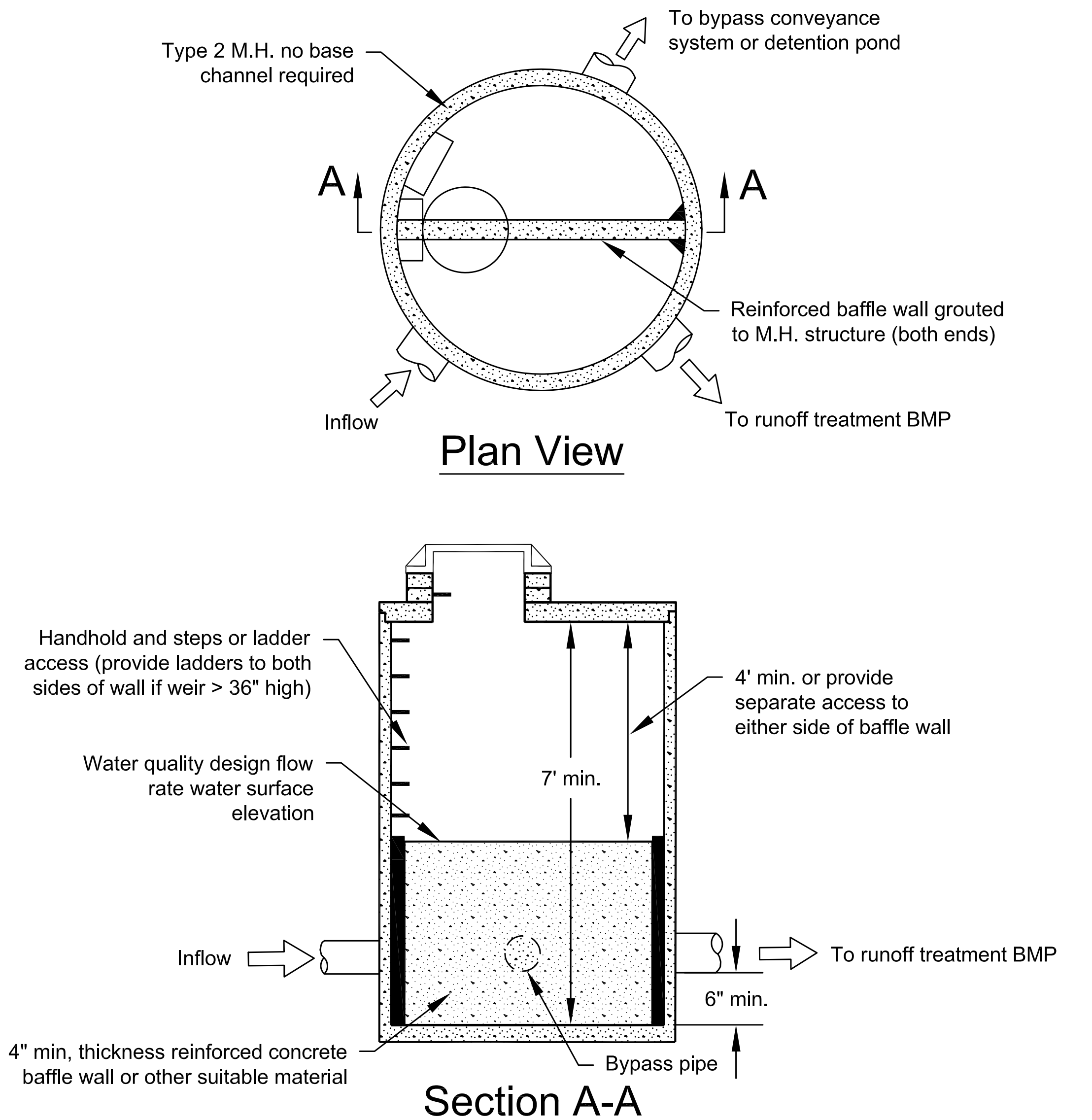
- A flow splitter must be designed to deliver the Water Quality Design Flow Rate to the Runoff Treatment BMP.
- Locate the top of the bypass weir at the water surface for the design flow. Remaining flows enter the bypass line.
- The maximum head must be minimized for flows in excess of the Water Quality Design Flow Rate. Specifically, flow to the Runoff Treatment BMP at the 100-year water surface must not be more than 110% of the Water Quality Design Flow Rate.
- Designers may use either design shown in Figure 6.3: Flow Splitter, Option A or Figure 6.4: Flow Splitter, Option B or an equivalent design.
- When using the design shown in Figure 6.3: Flow Splitter, Option A, the designer must consider the headwater depth under both inlet and outlet control on the pipe to the BMP.

- As an alternative to using a solid top plate in Figure 6.4: Flow Splitter, Option B, a full tee section may be used with the top of the tee slightly above the 100-year water surface. This alternative would route emergency overflows (if the overflow pipe were plugged) through the Runoff Treatment BMP rather than back up from the flow splitter.
- Special applications may require a modified flow splitter. The baffle wall may be fitted with a notch and adjustable weir plate to proportion runoff volumes other than high flows.
- For ponding BMPs, designers must include back water effects in designing the height of the standpipe in the flow splitter.
- Designers must provide ladder or step and handhold access. If the weir wall is higher than 36 inches, two ladders, one to either side of the wall, must be used.

Materials

- The splitter baffle may be installed in a Type 2 manhole or vault.
- The baffle wall must be made of reinforced concrete or another suitable material resistant to corrosion, and have a minimum 4-inch thickness. The minimum clearance between the top of the baffle wall and the bottom of the manhole cover must be 4 feet; otherwise, dual access points should be provided.
- All metal parts must be corrosion resistant. Examples of preferred materials include aluminum, stainless steel, and plastic. Zinc and galvanized materials are discouraged because of aquatic toxicity. Painted metal parts should not be used because of poor longevity.

Figure 6.3: Flow Splitter, Option A



Note: The outlet pipe to the Runoff Treatment BMP may require an orifice plate installed on the outlet to control the water quality design flow rate water surface elevation (weir height). The water quality design flow rate water surface elevation should be set to provide a minimum headwater/diameter ratio of 2.0 on the outlet pipe.

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Flow Splitter, Option A

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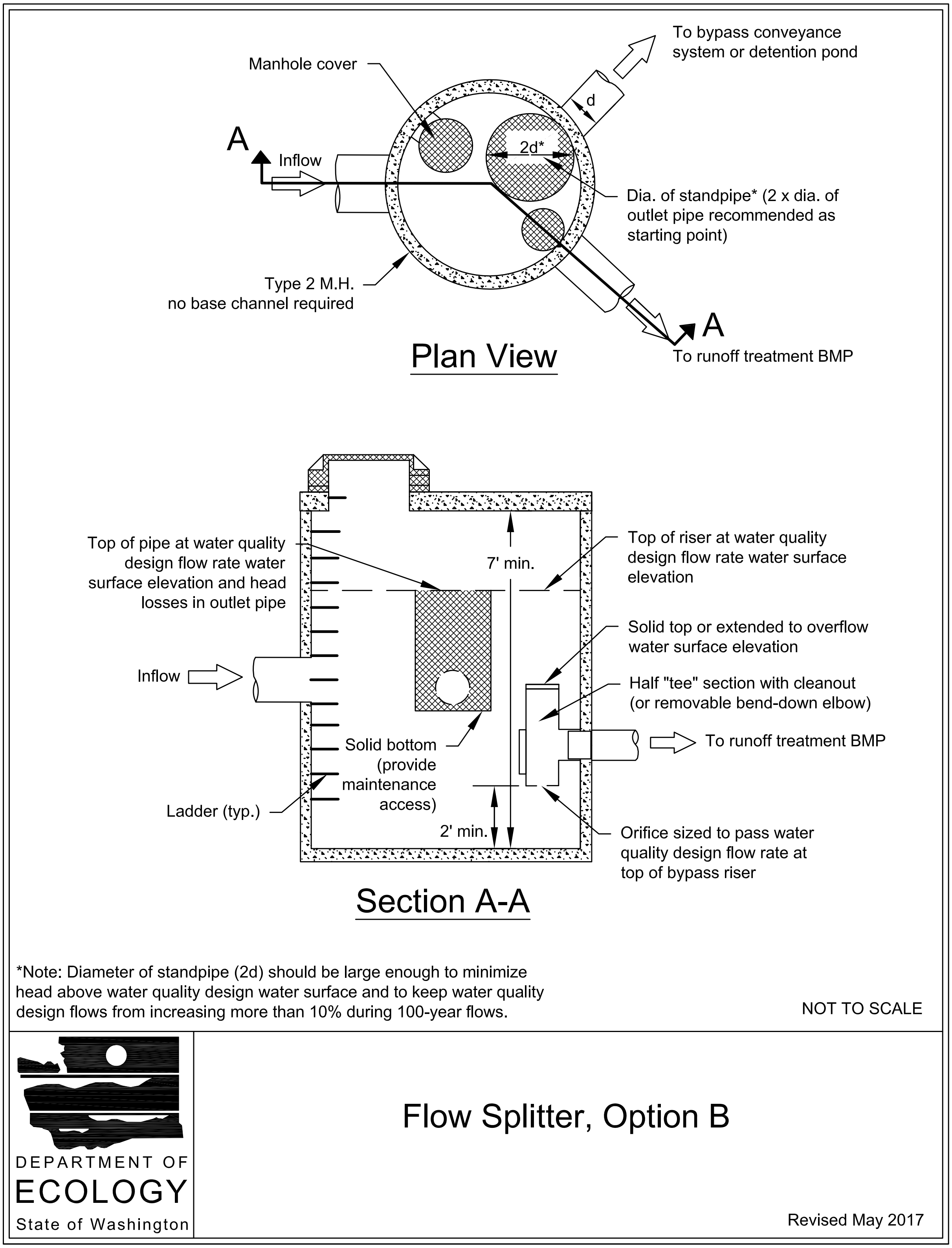
Figure 6.4: Flow Splitter, Option B



6.1.10.2 Flow Spreaders

A flow spreader functions to uniformly spread flows across the inlet of a Runoff Treatment BMP (e.g., sand filter, biofiltration swale, or filter strip). There are five flow spreader options presented here:

- 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 must be used (e.g. to correct for moderate grade changes along BMP T5.50: Vegetated Filter Strip).

Options D and E are only for flows that are already unconcentrated and enter BMP T5.50: Vegetated Filter Strip or BMP T9.30: Continuous Inflow Biofiltration Swale. Other flow spreader options are possible with approval from the reviewing authority.

General Design Criteria

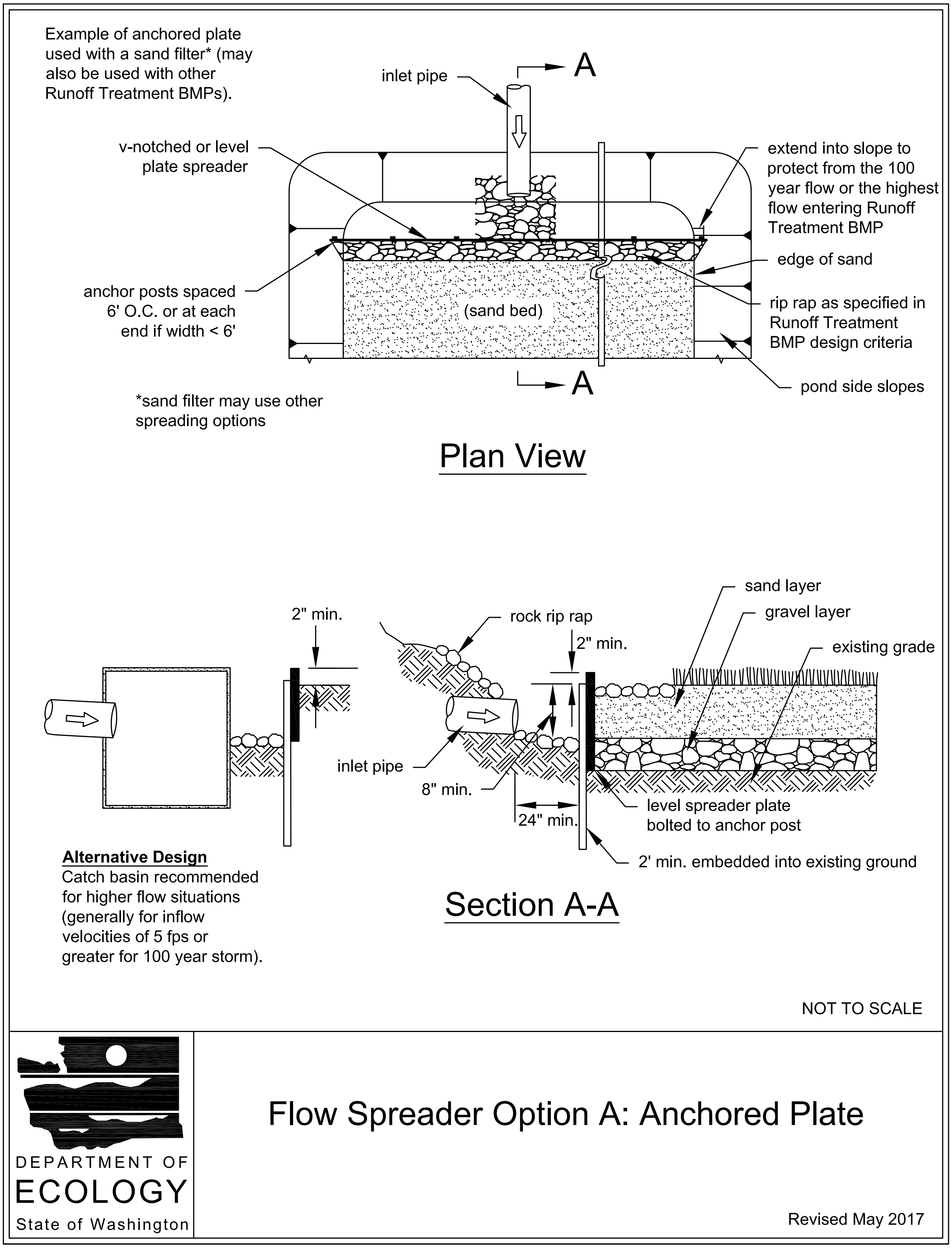
- Where flow enters the flow spreader through a pipe, it is recommended that the pipe be submerged to the extent practical to dissipate energy as much as possible.
- Flow spreaders are difficult to maintain and continue to evenly distribute flow and should not be used on slopes greater than five percent to prevent recombining of downstream flow that can create rills and gullies. Flow spreaders are not to be used in areas accessible by the public as walking on them can alter their flow characteristics.
- For higher inflows (greater than 5 cfs for the 100-yr 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.

Option A - Anchored Plate

- An anchored plate flow spreader must 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 must be lined to reduce erosion and to provide energy dissipation.
- The top surface of the flow spreader plate must be level, projecting a minimum of 2 inches above the ground surface of the Runoff 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 used.

- A flow spreader plate must extend horizontally beyond the bottom width of the Runoff Treatment BMP to prevent water from eroding the side slope. The horizontal extent should be such that the bank is protected for all flows up to the 100-year flow or the maximum flow that will enter the Runoff Treatment BMP.
- Flow spreader plates must 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 must be 4 inch square concrete, tubular stainless steel, or other material resistant to decay.

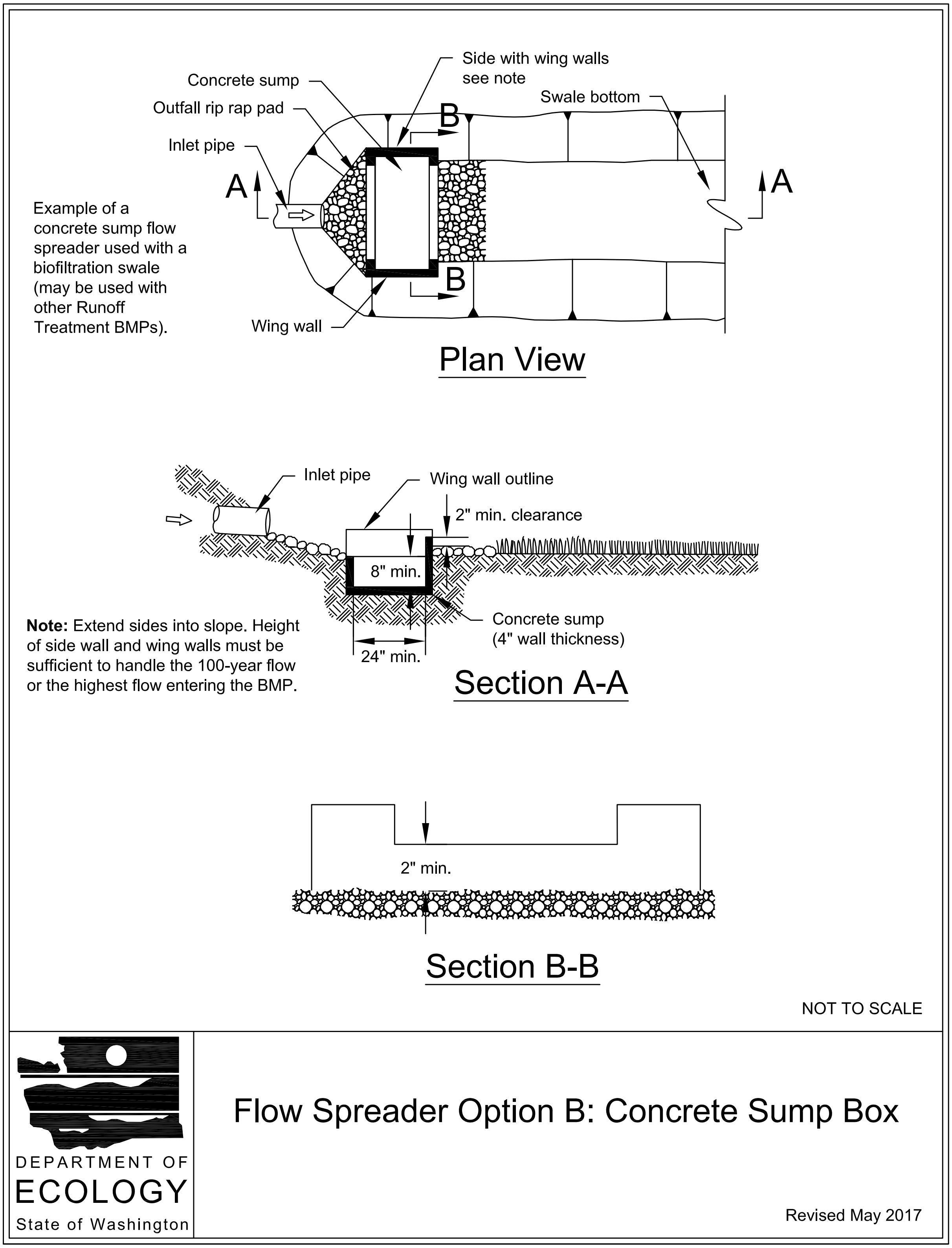
Figure 6.5: Flow Spreader Option A: Anchored Plate



Option B - Concrete Sump Box

- The wall of the downstream side of a rectangular concrete sump box must extend a minimum of 2 inches above the inlet to the Runoff Treatment BMP. This serves as a weir to spread the flows uniformly across the BMP inlet.
- The downstream wall of a sump box must have “wing walls” at both ends. Side walls and returns must 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 must be reinforced with wire mesh for cast-in-place sump boxes.
- Sump boxes must be placed over bases that consists of 4 inches of crushed rock, 5/8-inch minus to help assure the sump box remains level.

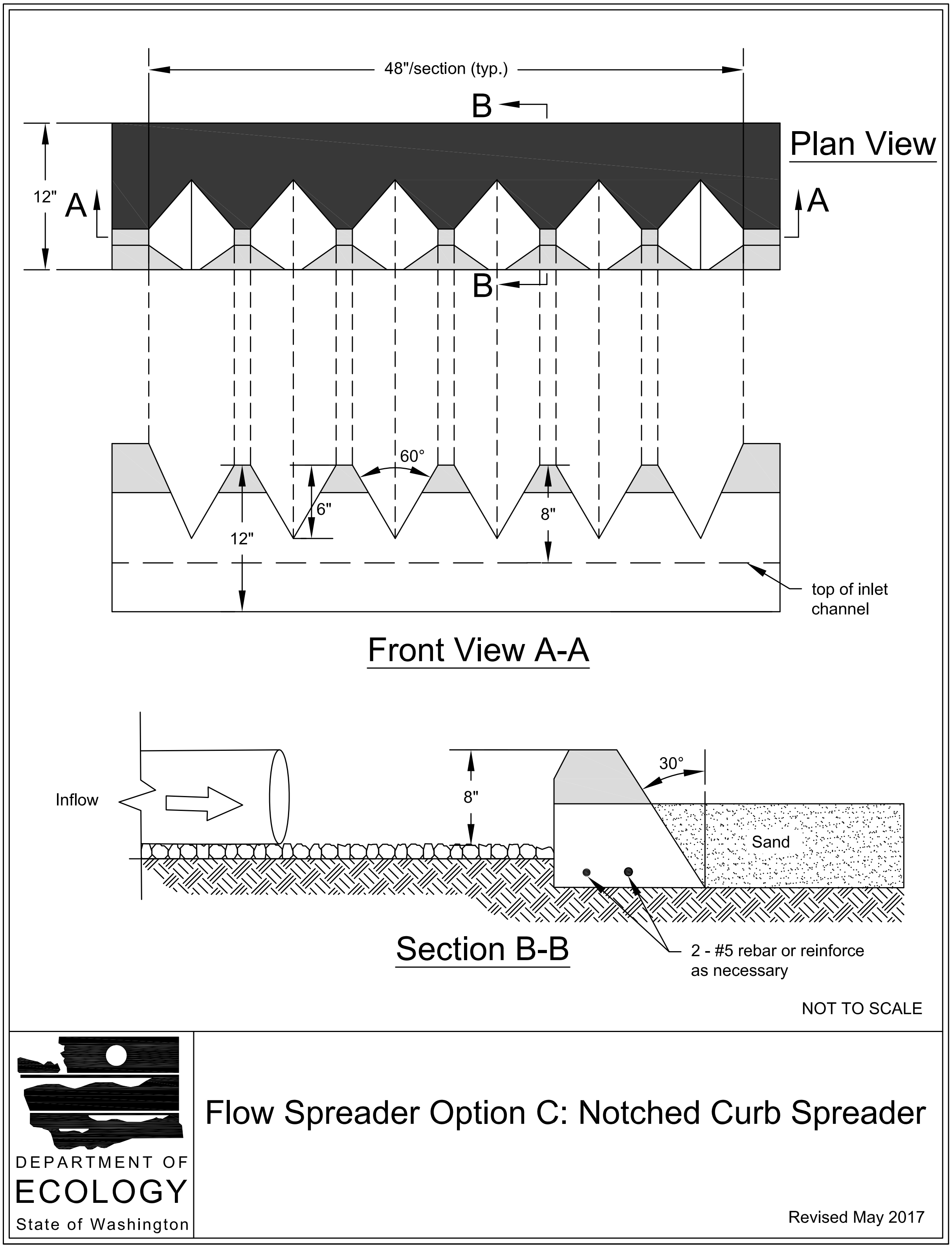
Figure 6.6: Flow Spreader Option B: Concrete Sump Box



Option C - Notched Curb Spreader

Notched curb spreader sections must be made of extruded concrete laid side-by-side and level. Typically five "teeth" per four-foot section provides good spacing. The space between adjacent "teeth" forms a v-notch.

Figure 6.7: Flow Spreader Option C: Notched Curb Spreader

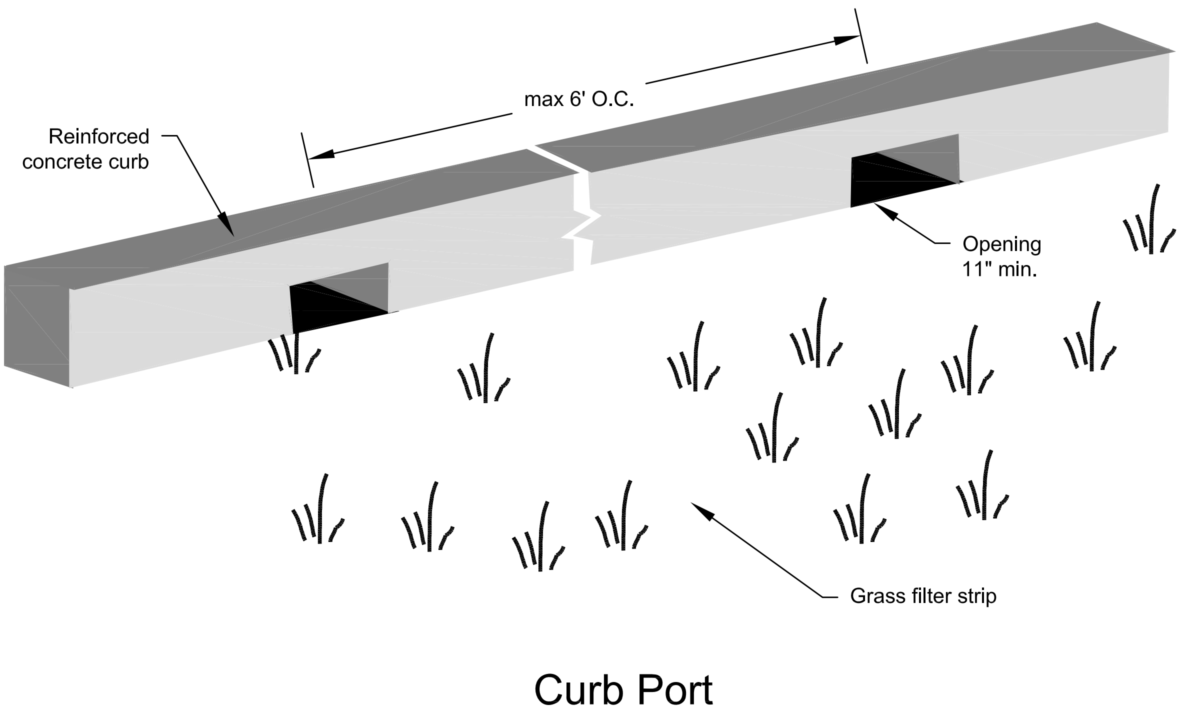


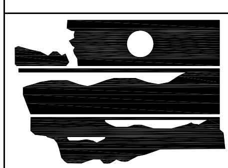
Option D - Through-Curb Ports

Unconcentrated flows from paved areas entering BMP T5.50: Vegetated Filter Strip or BMP T9.30: Continuous Inflow Biofiltration Swale can use through-curb ports (this option) or interrupted curbs (Option E) to allow flows from the pavement 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 Runoff Treatment BMP.

Openings in the curb must be at regular intervals and at least every 6 feet. The width of each opening must be at least 11 inches. 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.

Figure 6.8: Flow Spreader Option D: Through-Curb Port





Flow Spreader Option D: Through-Curb Port

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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 Runoff Treatment BMP it serves) of the treatment area. At a minimum, gaps must be every 6 feet to allow distribution of flows into the Runoff Treatment BMP before they become too concentrated. The gaps must be a minimum of 11 inches. As a general rule, no opening should discharge more than 10 percent of the overall flow entering the BMP.

6.1.10.3 Outfall Systems

Properly designed outfalls are critical to reducing adverse impacts that may result from concentrated discharges from pipe systems and culverts. Outfall systems include rock splash pads, flow dispersal trenches, gabion or other energy dissipators, and tightline systems. A tightline system is typically a continuous length of pipe used to convey flows down a steep or sensitive slope with appropriate energy dissipation at the discharge end.

Provided below are general design criteria for both Outfall Features and Tightline Systems.

Outfall Features

At a minimum, all outfalls must be provided with a rock splash pad (see Figure 6.9: Pipe/Culvert Outfall Discharge Protection), unless the site requires a more rubust energy dissipator. See the bullets below for guidance on outfall features, including other types of energy dissipation and appropriate uses for each. Also refer to Appendix 6-A: BMP Maintenance Tables for outfall protection needs based on maintenance observations.

- The flow dispersal trenches shown in Figure 6.10: Flow Dispersal Trench and Figure 6.11: Alternative Flow Dispersal Trench should only be used when both criteria below are met:
    1. An outfall is necessary to disperse concentrated flows across uplands where no conveyance system exists and the natural (existing) discharge is unconcentrated; and
    2. The 100-year peak discharge rate is less than or equal to 0.5 cfs.
- For freshwater outfalls with a design velocity greater than 10 fps, a gabion dissipator or engineered energy dissipator may be required. There are many possible designs.

  Note: The gabion outfall detail shown in Figure Figure 6.12: Gabion Outfall Detail is illustrative only. A design engineered to specific site conditions must be developed. This type of outfall should not be installed in fish bearing streams.
- Tightline systems may be needed to prevent aggravation or creation of a downstream erosion problem.
- Energy dissipators shall be located above the Ordinary High Water Mark on fish bearing streams. Stormwater outfalls not intended for fish passage shall have an invert elevation a minimum of 1’ above the Ordinary High Water Mark.
- In marine waters, rock splash pads and gabion structures are not recommended due to corrosion and destruction of the structure, particularly in high energy environments. Diffuser

Tee structures, such as that depicted in Figure 6.13: Diffuser TEE (an example of energy dissipating end feature), are also not generally recommended in or above the intertidal zone. They may be acceptable in low bank or rock shoreline locations. Stilling basins or bubble-up structures are acceptable. Generally, tightlines trenched to extreme low water or dissipation of the discharge energy above the ordinary high water line are preferred. Outfalls below extreme low water may still need an energy dissipation device (e.g. a tee structure) to prevent nearby erosion.

- Engineered energy dissipators, including stilling basins, drop pools, hydraulic jump basins, baffled aprons, and bucket aprons, are required for outfalls with design velocity greater than 20 fps. These should be designed using published or commonly known techniques found in such references as *Hydraulic Design of Energy Dissipators for Culverts and Channels* (FHWA, 2006), *Open-Channel Hydraulics* (Chow, 1959), *Hydraulic Design of Stilling Basins and Energy Dissipators* (Peterka, 1984), and other publications, such as those prepared by the Natural Resource Conservation Service (NRCS).

- Alternate mechanisms may be used, such as bubble-up structures that eventually drain and structures fitted with reinforced concrete posts. If alternate mechanisms are considered, they should be designed using sound hydraulic principles and consideration of ease of construction and maintenance.

- Mechanisms that reduce velocity prior to discharge from an outfall are encouraged. Some of these are drop manholes and rapid expansion into pipes of much larger size. Other discharge end features may be used to dissipate the discharge energy. An example of such an end feature is a Diffuser Tee with holes in the front half, as shown in Figure 6.13: Diffuser TEE (an example of energy dissipating end feature).

  Note: Stormwater outfalls submerged in a marine environment can be subject to plugging due to biological growth and shifting debris and sediments. Therefore, unless intensive maintenance is regularly performed, they may not meet their long-term designed function.

- New pipe outfalls can provide an opportunity for low-cost fish habitat improvements. For example, an alcove of low-velocity water can be created by constructing the pipe outfall and associated energy dissipator back from the stream edge and digging a channel, over widened to the upstream side, from the outfall to the stream (as shown in Figure 6.14: Fish Habitat Improvement at New Outfalls). Overwintering juvenile and migrating adult salmonids may use the alcove as shelter during high flows. Potential habitat improvements should be discussed with the Washington Department of Fish and Wildlife biologist prior to inclusion in design.

- Bank stabilization, bioengineering and habitat features may be required for disturbed areas.

- Outfall structures should be located where they minimize impacts to fish, shellfish, and their habitats.

- One caution to note is that the in-stream sample gabion mattress energy dissipator may not be acceptable within the ordinary high water mark of fish-bearing waters or where gabions will be subject to abrasion from upstream channel sediments. A four-sided gabion basket located outside the ordinary high water mark should be considered for these applications.

Note: A Hydraulic Project Approval (Chapter 77.55 RCW) and an Army Corps of Engineers permit may be required for any work within the ordinary high water mark. Other provisions of the RCW or the Hydraulic Code Rules (Chapter 220-660 WAC) may also apply. Contact the appropriate regional office of the State Department of Fish and Wildlife.

Table 6.14: Rock Protection at Outfalls

Discharge Velocity at Design Flow in feet per second (fps)	Required Protection Minimum Dimensions				
	Type	**Thickness**	**Width**	**Length**	**Height**
0 - 5	Rock lining(1)	1 foot	Diameter +6 feet	8 feet *or* 4 x diameter, whichever is greater	Crown + 1 foot
5+ - 10	Riprap(2)	2 feet	Diameter +6 feet *or* 3 x diameter, whichever is greater	12 feet *or* 4 x diameter, whichever is greater	Crown + 1 foot
10+ - 20	Gabion outfall	As required	As required	As required	Crown + 1 foot
20+	Engineered energy dissipater required				

Footnotes:

1. **Rock lining** shall be quarry spalls with gradation as follows:
   - Passing 8-inch square sieve: 100%
   - Passing 3-inch square sieve: 40 to 60% maximum
   - Passing 3/4-inch square sieve: 0 to 10% maximum
2. **Riprap** shall be reasonably well graded with gradation as follows:
   - Maximum stone size: 24 inches (nominal diameter)
   - Median stone size: 16 inches
   - Minimum stone size: 4 inches

Note: Riprap sizing governed by side slopes on outlet channel, assumed to be approximately 3H:1V.

Figure 6.9: Pipe/Culvert Outfall Discharge Protection

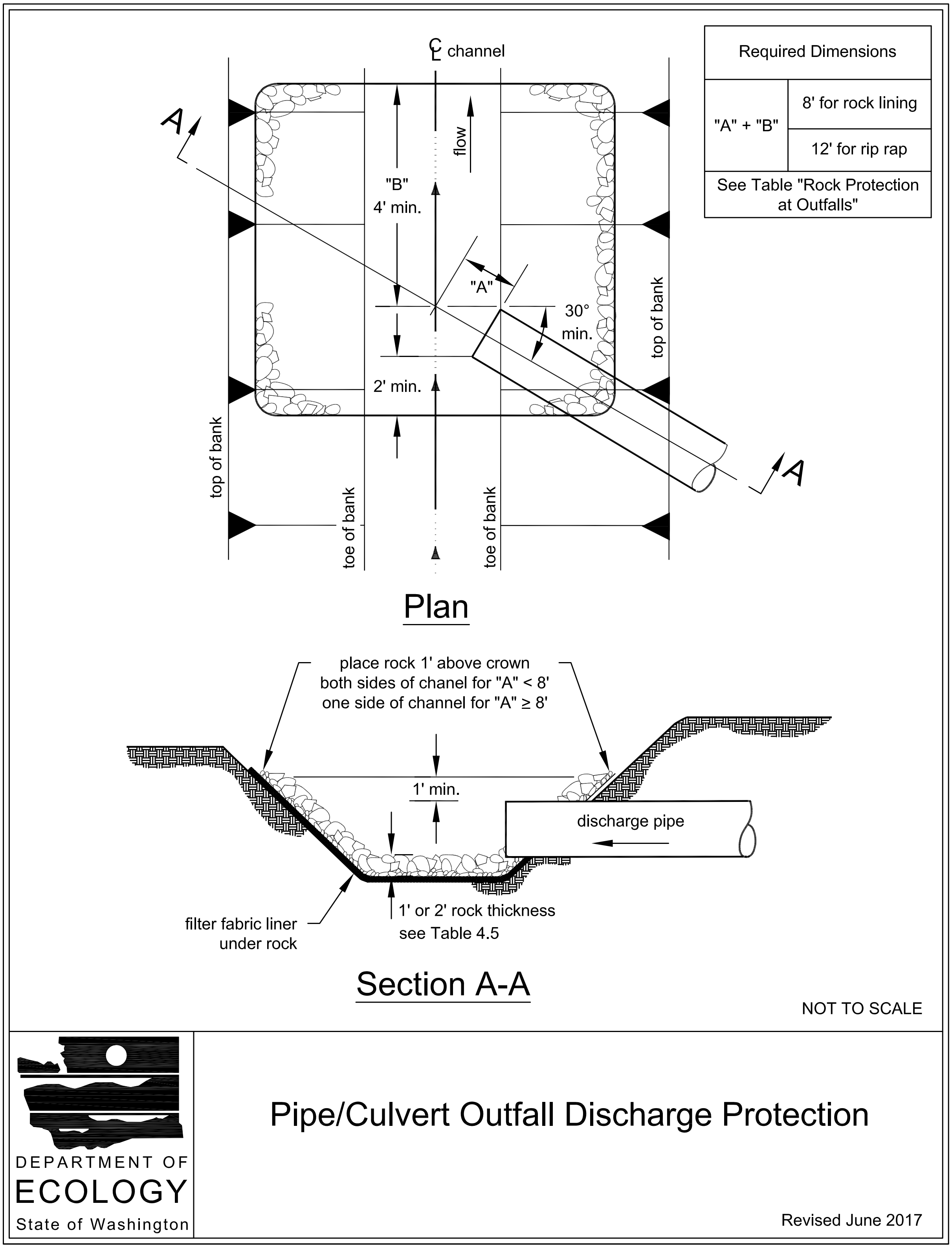


Figure 6.10: Flow Dispersal Trench

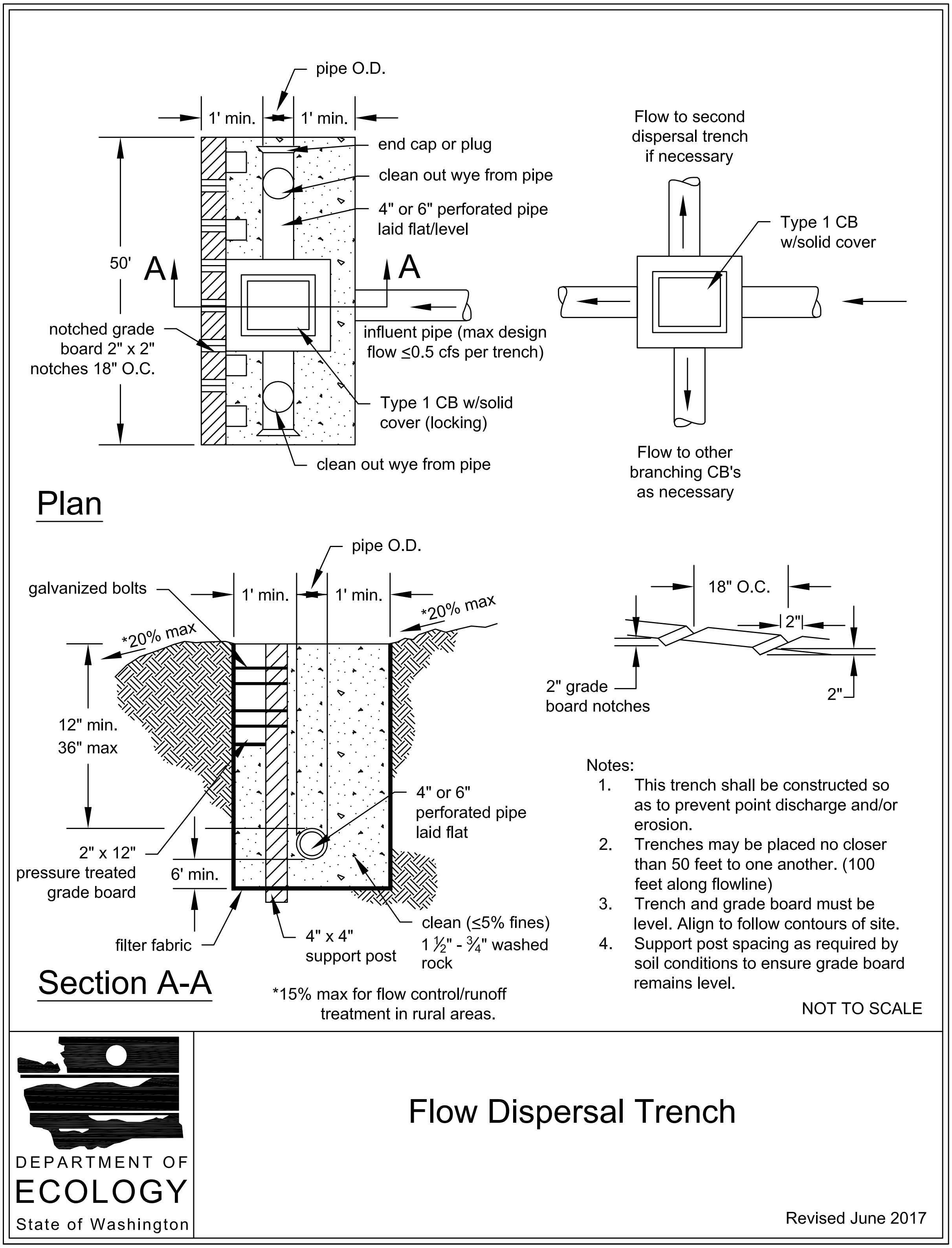
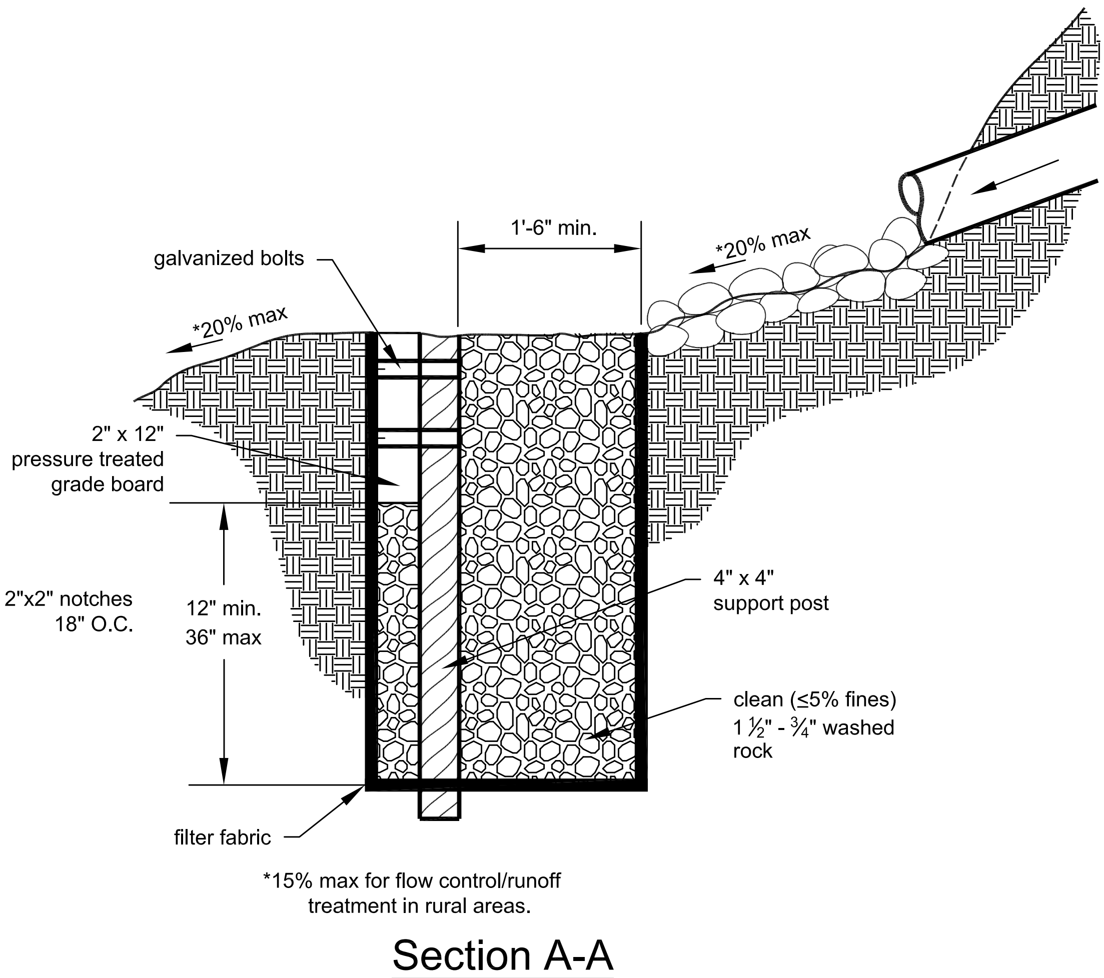


Figure 6.11: Alternative Flow Dispersal Trench



Notes:

1. This trench shall be constructed so as to prevent point discharge and/or erosion.
2. Trenches may be placed no closer than 50 feet to one another. (100 feet along flowline)
3. Trench and grade board must be level. Align to follow contours of site.
4. Support post spacing as required by soil conditions to ensure grade board remains level.

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Alternative Flow Dispersal Trench

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Figure 6.12: Gabion Outfall Detail

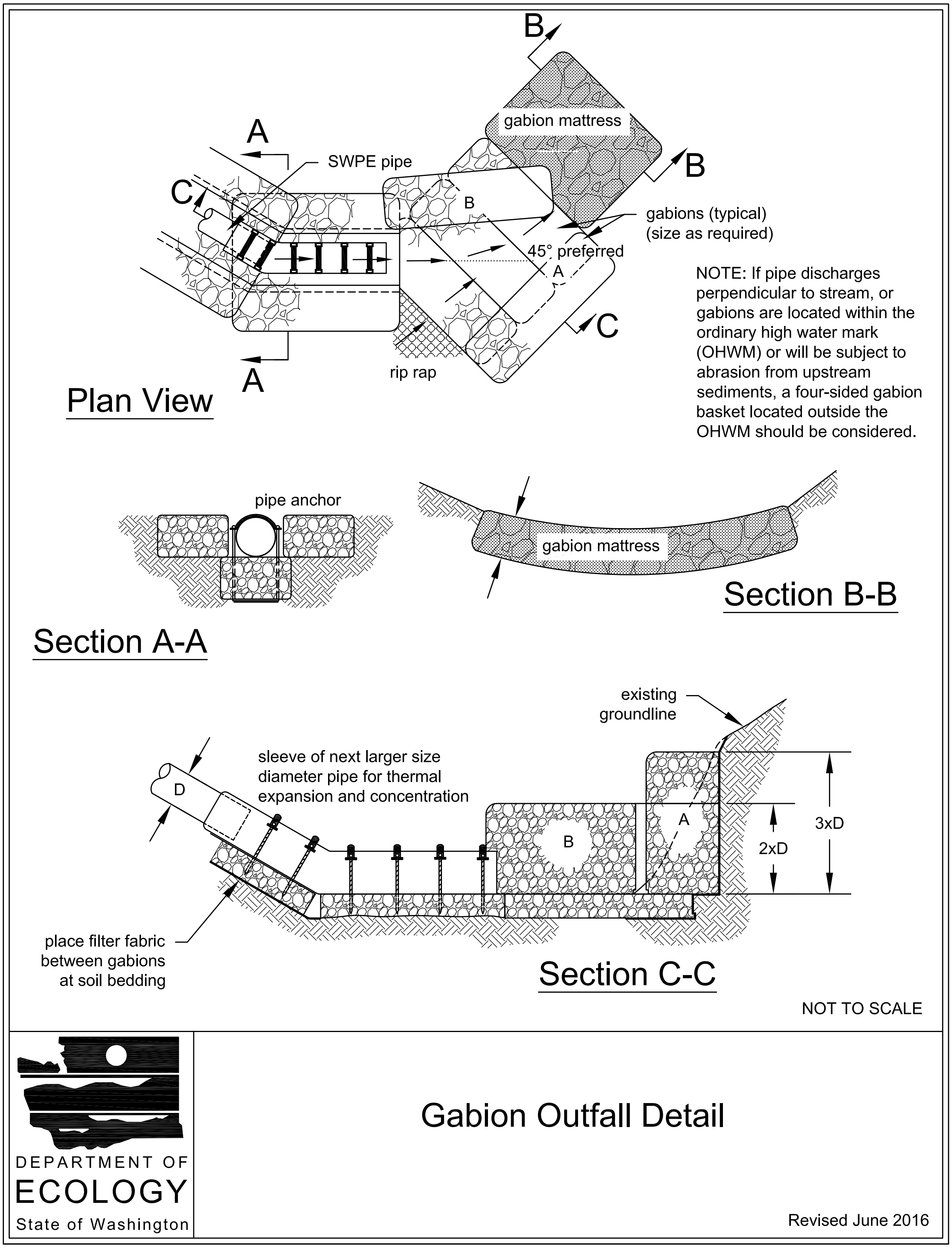
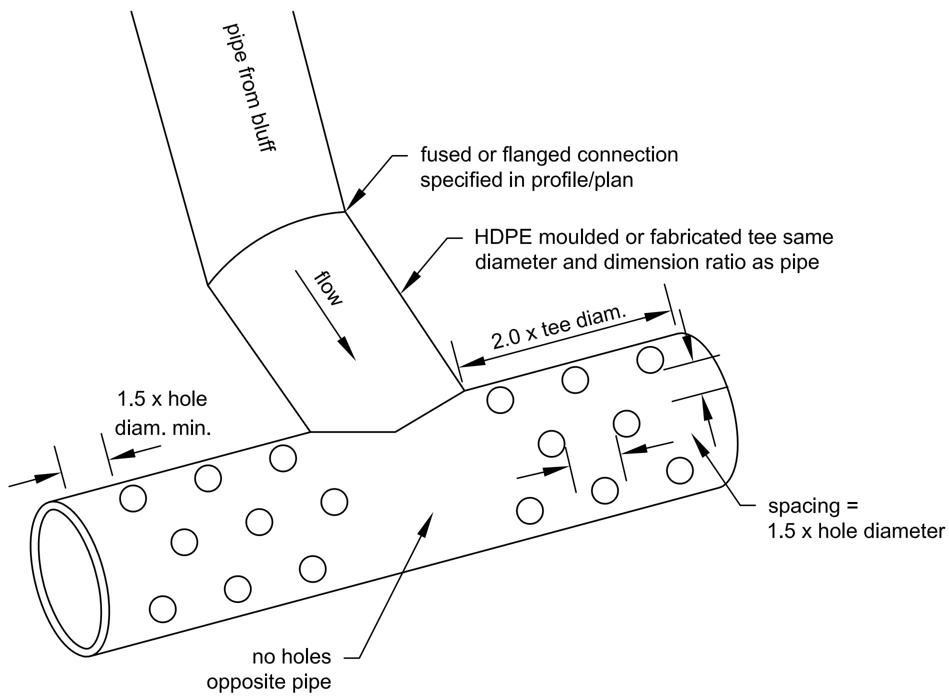


Figure 6.13: Diffuser TEE (an example of energy dissipating end feature)



Drill holes in front half of tee only.
Hole diameter (inches) = tee diameter (inches) divided by 6
(ex. 6 inch tee = 1 inch holes
18 inch tee = 3 inch holes)

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Diffuser TEE
(an example of energy dissipating end feature)

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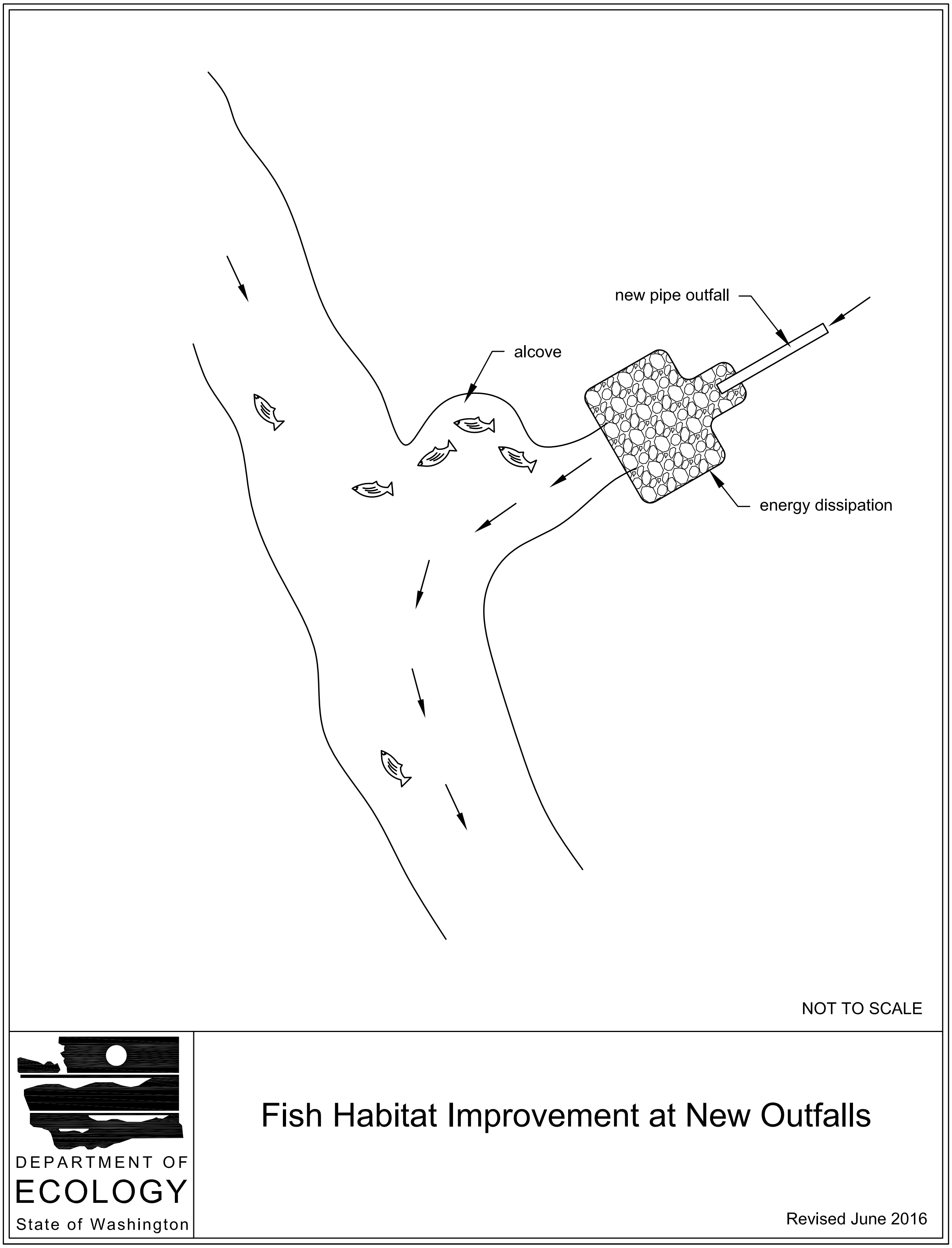
Figure 6.14: Fish Habitat Improvement at New Outfalls



Tightline Systems

- Outfall tightlines may be installed in trenches with standard bedding on slopes up to 20%. In order to minimize disturbance to steep slopes, it is recommended that tightlines be welded HDPE or restrained joint ductile iron pipe placed at grade with proper pipe anchorage and support.
- Except as indicated above, tightlines or conveyances that traverse the marine intertidal zone and connect to outfalls must be buried to a depth sufficient to avoid exposure of the line during storm events or future changes in beach elevation. If non-native material is used to bed the tightline, such material shall be covered with at least 3 feet of native bed material or equivalent.
- High density polyethylene pipe (HDPE) tightlines must be designed to address the material limitations, particularly thermal expansion and contraction and pressure design, as specified by the manufacturer. The coefficient of thermal expansion and contraction for solid wall polyethylene pipe (SWPE) is on the order of 0.001 inch per foot per Fahrenheit degree. Sliding sleeve connections must be used to address this thermal expansion and contraction. These sleeve connections consist of a section of the appropriate length of the next larger size diameter of pipe into which the outfall pipe is fitted. These sleeve connections must be located as close to the discharge end of the outfall system as is practical.
- Due to the ability of HDPE tightlines to transmit flows of very high energy, special consideration for energy dissipation must be made. Details of a sample gabion mattress energy dissipator have been provided as Figure 6.12: Gabion Outfall Detail. Flows of very high energy will require a specifically engineered energy dissipator structure.

6.2 Site Design BMPs

6.2.1 Introduction to Site Design BMPs

Site Design BMPs are general practices for site design to minimize the impacts of development on stormwater runoff. They are provided here as an encouragement to project designers. The extent to which these BMPs must be followed depends upon the site development codes, rules, and standards adopted by the local government.

BMP T5.40: Preserving Native Vegetation

Purpose and Definition

Preserving native vegetation on-site to the maximum extent practicable will minimize the impacts of development on stormwater runoff. Preferably 65 percent or more of the development site should be protected for the purposes of retaining or enhancing existing forest cover and preserving wetlands and stream corridors. Maintain tree canopy on the project site to the greatest extent feasible and in accordance with the requirements of the local jurisdiction.

Applications and Limitations

New development often takes place on tracts of forested land. In fact, building sites are often selected because of the presence of mature trees. However, unless sufficient care is taken and planning done, in the interval between buying the property and completing construction much of this resource is likely to be destroyed. The property owner is ultimately responsible for protecting as many trees as possible, with their understory and groundcover. This responsibility is usually exercised by agents, the planners, designers and contractors. It takes 20 to 30 years for newly planted trees to provide the benefits for which trees are so highly valued.

Forest and native growth areas allow rainwater to naturally percolate into the soil, recharging groundwater for summer stream flows and reducing surface water runoff that creates erosion and flooding. Conifers can hold up to about 50 percent of all rain that falls during a storm. Twenty to 30 percent of this rain may never reach the ground but evaporates or is taken up by the tree. Forested and native growth areas also may be effective as stormwater buffers around smaller developments.

Design Guidelines

- The preserved area should be situated to minimize the clearing of existing forest cover, to maximize the preservation of wetlands, and to buffer stream corridors.
- The preserved area should be placed in a separate tract or protected through recorded easements for individual lots.
- If feasible, the preserved area should be located downslope from the building sites, since Flow Control and Runoff Treatment are enhanced by flow dispersion through duff, undisturbed soils, and native vegetation.
- The preserved area should be shown on all property maps and should be clearly marked during clearing and construction on the site.

Maintenance

Vegetation and trees should not be removed from the natural growth retention area, except for approved timber harvest activities and the removal of dangerous and diseased trees.

BMP T5.41: Better Site Design

Purpose and Definition

Fundamental hydrological and stormwater management concepts can be applied at the site design phase that are:

- more integrated with natural topography,
- reinforcing the hydrologic cycle,
- more aesthetically pleasing, and
- often less expensive to build.

A few site planning principles help to:

- locate development on the least sensitive areas of a site;
- accommodate residential land use; and
- mitigate the impact on stormwater quality.

Design Guidelines

- **Define Development Envelope and Protected Areas** - The first step in site planning is to define the development envelope. This is done by identifying protected areas, setbacks, easements and other site features, and by consulting applicable local standards and requirements. Site features to be protected may include important existing trees, steep slopes, erosive soils, riparian areas, or wetlands.

  By keeping the development envelope compact, environmental impacts can be minimized, construction costs can be reduced, and many of the site's most attractive landscape features can be retained. In some cases, economics or other factors may not allow avoidance of all sensitive areas. In these cases, care can be taken to mitigate the impacts of development through site work and other landscape treatments.

- **Minimize Directly Connected Impervious Areas** - Impervious areas directly connected to the drainage system are the greatest contributors to urban nonpoint source pollution. Any impervious surface that drains into a catch basin or other conveyance structure is a "directly connected impervious surface." As stormwater runoff flows across parking lots, roadways, and other paved areas, the oil, sediment, metals, and other pollutants are collected and concentrated. If this runoff is collected by a drainage structure and carried directly along impervious gutters or in sealed underground pipes, it has no opportunity for filtering by plant material or infiltration into the soil. It also increases in velocity and amount, causing increased peak-flows in the winter and decreased base-flows in the summer.

  A basic site design principle for stormwater management is to minimize these directly connected impervious areas. This can be done by limiting overall impervious land coverage or by infiltrating and/or dispersing runoff within these impervious areas.

- **Maximize Permeability** - Within the development envelope, many opportunities are available to maximize the permeability of new construction. These include minimizing impervious areas, paving with permeable materials, clustering buildings, and reducing the land coverage of buildings by smaller footprints. All of these strategies make more land available for infiltration and dispersion through natural vegetation.

  Clustered driveways, small visitor parking bays and other strategies can also minimize the impact of transportation-related surfaces while still providing adequate access.

  Once site coverage is minimized through clustering and careful planning, pavement surfaces can be selected for permeability. A patio of brick-on-sand, for example, is more permeable than a large concrete slab. Engineered soil/landscape systems are permeable ground covers suitable for a wide variety of uses. Permeable/porous pavements can be used in place of traditional concrete or asphalt pavements in many low traffic applications.

  Maximizing permeability at every possible opportunity requires the integration of many small strategies. These strategies will be reflected at all levels of a project, from site planning to materials selection. In addition to the environmental and aesthetic benefits, a high-permeability site plan may allow the reduction or elimination of expensive underground conveyance systems, Flow Control BMPs, and/or Runoff Treatment BMPs, yielding significant savings in development costs.

- **Build Narrower Streets** - More than any other single element, street design has a powerful impact on stormwater quantity and quality. In residential development, streets and other transportation-related structures typically can comprise between 60 and 70 percent of the total impervious area, and, unlike rooftops, streets are almost always directly connected to the drainage system.

  The combination of large, directly connected impervious areas, together with the pollutants generated by automobiles, makes the street network a principal contributor to stormwater pollution in residential areas.

  Street design is usually mandated by local municipal standards. These standards have been developed to facilitate efficient automobile traffic, maximize parking, and allow for emergency vehicle access. Most require large impervious land coverage. In recent years, new street standards have been gaining acceptance that meet the access requirements of local residential streets while reducing impervious land coverage. These standards generally create a new class of street that is narrower than the current local street standard, called an “access” street. An access street is intended only to provide access to a limited number of residences.

  Because street design is the greatest factor in a residential development’s impact on stormwater quality, it is important that designers, municipalities and developers employ street standards that reduce impervious land coverage.

- **Maximize Choices for Mobility** - Given the costs of automobile use, both in land area consumed and pollutants generated, maximizing choices for mobility is a basic principle for environmentally responsible site design. By designing residential developments to promote alternatives to automobile use, a primary source of stormwater pollution can be mitigated.

  Bicycle lanes and paths, secure bicycle parking at community centers and shops, direct, safe pedestrian connections, and transit facilities are all site-planning elements that maximize choices for mobility.

- **Use Drainage as a Design Element** - Unlike conveyance drainage systems that hide water beneath the surface and work independently of surface topography, a drainage system for stormwater infiltration or dispersion can work with natural land forms and land uses to become a major design element of a site plan.

  By applying stormwater management techniques early in the site plan development, the drainage system can suggest pathway alignments, optimum locations for parks and play areas, and potential building sites. In this way, the drainage system helps to generate urban form, giving the development an integral, more aesthetically pleasing relationship to the natural features of the site. Not only does the integrated site plan complement the land, it can also save on development costs by minimizing earthwork and expensive drainage features.

6.3 Dispersion BMPs

6.3.1 Introduction to Dispersion BMPs

Introduction

Dispersion attempts to minimize the hydrologic changes created by new impervious surfaces by restoring the natural drainage patterns of sheet flow and infiltration. There are four types of dispersion BMPs:

- BMP F6.40: Concentrated Flow Dispersion: Redispersal of concentrated flows from driveways or other pavement areas through a vegetated pervious area, attenuating peak flows by slowing entry of the runoff into the drainage system and allowing some infiltration and water quality benefits.
- BMP F6.41: Sheet Flow Dispersion: Considered the simplest method for flow control and can be used for any impervious or pervious surface that is graded to avoid concentrating flows. Because flows are already dispersed as they leave the surface, they need only traverse a narrow band of adjacent vegetation for effective attenuation and treatment.
- BMP F6.42: Full Dispersion: Allows full dispersal of stormwater runoff from impervious surfaces and cleared areas of commercial and residential development sites, as well as rural roadway projects, that protect a portion of the site (or for large sites, a portion of an area within a subbasin drainage on the site) in a natural, native vegetation cover condition and prevents runoff from leaving the site. Natural vegetation is preserved and maintained in accordance with guidelines. Runoff from roofs, driveways, and roads within the development is dispersed within the site using the areas of preserved vegetation.
- BMP F6.43: Channelized Flow Dispersion: Redispersal of influent channelized flows to natural or engineered dispersion areas.

Purpose

Dispersion is the simplest method of Flow Control, using the vegetation, soils, and topography to effectively provide sheet flow and infiltration. It generally requires little or no construction activity.

When using dispersion, flows from the contributing area enter the dispersion area as sheet flow or as concentrated flow that is modified to sheet flow. The runoff then continues to sheet flow through the dedicated vegetated dispersion area where it infiltrates and absorbs.

Absorption capacity can be gained by using compost-amended soils to disperse and absorb contributing flows to the dispersion area. The goal is to have the flows dispersed into the surrounding landscape such that there is a low probability that any surface runoff will leave the dedicated dispersion area.

Application

- Dispersion is ideal for highways and linear roadway projects.
- Dispersion helps maintain the temperature norms of stormwater because it promotes infiltration, evaporation, and transpiration and should not have a surface discharge from the project site.
- All dispersion BMPs may be used to help meet Flow Control based performance standards. Only Full Dispersion (BMP F6.42: Full Dispersion) can be used to help meet both Runoff Treatment and Flow Control requirements.

Limitations

- The effectiveness of dispersion relies on maintaining sheet flow through the dispersion area, which maximizes soil and vegetation contact and prevents short-circuiting due to channelized flow.
- Dispersion areas must be protected from future development.
- Note that dispersion areas may initially cost as much as other constructed BMPs (e.g. ponds or vaults) because right-of-way or easements often need to be purchased, but long-term maintenance costs are lower. These natural areas will also contribute to the preservation of native habitat and provide visual buffering of the roadway or driveway.
- Do not use dispersion for floodplains.

For project sites with high velocities through the dispersion areas (e.g. > 2 ft/sec or per local jurisdiction requirement), provide energy dissipaters in conjunction with dispersal BMPs to minimize or prevent erosion through the dispersion areas.

The following additional limitations apply to BMP F6.43: Channelized Flow Dispersion:

- Redisperse the channelized flow before entering the dispersion area using flow spreaders. Dispersion BMPs require sheet flow conditions.
- Channelized flows are limited to on-site flows. If off-site flows contribute to the project site, provide parallel conveyance systems as needed to divert off-site flows around channelized dispersion BMPs. In some situations, it may be more beneficial to disperse off-site flows.

Cold Climate Considerations

Dispersion BMPs can be effective in cold climates, but may be restricted by groundwater quality concerns related to infiltration of chlorides. Frozen ground may inhibit the infiltration capacity of the ground. Grasses or other vegetation used in dispersion BMPs may also be dormant and may provide less effective treatment mechanisms, such as filtration or pollutant uptake, during the winter. For vegetated BMPs, plants should be selected to be tolerant of cold and freezing climates.

For more information: See 6.1.8 Cold Weather Considerations for additional cold weather considerations.

Arid and Semiarid Climate Considerations

In arid/semiarid portions of eastern Washington, grasses and plants should be selected to be drought tolerant and not require watering after establishment (2 to 3 years). In more arid environments, watering may be needed during prolonged dry periods after plants are established.

BMP F6.40: Concentrated Flow Dispersion

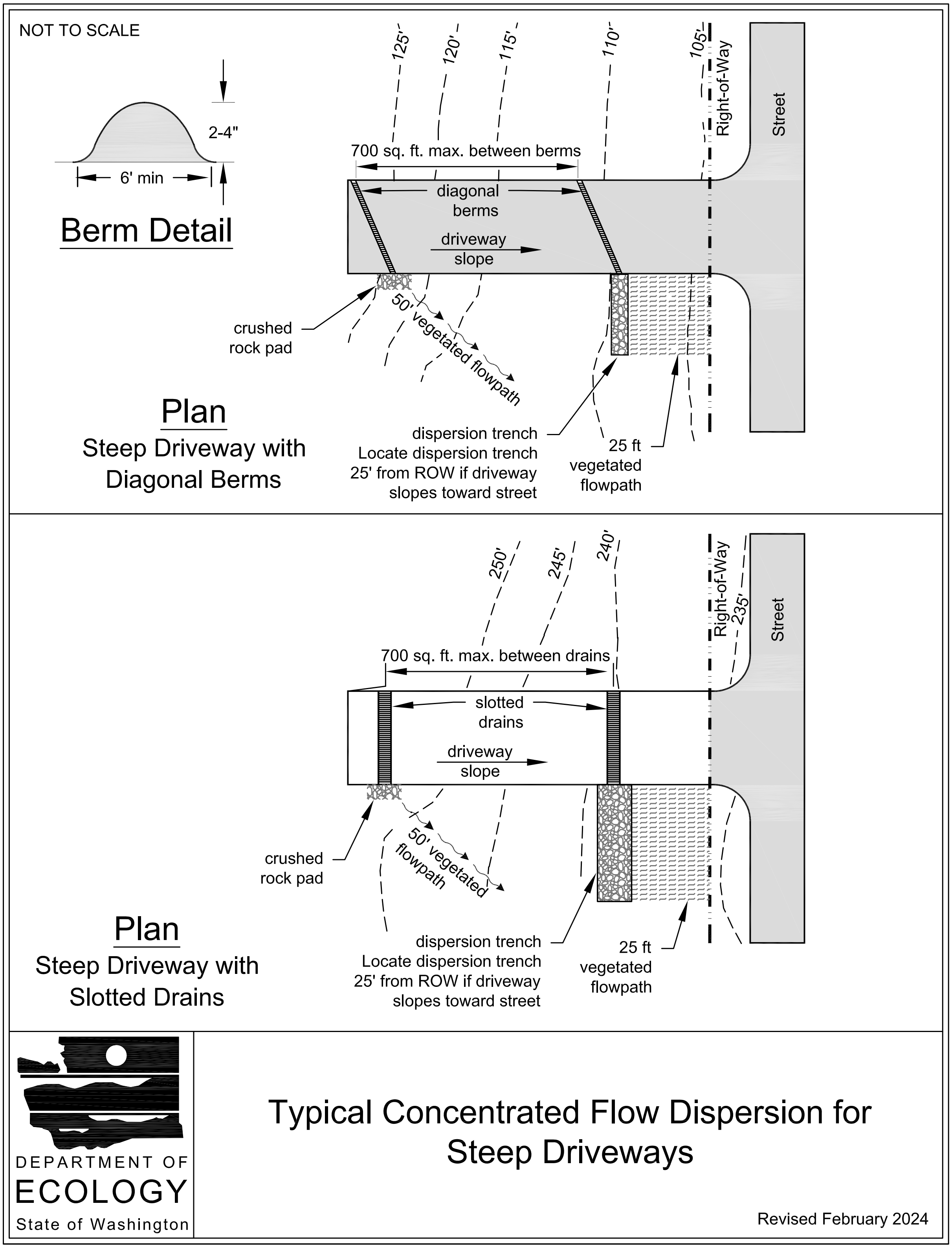
Purpose and Definition

Dispersion of concentrated flows from driveways or other pavement through a vegetated pervious area attenuates peak flows by slowing entry of the runoff into the conveyance system, allowing for some infiltration, and providing some water quality benefits.

Applications and Limitations

- Use this BMP in any situation where concentrated flow can be dispersed through vegetation.
- Dispersion for driveways will generally be effective only for single-family residences on large lots and in rural short plats. Lots proposed by short plats in urban areas will generally be too small to provide effective dispersion of driveway runoff.
- Figure 6.15: Typical Concentrated Flow Dispersion for Steep Driveways shows two possible ways of spreading flows from steep driveways.

Figure 6.15: Typical Concentrated Flow Dispersion for Steep Driveways



Design Guidelines

General Criteria

- Maintain a vegetated flow path of at least 25 feet between the discharge point and any property line, structure, steep slope, stream, wetland, lake, or other impervious surface.
    - If the vegetated flow path is 25 - 50 ft, the design must include a dispersion trench prior to discharge over the vegetated flow path.
    - If the vegetated flow path is 50 ft or more, the design may use either a dispersion trench or a pad of crushed rock (as described below) prior to discharge over the vegetated flow path.
    - The vegetated flow path must be at least 50 feet between the discharge point and any slope steeper than 15%
- A maximum of 700 square feet of impervious area may drain to each concentrated flow dispersion BMP.
- Provide a pad of crushed rock (a minimum of 2 feet wide by 3 feet long by 6 inches deep) at each discharge point, unless a dispersion trench is used.
- See BMP T5.10B: Downspout Dispersion Systems for dispersion trench design criteria.
- No erosion or flooding of downstream properties may result.
- Runoff discharged towards landslide hazard areas must be evaluated by a licensed engineer in the state of Washington with geotechnical expertise or a licensed geologist. The discharge point shall not be placed on or above slopes greater than 6H:1V or above erosion hazard areas without evaluation by a licensed engineer in the state of Washington with geotechnical expertise or a licensed geologist and approval by the local jurisdiction.
- For sites with septic systems, the discharge point must be at least ten feet downgradient of the drain field primary and reserve areas (WAC 246-272A-0210). This requirement may be waived by the local jurisdiction if site topography clearly prohibits flows from intersecting the drain field.

Flows to Be Dispersed

- Dispersion areas should be suited to handle stormwater from tributary areas so that ideally there is no runoff leaving the dispersion area.

Siting Criteria

The key to dispersion is having vegetative land cover with a good established root zone where the roots, organic matter, and soil macroorganisms provide macropores to reduce surface compaction and prevent soil pore sealing. The vegetative cover also provides filtration and maintains sheet flow, reducing the chance for erosion. Dispersion areas must be protected from future development.

The following areas are considered appropriate candidates for dispersion because they are likely to retain these vegetative conditions over the long term:

- Publicly owned rights-of-way
- Protected beautification areas
- Agricultural areas
- State parks
- Commercial or government-owned forest lands
- Rural areas with zoned densities of less than one dwelling unit per 5 acres

Note: Though dispersion areas should be adjacent to the project site, they do not have to be immediately adjacent to the length of the tributary surface areas (e.g. roadway or driveway).

Dispersion areas should have the following attributes:

- Well vegetated, with established root zones
- Average longitudinal slope of ≤ 15%
- Average lateral slope of ≤ 15% for both the roadway or other driveway side slope and the natural area to be part of the dispersion area
- Average lateral slope of ≤ 3H:1V where a level spreader is located immediately upstream of the dispersion area

Dispersion areas should have a separation of ≥ 3 feet between the existing ground elevation and the average annual maximum groundwater elevation. This separation depth requirement applies to the entire limits of the dispersion area. There should be no discernible continuous flow paths through the dispersion area.

When selecting dispersion areas, determine whether there are groundwater management plans for the area and contact the local water purveyors to determine whether the project lies within a wellhead or groundwater protection zone, septic drain fields, or aquifer recharge area. These areas typically restrict stormwater infiltration; however, the local jurisdiction may waive this requirement.

Intent: Dispersion areas are not likely to have a uniform slope across their entire area. As a result, there are ponding areas and uneven terrain. Minor channelization of flow within the dispersion area is expected. However, a continuous flow path through the entire dispersion area disqualifies its use as a BMP because channelized flow promotes erosion of the channel that carries the flow and greatly reduces the potential for effective pollutant removal and peak flow attenuation.

Setback Requirements

Dispersion areas can extend beyond public right-of-way provided that documentation on right-of-way plans ensures (via easements or agreements) the dispersion area is not developed in the future. Set dispersion areas back ≥ 100 feet from drinking water wells and springs used for public drinking water supplies. Ensure dispersion areas upgradient of drinking water supplies and within the 1-, 5-, and 10-year time of travel zones comply with the Washington State Department of Health (DOH) requirements (DOH, 2010).

Check with the local jurisdiction for additional setback requirements.

If the project significantly increases flows to off-site properties, determine whether a drainage easement is needed and obtain one if it is needed.

Construction Criteria

- For installation of dispersal BMPs and conveyance systems near dispersion areas, minimize the area that needs to be cleared or grubbed. Maintaining plant root systems is important for dispersion areas.
- Do not compact the area around dispersion areas.
- To the maximum extent practicable, use low-ground-pressure vehicles and equipment during construction.

Operation and Maintenance Criteria

See the operation and maintenance criteria in Appendix 6-A: BMP Maintenance Tables and the criteria below for maintenance access roads and signage.

Maintenance Access Roads (Access Requirements)

Consider maintenance pullout areas to promote successful maintenance practices at dispersion areas. Make sure pullout areas are large enough to accommodate a typical maintenance vehicle.

Signage

Physically mark the limits of the dispersion area in the field (during and after construction). Signage ensures the dispersion area is protected from construction activity disturbance and is adequately protected by measures provided in the Construction Stormwater Pollution Prevention Plan (SWPPP).

Signage helps ensure the dispersion area is not cleared or disturbed after the construction project.

Runoff Model Representation

When modeling the hydrology of the project site (see Chapter 4 - Hydrologic Analysis and Design), Ecology allows the following options:

- When a pad of crushed rock or dispersion trenches are used per the guidance above, and the length of the vegetated flow path is at least 50 feet, the impervious area may be modeled as a landscaped area (grass).
- When dispersion trenches are used per the guidance above, and the length of the vegetated flow path is 25 - 50 feet, the impervious area may be modeled as 50%land-scaped / 50%impervious.

BMP F6.41: Sheet Flow Dispersion

Purpose and Definition

Sheet flow dispersion is the simplest method of runoff control. This BMP can be used for any impervious or pervious surface that is graded to avoid concentrating flows. Because flows are already dispersed as they leave the surface, they need only traverse a narrow band of adjacent vegetation for effective on-site stormwater management.

There are two types of sheet flow dispersion: natural and engineered. Natural sheet flow dispersion uses existing soils, vegetation, and topography to disperse runoff into the surrounding landscape. Engineered sheet flow dispersion is similar to natural dispersion but uses newly developed dispersion areas with engineered soils to disperse runoff.

Applications and Limitations

Use this BMP for flat or moderately sloping (less than 15% slope) impervious surfaces such as roads, driveways, sport courts, patios, and roofs without gutters; cleared areas that consist of bare soil, nonnative landscaping, lawn, and/or pasture; or any situation where concentration of flows can be avoided.

Design Guidelines

General Criteria

- See BMP T5.10B: Downspout Dispersion Systems for dispersion trench design criteria.
- Provide a 2-foot-wide transition zone to discourage channeling between the edge of the impervious surface (or building eaves) and the downslope vegetation. This transition zone may consist of an extension of subgrade material (crushed rock), modular pavement, drain rock, or other material acceptable to the Local Plan Approval Authority.
- The design must not result in erosion or flooding of downstream properties.
- Runoff discharge toward landslide hazard areas must be evaluated by a licensed engineer in the state of Washington with geotechnical expertise or a licensed geologist. The discharge point may not be placed on or above slopes greater than 20% or above erosion hazard areas without evaluation by a licensed engineer in the state of Washington with geotechnical expertise or a licensed geologist and approval by the Local Plan Approval Authority.
- For sites with septic systems, the discharge area must be at least ten feet downgradient of the drainfield primary and reserve areas (WAC 246-272A-0210). A Local Plan Approval Authority may waive this requirement if site topography clearly prohibits flows from intersecting the drainfield.
- Ensure the sheet flow path leading to the dispersion area is < 150 feet. The sheet flow path is measured in the direction of flow and generally represents the width of the pavement area.
- Do not count pervious shoulders and side slopes in determining the sheet flow path.

- Ensure the longitudinal length of the dispersion area is equivalent to the longitudinal length of tributary drainage area that is contributing sheet flow.
- Ensure the resultant slope from the contributing pavement is ≤ 9.4%, calculated as follows:

Equation 6.1: Sheet Flow Dispersion Slope from Contributing Pavement:

$$S_{CFS} \leq \left(G^2 + e^2\right)^{0.5}$$

where:

S_{CFS} = resultant slope of the lateral and longitudinal slopes (%)

e = lateral slope (superelevation) (%)

G = longitudinal slope (grade) (%)

- Dispersion areas should have a separation of ≥ 3 feet between the existing ground elevation and the average annual maximum groundwater elevation. This separation depth requirement applies to the entire limits of the dispersion area. There should be no discernible continuous flow paths through the dispersion area.

  When selecting dispersion areas, determine whether there are groundwater management plans for the area and contact the local water purveyors to determine whether the project lies within a wellhead or groundwater protection zone, septic drain fields, or aquifer recharge area. These areas typically restrict stormwater infiltration; however, the local jurisdiction may waive this requirement.
- Dispersion areas are not likely to have a uniform slope across their entire area. As a result, there are ponding areas and uneven terrain. Minor channelization of flow within the dispersion area is expected. However, a continuous flow path through the entire dispersion area disqualifies its use as a BMP because channelized flow promotes erosion of the channel that carries the flow and greatly reduces the potential for effective pollutant removal and peak flow attenuation.

Flows to Be Dispersed

Dispersion areas should be suited to handle stormwater runoff from tributary areas so that ideally there is no runoff leaving the dispersion area.

Siting Criteria

See the siting criteria for BMP F6.40: Concentrated Flow Dispersion.

Setback Requirements

See the setback requirements for BMP F6.40: Concentrated Flow Dispersion.

Level Spreaders and Energy Dissipaters

- Where gravel level spreaders are not located between the flow contributing area and the dispersion area, side slopes leading to dispersion areas should be ≤ 25% (4H:1V). Side slopes that are 25% to 15% (7H:1V) should not be considered part of the dispersion area. Slopes > 25% are allowed if the existing side slopes are well vegetated and show no signs of erosion problems.
- Where gravel level spreaders are located between the flow contributing area and the dispersion area, consider flow contributing area side slopes ≤ 33% part of the dispersion area if existing side slopes are well vegetated and show no signs of erosion problems (WSDOT, 2011).
- For any existing slope that will lead to a dispersion area, if evidence of channelized flow (rills or gullies) is present, use a flow-spreading device before those flows are allowed to enter the dispersion area.
- When using an engineered dispersion area, roadway side slopes that are ≤ 15% are considered part of the dispersion area if the engineered dispersion practices are applied to the slope (6.5 feet of compost-amended side slope width mitigates 1 foot of impervious surface). Roadway side slopes ≤ 33% are considered part of the dispersion area if a gravel level spreader is located between the roadway and the dispersion area.

Design Procedure - Sizing the Dispersion Area

The size of the dispersion area depends on the flow contributing area and the predicted rates of water loss through the dispersion system. Ensure that the dispersion area is sufficient to dispose of the runoff through infiltration, evaporation, transpiration, and/or soil absorption.

There are three options that can be applied to size sheet flow dispersion areas, as follows:

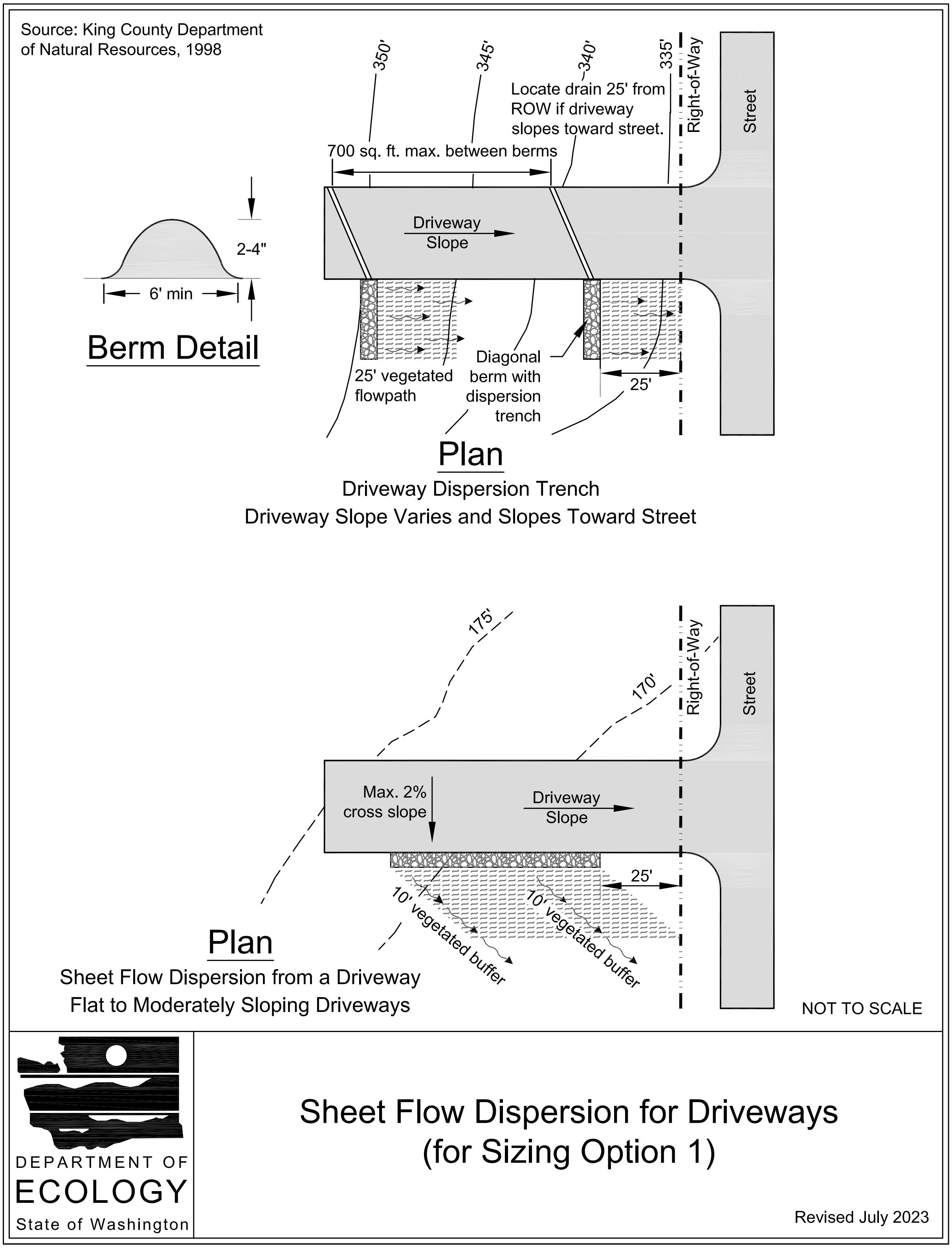
- Option 1 – Based on Contributing Area and Slope
- Option 2 – Based on Soil Characteristics
- Option 3 – Based on Simplified Equation

Option 1 – Based on Contributing Area and Slope

- Provide a 10-foot-wide vegetated buffer for up to 20 feet of width of contributing paved or impervious surface. Provide an additional 10 feet of vegetated buffer width for each additional 20 feet of impervious surface width or fraction thereof. For example, if a driveway is 30 feet wide and 60 feet long provide a 20-foot wide by 60-foot long vegetated buffer.
- Provide a 25-foot-wide vegetated buffer for up to 150 feet width of contributing cleared area (i.e. bare soil, nonnative landscaping, lawn, and/or pasture).
- Slopes within the 10- or 25-foot minimum flow path through vegetation should be no steeper than 8%. If this criterion cannot be met due to site constraints, the 10- or 25-foot flow path length must be increased 1.5 feet for each 1% increase in slope above 8%.

- Figure 6.16: Sheet Flow Dispersion for Driveways (for Sizing Option 1) shows two possible ways of achieving sheet flow dispersion for driveways.

Figure 6.16: Sheet Flow Dispersion for Driveways (for Sizing Option 1)



Option 2 – Based on Soil Characteristics

The following criteria are specific to sheet flow dispersion on all Type A and some Type B soils on slopes ≤ 15% (depending on saturated hydraulic conductivity rates):

- For saturated hydraulic conductivity rates (see 6.5.4 Determining the Design Infiltration Rate of the Native Soils) of ≥ 4 in/hr and for the first 20 feet (along the sheet flow path) of impervious surface that drains to the dispersion area, there must be 10 lateral feet of dispersion area width. For each additional foot of impervious surface (along the sheet flow path) that drains to the dispersion area, provide 0.25 lateral feet of dispersion area.
- For dispersion areas that receive sheet flow from only disturbed pervious areas (bare soil and nonnative landscaping), for every 6 feet (along the sheet flow path) of disturbed pervious area, provide 1 lateral foot width of dispersion area.

The following criteria are specific to sheet flow dispersion on all Type C and D soils and some Type B soils with saturated hydraulic conductivity rates of ≤ 4 in/hr on slopes ≤ 15%:

- For every 1 foot of contributing pavement width, provide a dispersion area width of 6.5 feet.
- The dispersion area should have a minimum width of native vegetation of 100 feet (measured in the direction of the flow path).

Option 3 – Based on Simplified Equation

This option is based on a simplified equation that was derived from a water balance model (WSDOT, 2005). This equation takes into account the roadway or driveway width, saturated hydraulic conductivity, and rainfall intensity to derive the width needed for dispersion.

Equation 6.2: Sheet Flow Dispersion Simplified Equation:

$$W_d = \frac{W_r}{\left[\left(\frac{K_s}{r_i}\right) - 1\right]}$$

where:

w_d=width of the dispersion (feet)

w_r=width of the roadway or driveway (feet)

K_{sat}=saturated hydraulic conductivity (in/hr) (see 6.5.4 Determining the Design Infiltration Rate of the Native Soils)

r_i=rainfall intensity (in/hr)

The K_s/r_i ratio must be > 2 for dispersion to have a viable benefit. If the ratio is ≤ 1, the equation is not valid and will result in negative values.

Calculating Rainfall Intensity

The rainfall intensity (r_i) is the peak 5-minute intensity of the 6-month, 3-hour short-duration storm. To calculate r_i, multiply the precipitation depth (2-year, 2-hour) by the peak intensity factor based on the mean annual precipitation (MAP) for the area. Use Table 6.15: Peak Intensity Factors for Calculating Rainfall Intensity to convert the MAP value to PIF.

Equation 6.3: Rainfall Intensity (Sheet Flow Dispersion):

$$r_i = P_{2yr2hr} * PIF$$

where:

r_i=rainfall intensity (in/hr)

P_{2yr2hr} = 2-year, 2-hour precipitation (inches)

PIF=peak intensity factor (unitless)

Table 6.15: Peak Intensity Factors for Calculating Rainfall Intensity

Climate Region	Mean Annual Precipitation (inches)	Isopluvial to Peak Intensity Factor
2	6–8	1.85
	8–10	1.88
	10–12	1.94
2–3	12–16	2.00
3	16–22	2.03
1–4	22–28	2.09
	28–40	2.12
	40–60	2.19
	60–120	2.25

For more information: The 2-year, 2-hour precipitation depth information can be found in Figure 4.6: 2-Year, 2-Hour Isopluvial Map.

Example

- Spokane 2-year, 2-hour precipitation = 0.48 inches
- Spokane MAP depth = 18 inches
- Spokane PIF for 18 inches = 2.03 inches per hour (in/hr)
- Calculate r_i = 0.48 in * 2.03 in/hr = 0.97 in/hr

Construction Criteria

See the construction criteria for BMP F6.40: Concentrated Flow Dispersion.

Operation and Maintenance Criteria

See the operation and maintenance criteria for BMP F6.40: Concentrated Flow Dispersion.

Runoff Model Representation

When modeling the hydrology of the project site (see Chapter 4 - Hydrologic Analysis and Design), Ecology allows the following options:

- Where this BMP is used to disperse runoff into an undisturbed native landscape area or an area that meets BMP F6.61: Post-Construction Soil Quality and Depth, and the vegetated flow path is 50 feet or more, the impervious area may be modeled as landscaped area.
- Where the vegetated flowpath is 25 to 50 feet, use of a dispersion trench (see BMP T5.10B: Downspout Dispersion Systems) allows modeling the impervious area as 50% impervious/50% landscape.

BMP F6.42: Full Dispersion

Purpose and Definition

This BMP allows for "fully dispersing" runoff from impervious surfaces and cleared areas of Project Sites into areas preserved as forest, native vegetation, or cleared area. Runoff is presumed to not leave the dispersion area because it will “disappear” through a combination of infiltration, transpiration, and evapotranspiration.

Surfaces that comply with this BMP are considered to be “fully dispersed” (i.e. have zero percent effective imperviousness). This BMP is presumed to meet Ecology's Basic and Metals Runoff Treatment Performance goals.

Hard surfaces that are not fully dispersed should be partially dispersed to the maximum extent practicable.

Applications and Limitations

The site (or area of the site) that is applying full dispersion per this BMP must be laid out to allow the runoff from the impervious (or cleared) surface to fully disperse into the preserved dispersion area. (i.e. Have full access to and not be intercepted by pipe(s), ditch(es), stream(s), river(s), pond (s), lake(s), or wetland(s)).

Projects that successfully apply this BMP on all or a portion of their site will decrease effective impervious surfaces, and may avoid triggering the Core Element Thresholds in 2.4.6 CE6: Flow Control.

Design Guidelines - General Criteria

A site (or an area of a site) that applies full dispersion per this BMP consists of the following elements:

- **An impervious (or cleared) area**. The impervious (or cleared) area is the area that the design is mitigating for by using this BMP.

- **A flow spreader.** Runoff from the impervious (or cleared) area may need to be routed through a flow spreader (see 6.1.10.2 Flow Spreaders), depending on the site layout and type of impervious surface, as further described below.
- **A dispersion area.** This area defines the limits of the Full Dispersion BMP. The impervious (or cleared) area must disperse into the preserved dispersion area.
    - The dispersion area must be forest, native vegetation, or a cleared area depending on the site type. Details are provided below for what amount of vegetation the dispersion area must contain based on site type.
    - If the dispersion area must be preserved as forest or native vegetation, it may be a previously cleared area that has been replanted in accordance with Native Vegetation Landscape Specifications (below).
    - The dispersion area should be situated to minimize the clearing of existing forest cover, wetlands, and stream buffers.
    - Wetlands, streams, lakes, and their buffers, if situated within a dispersion area, do not count toward the required area.
    - The dispersion area should be placed in a separate tract or protected through recorded easements for individual lots.
    - The dispersion area should be shown on all property maps and should be clearly marked during clearing and construction on the site.
    - All trees within the dispersion area at the time of permit application shall be retained, aside from:
        - dangerous or diseased trees, and
        - approved timber harvest activities regulated under WAC Title 222. Class IV General Forest Practices that are conversions from timberland to other uses are not acceptable for the preserved area.
    - The dispersion area may be used for passive recreation and related facilities, including pedestrian and bicycle trails, nature viewing areas, fishing and camping areas, and other similar activities that do not require permanent structures. Cleared areas and areas of compacted soil associated with these areas and facilities must not exceed eight percent of the dispersion area.
    - The dispersion area may contain utilities and utility easements, but not septic systems. For the purpose of this BMP, utilities are defined as potable and wastewater underground piping, underground wiring, and power and telephone poles.
    - The dispersion area is not allowed in critical area buffers or on slopes steeper than 20%. Dispersion areas proposed on slopes steeper than 15% or within 50 feet of a geologically hazardous area (RCW 36.70A.030(5)) must be approved by a geotechnical engineer or engineering geologist.
    - For sites with on-site sewage disposal systems, the discharge of runoff from the dispersion area must be located downslope of the primary and reserve drainfield

areas. This requirement may be waived by the permitting jurisdiction if site topography clearly prevents discharged flows from intersecting the drainfield.

- **A flow path through the dispersion area.** The length of the flow path from the impervious (or cleared) area through the dispersion area varies based on the site layout and type of impervious surface, as further described below. Regardless of the site layout and type of impervious surface, the flow path must meet the following criteria:
  - The slope of the flow path must be no steeper than 15% for any 20-foot reach of the flow path. Slopes up to 20% are allowed where flow spreaders are located upstream of the dispersion area and at sites where vegetation can be established.
  - The flow paths from adjacent flow spreaders must be sufficiently spaced to prevent overlap of flows in the flow path areas.

The dispersion of runoff must not create flooding or erosion impacts.

Design Guidelines - Residential Projects

Rural single family residential developments should use this BMP wherever possible to minimize effective impervious surfaces.

Full Dispersion from Impervious Surfaces in Residential Projects

Impervious surfaces within residential projects may be "fully dispersed" if they are within aProject Site that is less than 10% impervious. If the Project Site has more than 10% impervious area, the design may still fully disperse up to 10% of the Project Site's area. The impervious areas that are beyond the 10% cannot drain to the dispersion area, and are subject to the thresholds in 2.4.5 CE5: Runoff Treatment and 2.4.6 CE6: Flow Control.

The lawn and landscaping areas associated with the impervious area being mitigated may be dispersed into the dispersion area. The lawn and landscaped area must comply with BMP F6.61: Post-Construction Soil Quality and Depth.

The dispersion area must be preserved as forest or native vegetation.

The dispersion area shall have a minimum area 6.5 times the area of the impervious surface draining to it.

The flow path from the impervious surface through the area preserved as forest or native vegetation must be at least 100 feet in length, or 25 feet for sheet flow from lawn and landscaping areas associated with the impervious area being mitigated.

The following additional guidelines must be followed for the following types of impervious surfaces within residential projects:

- **Full dispersion from roof surfaces:** Runoff from roof surfaces must either:
  - Provide dispersion BMPs as described in BMP T5.10B: Downspout Dispersion Systems prior to the runoff entering the dispersion area. The dispersion area and flow path must meet the criteria described in this BMP.

    or

    - Combine the roof runoff with the road runoff, and follow the guidance for full dispersion from roadway surfaces (below).

- **Full dispersion from driveway surfaces:** Runoff from driveway surfaces must either:
    - Provide dispersion BMPs as described in BMP F6.40: Concentrated Flow Dispersion and BMP F6.41: Sheet Flow Dispersion prior to the runoff entering the dispersion area. The dispersion area and flow path must meet the criteria described in this BMP.

      or

    - Combine the driveway runoff with the road runoff, and follow the guidance for full dispersion from roadway surfaces (below).

- **Full Dispersion from Roadway Surfaces:** Runoff from roadway surfaces must comply with all of the following requirements:
    - The road section shall be designed to minimize collection and concentration of roadway runoff. Sheet flow over roadway fill slopes (i.e., where roadway subgrade is above adjacent right-of-way) should be used wherever possible to avoid concentration.
    - When it is necessary to collect and concentrate runoff from the roadway and adjacent upstream areas (e.g., in a ditch on a cut slope), concentrated flows shall be incrementally discharged from the ditch via cross culverts or at the ends of cut sections. These incremental discharges of newly concentrated flows shall not exceed 0.5 cfs at any one discharge point from a ditch for the 100-year runoff event. Where flows at a particular ditch discharge point were already concentrated under existing site conditions (e.g., in a natural channel that crosses the roadway alignment), the 0.5-cfs limit would be in addition to the existing concentrated peak flows.
    - Ditch discharge points with up to 0.2 cfs discharge for the 100-year peak flow shall use rock pads or dispersion trenches to disperse flows into the dispersion area. Ditch discharge points with between 0.2 and 0.5 cfs discharge for the 100-year peak flow shall use dispersion trenches to disperse flows into the dispersion area. See 6.1.10.3 Outfall Systems for details on rock pads and dispersion trenches.
        - Dispersion trenches shall be designed to accept surface flows (free discharge) from a pipe, culvert, or ditch end, shall be aligned perpendicular to the flow path, and shall have a minimum 2 feet by 2 cross section, 50 feet in length, filled with 3/4-inch to 1 1/2-inch washed rock, and provided with a level notched grade board (see BMP T5.10B: Downspout Dispersion Systems for dispersion trench design criteria). Manifolds may be used to split flows up to 2 cfs discharge for the 100-year peak flow between up to 4 trenches. Dispersion trenches shall have a minimum spacing of 50 feet between centerlines.
    - Where the Local Plan Approval Authority determines there is a potential for significant adverse impacts downstream (e.g., erosive steep slopes or existing downstream drainage problems), dispersion of runoff from roadway surfaces may not be allowed, or other measures may be required.

Full Dispersion from Cleared Areas in Residential Projects

The runoff from cleared areas of residential projects that are comprised of bare soil, non-native landscaping, lawn, and/or pasture is "fully dispersed" if it meets all of the following criteria:

- Cleared areas must comply with BMP F6.61: Post-Construction Soil Quality and Depth.
- The dispersion area must be preserved as forest or native vegetation.
- The flow path through the cleared area (and leading to the dispersion area) must not be greater than 25 feet.
- If the cleared area has a width of up to 25 feet:
  - The minimum flow path length from the cleared area through the dispersion area must be at least 25 feet.
- If the cleared area has a width of 25 to 250 feet:
  - The minimum flow path length from the cleared area through the dispersion area must be 25 feet, plus an additional 1 foot for every 3 feet of width of the cleared area (beyond the initial 25 feet) up to a maximum width of 250 feet.
- The topography of the cleared area must be such that runoff will not concentrate prior to discharge to the dispersion area.
- The width of the dispersion area must equal the width of the cleared area.

Design Guidelines - Public Road Projects

These criteria apply to the construction of public roads not within the context of residential, commercial, or industrial site development. They will likely only be implementable on roads outside of the urban growth areas where roadside areas are not planned for urban density development.

Full dispersion can be applied to public road projects that meet the following requirements:

- The dispersion area must be outside of the urban growth area; or if inside the urban growth area, in legally protected areas (easements, conservation tracts, public parks).
- If the dispersion area is outside urban growth areas, legal agreements should be reached with the owner(s) of the property(ies) that contain the dispersion area.
- An agreement with the property owner(s) is advised for any dispersion areas that represent a continuation of past practice. If not a continuation of past practice, an agreement should be reached with the property owner.

Full Dispersion by Sheet Flow from Uncollected, Unconcentrated Runoff into the Dispersion Area

The runoff from public road projects that sheet flow into the dispersion area is "fully dispersed" if it meets all of the following criteria:

- The dispersion area must be preserved as forest or native vegetation.
- Depth to the seasonal high groundwater elevation should be at least 3 feet.
- The flow path through any impervious area leading to the dispersion area must not be greater than 75 feet.
- The flow path through any pervious area leading to the dispersion area must not be greater than 150 feet. Pervious flow paths include up-gradient road side slopes that run onto the road and down-gradient road side slopes that precede the dispersion area.
- The width of the dispersion area should be equivalent to the width of impervious surface sheet flowing into it.
- Flow path length through the dispersion area:
    - For outwash soils: The following criteria apply to sites (or areas of sites) with outwash soils (Type A – sands and sandy gravels, possibly some Type B – loamy sands). The outwash soils must have an initial saturated hydraulic conductivity rate of 4 inches per hour or greater. The saturated hydraulic conductivity must be based on a Pilot Infiltration Test or the Soil Grain Size Analysis method as identified in 6.5.4 Determining the Design Infiltration Rate of the Native Soils, or another method as allowed by the local government.
        - If the impervious area has a flow path length of up to 20 feet, the flow path length through the dispersion area must be at least 10 feet.
        - If the impervious area has a flow path length greater than 20 feet, the flow path length through the dispersion area must be 10 feet, plus an additional 0.25 feet for every 1 foot of impervious flow path length beyond the initial 20 feet.
    - For other soils: The following criteria apply to sites (or areas of sites) with soils other than those described in the bullet above (Types C and D and some Type B not meeting the criterion described in the bullet above).
        - For every 1 foot of flow path length across the impervious surface, the flow path length through the dispersion area must be 6.5 feet.
        - The minimum flow path length through the dispersion area is 100 feet.
- The lateral slope of the impervious area should be less than 8%.
- Road side slopes must be less than 25%. Road side slopes do not count as part of the dispersion area unless native vegetation is re-established and slopes are less than 15%. Road shoulders that are paved or graveled to withstand occasional vehicle loading count as impervious surface.
- Longitudinal slope of road should be ≤ 5%.
- The average longitudinal (parallel to road) slope of dispersion area should be less than or equal to 15%.
- The average lateral slope of dispersion area should be less than or equal to 15%.

Full Dispersion of Channelized (Collected and Re-dispersed) Stormwater into the Dispersion Area

The runoff from public road projects that is collected and re-dispersed is "fully dispersed" if it meets all of the following criteria:

- The dispersion area may be either:
  - preserved as forest or native vegetation, or
  - cleared land. This cleared land option may only be used if the site is outside of the Urban Growth Area and does not have a natural or man-made drainage system.
- Depth to the seasonal high groundwater elevation should be at least three feet.
- Channelized flow must be re-dispersed to produce the longest possible flow path.
- Flows must be evenly dispersed across the dispersion area.
- Ditch discharge points with up to 0.2 cfs discharge for the peak 100-year flow shall use rock pads or dispersion trenches to disperse flows into the dispersion area. Ditch discharge points with between 0.2 and 0.5 cfs discharge for the 100-year peak flow shall use dispersion trenches to disperse flows into the dispersion area. See 6.1.10.3 Outfall Systems for details on rock pads and dispersion trenches.
  - Dispersion trenches shall be designed to accept surface flows (free discharge) from a pipe, culvert, or ditch end, shall be aligned perpendicular to the flowpath, and shall have a minimum 2 feet by 2 cross section, 50 feet in length, filled with 3/4-inch to 1 1/2-inch washed rock, and provided with a level notched grade board. Manifolds may be used to split flows up to 2 cfs discharge for the 100-year peak flow between up to 4 trenches. Dispersion trenches shall have a minimum spacing of 50 feet between centerlines.
- Approved energy dissipation techniques may be used.
- Limited to on-site (associated with the road) flows.
- The width of the dispersion area should be equivalent to length of the road from which runoff is collected.
- The average longitudinal and lateral slopes of the dispersion area should be ≤ 8%.
- The slope of any flowpath segment within the dispersion area must be no steeper than 15% for any 20-foot reach of the flowpath segment.
- Flow path length through the dispersion area:
  - For outwash soils: The following criteria apply to sites (or areas of sites) with outwash soils (Type A – sands and sandy gravels, possibly some Type B – loamy sands) that have an initial saturated hydraulic conductivity rate of 4 inches per hour or greater. The saturated hydraulic conductivity must be based on field results using procedures (Pilot Infiltration Test or Soil Grain Size Analysis Method) identified in 6.5.4 Determining the Design Infiltration Rate of the Native Soils, or another method as

allowed by the local government.

        - The dispersion area should be at least ½ of the impervious drainage area.

    - For other soils: The following criteria apply to sites (or areas of sites) with soils other than those described in the bullet above (Types C and D and some Type B not meeting the criterion in the bullet above).

        - For every 1 foot of flow path length across the impervious surface, the flow path length through the dispersion area must be 6.5 feet.

        - The minimum flow path length through the dispersion area is 100 feet.

Full Dispersion by Engineered Dispersion

The runoff from public road projects is "fully dispersed" if it meets all of the following criteria:

- Stormwater can be dispersed via sheet flow or via collection and re-dispersion in accordance with the techniques for Full Dispersion of Channelized (Collected and Re-dispersed) Stormwater into the Dispersion Area (above).

- The dispersion area should be planted with native trees and shrubs.

- For outwash soils: The following criteria apply to sites (or areas of sites) with outwash soils (Type A – sands and sandy gravels, possibly some Type B – loamy sands) that have an initial saturated hydraulic conductivity rate of 4 inches per hour or greater. The saturated hydraulic conductivity must be based on field results using procedures (Pilot Infiltration Test or Soil Grain Size Analysis Method) identified in 6.5.4 Determining the Design Infiltration Rate of the Native Soils, or another method as allowed by the local government.

    - The dispersion area must be compost amended in accordance with guidelines in BMP F6.61: Post-Construction Soil Quality and Depth. The guidance document *Building Soil: Guidelines and Resources for Implementing Soil Quality and Depth BMP T5.13 in WDOE Stormwater Management Manual for Western Washington* (Stenn et al., 2016) can be used, or an approved equivalent soil quality and depth specification approved by Ecology.

    - If the impervious area has a flow path length of up to 20 feet, the flow path length through the dispersion area must be at least 10 feet.

    - If the impervious area has a flow path length greater than 20 feet, the flow path length through the dispersion area must be 10 feet, plus an additional 0.25 feet for every 1 foot of impervious flow path length beyond the initial 20 feet.

- For other soils: The following criteria apply to sites (or areas of sites) with soils other than those described in the bullet above (Types C and D and some Type B not meeting the criterion in the bullet above).

-
    - The dispersion area must be compost-amended following guidelines in BMP F6.61: Post-Construction Soil Quality and Depth. The guidance document *Building Soil: Guidelines and Resources for Implementing Soil Quality and Depth BMP T5.13 in*

    WDOE Stormwater Management Manual for Western Washington (Stenn et al., 2016) can be used, or an approved equivalent soil quality and depth specification approved by Ecology.
  - The dispersion area must have be 6.5 times the area of the surface(s) draining to it.

- The average longitudinal (parallel to road) slope of the dispersion area should be ≤ 15%.
- The average lateral slope of the dispersion area should be ≤ 15%.
- The depth to the seasonal high groundwater elevation should be at least three feet.

Native Vegetation Landscape Specifications

These specifications may be used in situations where an applicant wishes to convert a previously developed surface to a native vegetation landscape for purposes of meeting full dispersion requirements or code requirements for forest retention. Native vegetation landscape is intended to have the soil, vegetation, and runoff characteristics approaching that of natural forestland (or other natural condition for the geographic area).

Conversion of a developed surface to native vegetation landscape requires the removal of impervious surface, de-compaction of soils, and the planting of native trees, shrubs, and ground cover in compost-amended soil according to all of the following specifications:

1. Existing impervious surface and any underlying base course (e.g., crushed rock, gravel) must be completely removed from the conversion area(s).
2. Underlying soils must be broken up to a depth of 18 inches. This can be accomplished by excavation or ripping with either a backhoe equipped with a bucket with teeth, or a ripper towed behind a tractor.
3. At least 4 inches of well-decomposed compost must be tilled into the broken up soil as deeply as possible. The finished surface should be gently undulating and must be only lightly compacted.
4. The area of native vegetated landscape must be planted with native species trees, shrubs, and ground cover. Species must be selected as appropriate for site shade and moisture conditions, and in accordance with the following requirements:
    a. Trees: a minimum of two species of trees must be planted, one of which is a conifer. Conifer and other tree species must cover the entire landscape area at a spacing recommended by a professional landscaper or in accordance with local requirements.
    b. Shrubs: a minimum of two species of shrubs should be planted. Space plants to cover the entire landscape area, excluding points where trees are planted.
    c. Groundcover: a minimum of two species of ground cover should be planted. Space plants so as to cover the entire landscape area, excluding points where trees or shrubs are planted.

For landscape areas larger than 10,000 square feet, planting a greater variety of species than the minimum suggested above is strongly encouraged. For example, an acre could easily accommodate three tree species, three species of shrubs, and two or three species of groundcover.

5. At least 4 inches of hog fuel or other suitable mulch must be placed between plants as mulch for weed control. It is also possible to mulch the entire area before planting; however, an 18-inch diameter circle must be cleared for each plant when it is planted in the underlying amended soil. *Note: Plants and their root systems that come in contact with hog fuel or raw bark have a poor chance of survival.*

6. Plantings must be watered consistently once per week during the dry season for the first two years.

7. The plantings must be well established on at least 90% of the converted area. A minimum of 90% plant survival is required after 3 years.

Conversion of an area that was under cultivation to native vegetation landscape requires a different treatment. Elimination of cultivated plants, grasses and weeds is required before planting and will be required on an on-going basis until native plants are well-established. The soil should be tilled to a depth of 18 inches. A minimum of 8 inches of soil having an organic content of 6 to 12 percent is required, or a four inch layer of compost may be placed on the surface before planting, or 4 inches of clean wood chips may be tilled into the soil, as recommended by a landscape architect or forester. After soil preparation is complete, continue with steps 4 through 7 above. Placing 4 inches of compost on the surface may be substituted for the hog fuel or mulch. For large areas where frequent watering is not practical, bare-root stock may be substituted at a variable spacing from 10 to 12 feet o.c. (with an average of 360 trees per acre) to allow for natural groupings and 4 to 6 feet o.c. for shrubs. Allowable bare-root stock types are 1-1, 2-1, P-1 and P-2. Live stakes at 4 feet o.c. may be substituted for willow and red-osier dogwood in wet areas.

Construction Criteria

See the construction criteria for BMP F6.40: Concentrated Flow Dispersion.

Operation and Maintenance Criteria

See the operation and maintenance criteria for BMP F6.40: Concentrated Flow Dispersion.

Runoff Model Representation

Areas that are fully dispersed per this BMP do not have to be modeled to demonstrate compliance. They are presumed to “fully disperse” (i.e. have zero percent effective imperviousness). This BMP is presumed to meet Ecology's Basic and Metals Runoff Treatment Performance goals.

BMP F6.43: Channelized Flow Dispersion

This BMP redisperses influent channelized flows to natural or engineered dispersion areas.

General Criteria

Channelized flow dispersion criteria for all soil types are summarized below.

Flows to Be Dispersed

Dispersion areas should be suited to handle stormwater runoff from tributary areas so that ideally there is no runoff leaving the dispersion area.

Siting Criteria

See the siting criteria for BMP F6.40: Concentrated Flow Dispersion.

Setback Requirements

See the setback requirements for BMP F6.40: Concentrated Flow Dispersion.

Redispersion Design Criteria

Flows collected in a pipe or ditch conveyance system require energy dissipation and dispersal at the end of the conveyance system before entering the dispersion area. See BMP T5.10B: Downspout Dispersion Systems for a typical detail for flow dispersion trench. Guidance for the design of energy dissipaters can be found in *Hydraulic Design of Energy Dissipators for Culverts and Channels* (FHWA, 2006) and in WSDOT's *Hydraulics Manual* (WSDOT, 2017).

Concentrated runoff from the flow contributing area and adjacent upstream areas (such as in a ditch or cut slope) must be incrementally discharged from the conveyance system (e.g., ditch, gutter, or storm drain) via cross culverts or at the ends of cut sections. These incremental discharges of newly concentrated flows must not exceed 0.5 cubic feet per second (cfs) at any single discharge point from the conveyance system for the 100-year design flow (see hydrologic modeling methods in Chapter 4 - Hydrologic Analysis and Design). Where flows at a particular discharge point are already concentrated under existing site conditions (for example, in a natural channel that crosses a roadway alignment), the 0.5 cfs limit would be in addition to the existing concentrated peak flows.

Discharge points with up to 0.2 cfs discharge for the 100-year design flow may use rock pads or dispersion trenches to disperse flows. Discharge points with between 0.2 and 0.5 cfs discharge for the 100-year design flow must use only dispersion trenches to disperse flows.

Design dispersion trenches to accept surface flows (free discharge) from a pipe, culvert, or ditch end; aligned perpendicular to the flow path; a minimum of 2 by 2 feet in section; 50 feet in length; filled with 0.75- to 1.5-inch-diameter washed rock; and provided with a level notched grade board (see BMP T5.10B: Downspout Dispersion Systems). Use manifolds to split flows up to 2 cfs discharge for the 100-year peak flow between four trenches (maximum). Provide a minimum spacing of 50 feet for dispersion trenches.

After being dispersed with rock pads or trenches, flows from discharge points must traverse the required flow path length of the dispersion area before entering an existing on-site channel carrying existing concentrated flows away from the roadway alignment.

Note: To provide the required flow path length to an existing channel, some roadway runoff may unavoidably enter the channel undispersed.

Do not allow flow paths from adjacent discharge points to intersect within the required flow path lengths, and ensure dispersed flow from a discharge point is not intercepted by another discharge point.

Locate ditch discharge points a minimum of 100 feet upgradient of steep slopes (slopes > 40% within a vertical elevation change of ≥ 10 feet), wetlands, and streams.

Where the local jurisdiction determines that there is a potential for significant adverse impacts downstream (such as erosive steep slopes or existing downstream drainage problems), dispersion of roadway runoff may not be allowed, or other measures may be required.

Level Spreaders and Energy Dissipaters

Where gravel level spreaders are not located between the flow contributing area and the dispersion area, side slopes leading to natural dispersion areas should be ≤ 25% (4H:1V). Side slopes that are 25% to 15% (7H:1V) should not be considered part of the dispersion area. Slopes > 25% are allowed if the existing side slopes are well vegetated and show no signs of erosion problems. See latest version of the WSDOT HRM.

Where gravel level spreaders are located between the flow contributing area and the dispersion area, consider flow contributing area side slopes ≤ 33% part of the natural dispersion area if existing side slopes are well vegetated and show no signs of erosion problems (WSDOT, 2011).

For any existing slope that will lead to a natural dispersion area, if evidence of channelized flow (rills or gullies) is present, use a flow-spreading device before those flows are allowed to enter the dispersion area.

Design Procedure

Natural Channelized Flow Dispersion

The following criterion is specific to channelized flow dispersion that discharged on slopes ≤ 15% to all Type A and some Type B soils, depending on saturated hydraulic conductivity rates.

- For saturated hydraulic conductivity rates (K_{sat}, as determined in 6.5.4 Determining the Design Infiltration Rate of the Native Soils) of 4 inches per hour (in/hr) or greater, the dispersion area should be ≥ 50% of the tributary drainage area.

The following criteria are specific to channelized flow dispersion that discharges on slopes ≤ 15% to all Type C and D soils and some Type B soils, depending on saturated hydraulic conductivity rates.

- For every 1 foot of contributing pavement width, a dispersion area width of 6.5 feet is needed.
- The dispersion area should have a minimum width of native vegetation of 100 feet, measured in the direction of the flow path.

Engineered Channelized Flow Dispersion

Engineered channelized flow dispersion criteria for Type A, B, C, and D soils are the same as described for natural channelized flow dispersion, with the following exceptions,

The following criterion is specific to engineered channelized flow dispersion on all Type A and some Type B soils on slopes ≤ 15%, depending on saturated hydraulic conductivity rates:

- For saturated hydraulic conductivity rates of ≥ 4 in/hr, and for the first 20 feet (along the sheet flow path) of impervious surface that drains to the dispersion areas, there must be 10 lateral feet of dispersion area width. For each additional foot of impervious surface (along the sheet flow path) that drains to the dispersion areas, provide 0.25 lateral feet of dispersion area.

The following criteria are specific to channelized engineered dispersion on Type C and D soils and some Type B soils on slopes ≤ 15%, depending on saturated hydraulic conductivity rates:

- For every 1 foot of contributing pavement width, a dispersion area width of 6.5 feet is needed.
- The dispersion area should have a minimum width of 100 feet, measured in the direction of the flow path.

Construction Criteria

See the construction criteria for BMP F6.40: Concentrated Flow Dispersion.

Operation and Maintenance Criteria

See the operation and maintenance criteria BMP F6.40: Concentrated Flow Dispersion.

BMP F6.70: Light Rail Elevated Guideway Dispersion

Purpose and Definition

This BMP is a dispersion style BMP that provides Flow Control to elevated light rail guideways. It 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.

Applications and Limitations

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).

This BMP must be approved by a geotechnical engineer or engineering geologist if the dispersion area is placed on slopes steeper than 15% or within 50 feet of a geologically hazardous area.

This BMP shall:

- Not be placed in sections of the track that cross or run over roadways, sidewalk, or multi-use paths.

  This BMP is not feasible for sections of track that run over hard surfaces such as roadways, sidewalks, and multi-use paths. These sections of track must collect and convey the runoff to an appropriate stormwater BMP to meet the project requirements. Alternative solutions may include use of regional facilities and/or treating equivalent areas, with local jurisdiction approval.

- Not be placed in areas where the drip line would lie above impervious surfaces.

- Only be used on elevated guideway portions of a light rail track with a resultant grade less than 9%.

Design Guidelines

Protection of Dispersion Area as a Flow Control BMP

Upon acquisition of elevated guideway easements in which Sound Transit intends to implement this BMP, the extent of the dispersion area will be reflected in the easement document, which shall restrict the uses of the underlying property so as not to interfere with the BMP.

Upon acquisition of fee simple property in which Sound Transit intends to implement this BMP, the extent of the dispersion area will be reflected in a covenant, which shall restrict the uses of the underlying property so as not to interfere with the BMP.

BMP Components

A site (or an area of a site) that applies guideway dispersion per this BMP consists of the following elements;

- **Overhead guideway area.** The travel surface on which the light rail tracks are installed which intercepts stormwater.

- **Dispersal device.** Runoff from the elevated guideway area shall flow through a dispersal device as further described below.

- **Dispersion area.** The guideway area must disperse into this preserved dispersion area. The extents of this area define the limits of the elevated guideway dispersion BMP.

Components shall be designed per the criteria listed below.

Dispersal Device

The dispersal device shall be placed on the downslope edge or edges (if crowned) of the elevated guideway for the full limits of the designated dispersion areas (see Figure 6.17: Elevated Guideway Dispersion and Figure 6.18: Elevated Guideway Dispersion Area). All runoff from these areas shall be designed to reach the device prior to discharging from the guideway. Segments shall be placed and trimmed as needed to continuously cover the length of the guideway dispersion area with a maximum gap between segments of 0.5 inch.

Special care should be taken at gaps in the dispersal device, at expansion joints, or other locations on the guideway surface that could bypass or concentrate sheet flow from the guideway to the dispersal device.

Dispersion Area

- Where the dispersal device is installed along the guideway, a dispersion area must be established below to receive the dispersed runoff. Runoff must flow through the entire dispersion area before being intercepted by pipes and ditches.
- The surface subject to direct runoff from the dispersal device must be stabilized to withstand the erosive effects of the runoff. It may consist of forest or native vegetation or be densely planted as shown in Figure 6.18: Elevated Guideway Dispersion Area.
- Plantings and associated disturbed areas shall be placed to minimize the clearing of existing forest cover and environmentally sensitive areas.
- Dispersion areas shall be located within an air space lease or agency right-of-way.
- The average lateral and longitudinal slopes of the dispersion area should be less than or equal to 15%.

Landscaping Restoration of Dispersion Area

Where established forested areas or plantings are not within the guideway driplines, permanent vegetation shall be installed along the existing ground under all sections of guideway dispersion. An area a minimum of 6 feet wide shall be cleared, soil tilled to a depth of 8 inches, amended to meet the specifications in BMP F6.61: Post-Construction Soil Quality and Depth, and topped with jute matting. The upper edge of the dispersion area shall be in line with the dispersal device. The dispersion area shall extend 6 feet downslope. See Figure 6.17: Elevated Guideway Dispersion and Figure 6.18: Elevated Guideway Dispersion Area for further details.

Established plantings shall be spaced within the dispersion area to provide dense coverage that will dissipate energy and provide Flow Control benefits through plant uptake and evapotranspiration. Native plants shall be used in environmentally sensitive areas. Leaf canopy during the winter months should be considered when selecting plant species to aid dispersion during the wet season. The exact spacing and plant species shall be determined by a qualified professional licensed landscape architect.

Construction Criteria

The dispersal device shall be screwed onto a metal plate which is bolted onto the handrail stanchion. All mounting components and hardware shall be corrosion resistant. See Figure 6.19: Elevated Guideway Dispersion System Details. The dispersal device shall not be put into operation until all construction debris has been cleared from the track. If any debris accumulates in the device during construction, the debris shall be removed prior to project completion.

Inspection and Maintenance Criteria

Dispersion devices shall be inspected per the operation and maintenance plan. Debris shall be removed from the dispersion device to restore full dispersion capabilities and any loose or damaged components shall be repaired or replaced.

Plants selected for the dispersion area should be drought tolerant and not require watering after establishment (2 to 3 years). If planted vegetation does not take hold and establish, additional plantings shall be added until a dense leaf canopy is achieved.

Weeding for invasive or nuisance plants should be done regularly until plants have established. Over time the selected plants should capture the site and the dense leaf canopy should limit new weed growth.

Runoff Model Representation

Where this BMP is designed per the guidance above, Ecology allows modeling the impervious area as 50% impervious/50% landscape.

Figure 6.17: Elevated Guideway Dispersion

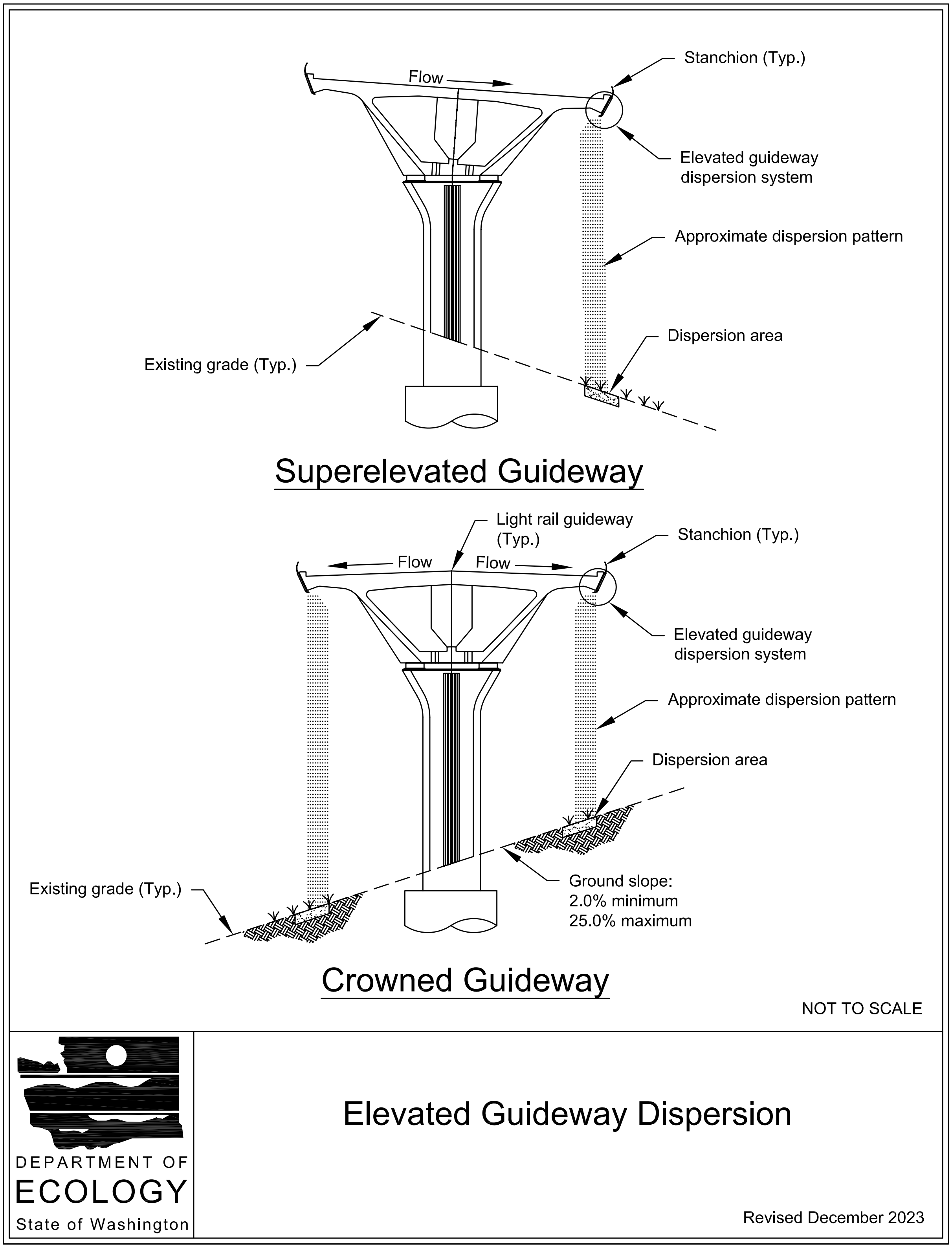
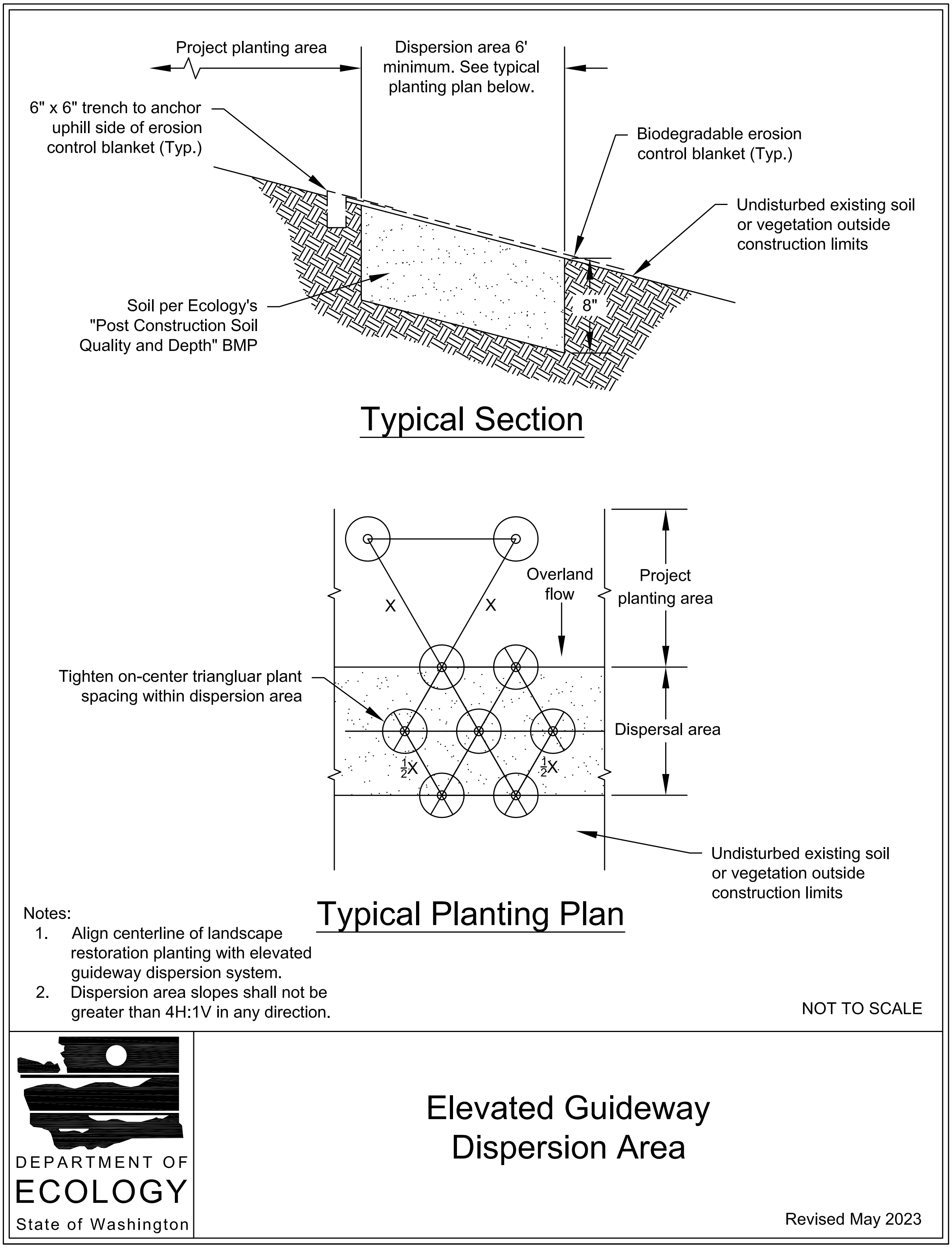


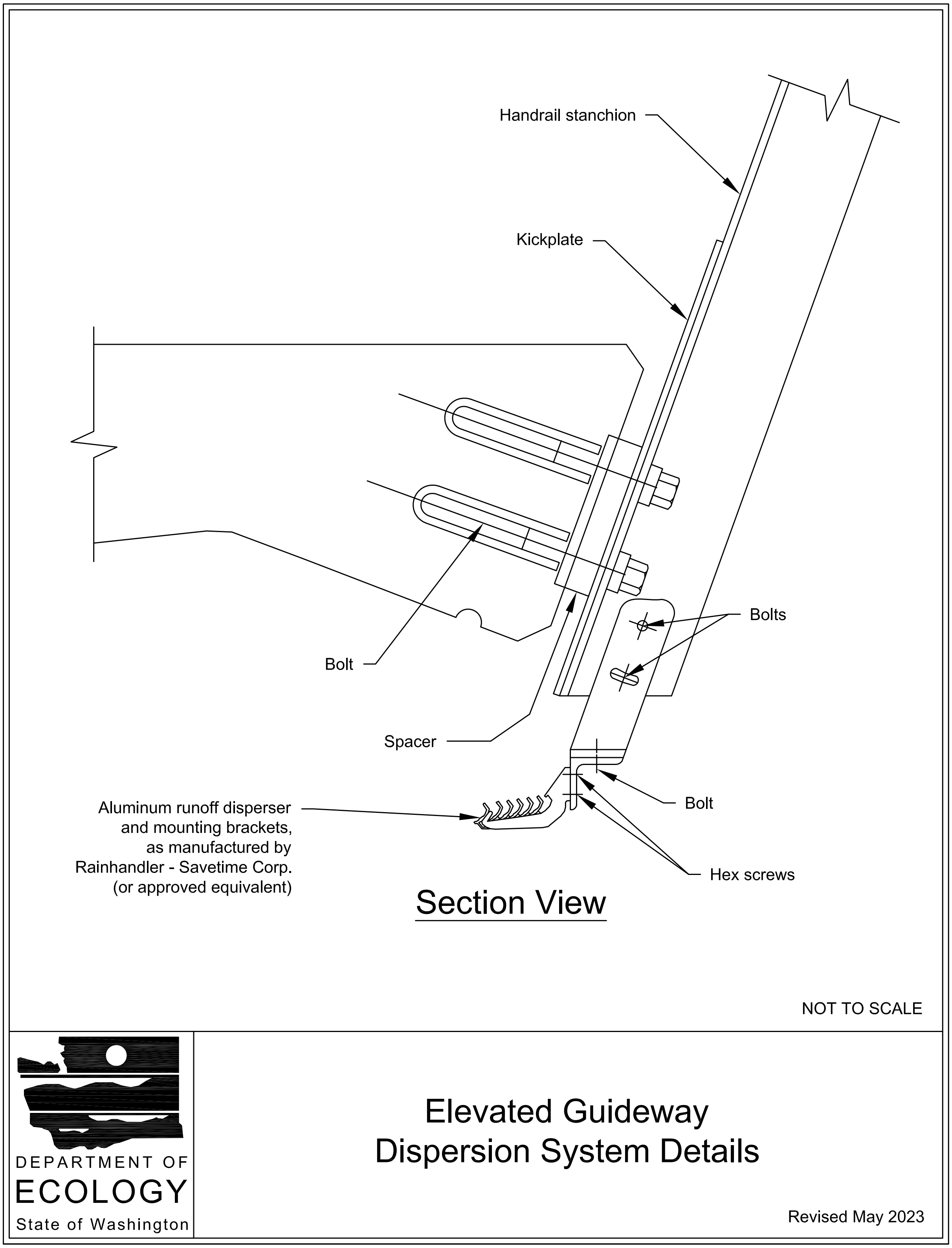
Figure 6.18: Elevated Guideway Dispersion Area



Notes:

1. Align centerline of landscape restoration planting with elevated guideway dispersion system.
2. Dispersion area slopes shall not be greater than 4H:1V in any direction.

Figure 6.19: Elevated Guideway Dispersion System Details



6.4 Roof Downspout BMPs

6.4.1 Introduction to Roof Downspout BMPs

Roof downspout BMPs are simple pre-engineered designs for infiltrating and/or dispersing runoff from roof areas for the purposes of increasing opportunities for groundwater recharge and reduction of runoff volumes from development.

Roof downspout BMPs include infiltration trenches, dry wells, and partial dispersion systems for use in individual lots, proposed plats, and short plats. Roof downspout BMPs are used in conjunction with, and in addition to, any Flow Control BMPs that may be necessary.

How to Select Roof Downspout BMPs

Large lots in rural areas (5 acres or greater) typically have enough area to disperse or infiltrate roof runoff. Lots created in urban areas will typically be smaller (about 8,000 square feet) and have a limited amount of area in which to site infiltration or dispersion trenches.

- BMP T5.10A: Downspout Full Infiltration should be used on sites with soils that readily infiltrate.
- BMP T5.10B: Downspout Dispersion Systems should be used for urban lots located in less permeable soils, where infiltration is not feasible.
- Where BMP T5.10B: Downspout Dispersion Systems is not feasible because of very small lot size, or where there is a potential for creating drainage problems on adjacent lots, use BMP T5.10C: Perforated Stub-out Connections to connect downspouts with perforated stub-out connections to the street drainage system, which directs the runoff to a stormwater management facility.

Where supported by appropriate soil infiltration tests, downspout full infiltration in finer soils may be practical using a larger infiltration system.

Roof downspout BMPs can be applied to individual commercial lot developments when the percent impervious area and pollutant characteristics are comparable to those from residential lots.

Note: Other innovative downspout control BMPs such as rain barrels, ornamental ponds, downspout cisterns, or other downspout water storage devices may be used to supplement any of the BMPs in this chapter if approved by the reviewing authority.

BMP T5.10A: Downspout Full Infiltration

Downspout full infiltration systems are trench or drywell designs intended only for use in infiltrating runoff from roof downspout drains. They are not designed to directly infiltrate runoff from pollutant-generating impervious surfaces.

Roof surfaces that comply with this BMP are considered to be "fully infiltrated" (i.e. zero percent effective imperviousness).

Procedure for Evaluating Feasibility

1. Have one of the following prepare a soils report to determine if soils suitable for infiltration are present on the site:

   - A professional soil scientist certified by the Soil Science Society of America (or an equivalent national program)
   - A locally licensed on-site sewage designer
   - A suitably trained person working under the supervision of a professional engineer, geologist, hydrogeologist, or engineering geologist registered in the State of Washington.

   The report shall reference a sufficient number of soils logs to establish the type and limits of soils on the project site. The report should at a minimum identify the limits of any outwash type soils (i.e. those meeting USDA soil texture classes ranging from coarse sand and cobbles to medium sand) versus other soil types and include an inventory of topsoil depth.

2. Complete additional site-specific testing on lots or sites containing outwash (coarse sand and cobbles to medium sand) and loam type soils.

   Individual lot or site tests must consist of at least one soils log at the location of the infiltration system, a minimum of 4 feet in depth from the proposed grade and at least 1 foot below the expected bottom elevation of the infiltration trench or dry well.

   Identify the NRCS series of the soil and the USDA textural class of the soil horizon through the depth of the log, and note any evidence of high groundwater level, such as mottling.

3. Downspout full infiltration is considered feasible on lots or sites that meet all of the following:

   - 3 feet or more of permeable soil from the proposed final grade to the seasonal high groundwater table.
   - At least 1-foot of clearance from the expected bottom elevation of the infiltration trench or dry well to the seasonal high groundwater table.
   - The downspout full infiltration system can be designed to meet the minimum design criteria specified below.

Setbacks

Local governments may require specific setbacks in sites with slopes over 40%, land slide areas, open water features, springs, wells, and septic tank drain fields. Adequate room for maintenance access and equipment should also be considered. Examples of setbacks commonly used include the following:

1. All infiltration systems should be at least 10 feet from any structure, property line, or sensitive area (except slopes over 40%).
2. All infiltration systems must be at least 50 feet from the top of any slope over 40%. This setback may be reduced to 15 feet based on a geotechnical evaluation, but in no instances

may it be less than the buffer width.

3. For sites with septic systems, infiltration systems must be downgradient of the drainfield unless the site topography clearly prohibits subsurface flows from intersecting the drainfield.

Design Criteria

Infiltration Trenches

Figure 6.20: Typical Downspout Infiltration Trench shows a typical downspout infiltration trench system, and Figure 6.21: Alternative Downspout Infiltration Trench System for Coarse Sand and Gravel presents an alternative infiltration trench system for sites with coarse sand and cobble soils. These systems are designed as specified below.

1. The following minimum lengths (linear feet) per 1,000 square feet of roof area based on soil type may be used for sizing downspout infiltration trenches:
   - Coarse sands and cobbles: 20 LF
   - Medium sand: 30 LF
   - Fine sand, loamy sand: 75 LF
   - Sandy loam: 125 LF
   - Loam: 190 LF
2. Silt and clay type soils have a saturated hydraulic conductivity that is too small for adequate infiltration and are infeasible for downspout infiltration trenches.
3. The maximum length of the trench shall not exceed 100 feet from the inlet sump.
4. The minimum spacing between trench centerlines shall be 6 feet.
5. Filter fabric shall be placed over the drain rock as shown on Figure 6.20: Typical Downspout Infiltration Trench prior to backfilling.
6. Infiltration trenches may be placed in fill material if:
   - the fill is placed and compacted under the direct supervision of a geotechnical engineer or professional civil engineer with geotechnical expertise, and
   - the measured infiltration rate is at least 8 inches per hour.

   Trench length in fill must be 60 linear feet per 1,000 square feet of roof area. Infiltration rates can be tested using the methods described in 6.5.4 Determining the Design Infiltration Rate of the Native Soils.
7. Infiltration trenches should not be built on slopes steeper than 25% (4:1). A geotechnical analysis and report may be required on slopes over 15%, or if the proposed trench is located within 200 feet of the top of a slope steeper than 40%, or in a landslide hazard area.

8. Infiltration trenches may be located under pavement if a small yard drain or catch basin with grate cover is placed at the end of the trench pipe such that overflow would occur out of the catch basin at an elevation at least one foot below that of the pavement, and in a location which can accommodate the overflow without creating a significant adverse impact to downhill properties or drainage systems. This is intended to prevent saturation of the pavement in the event of system failure.

Figure 6.20: Typical Downspout Infiltration Trench

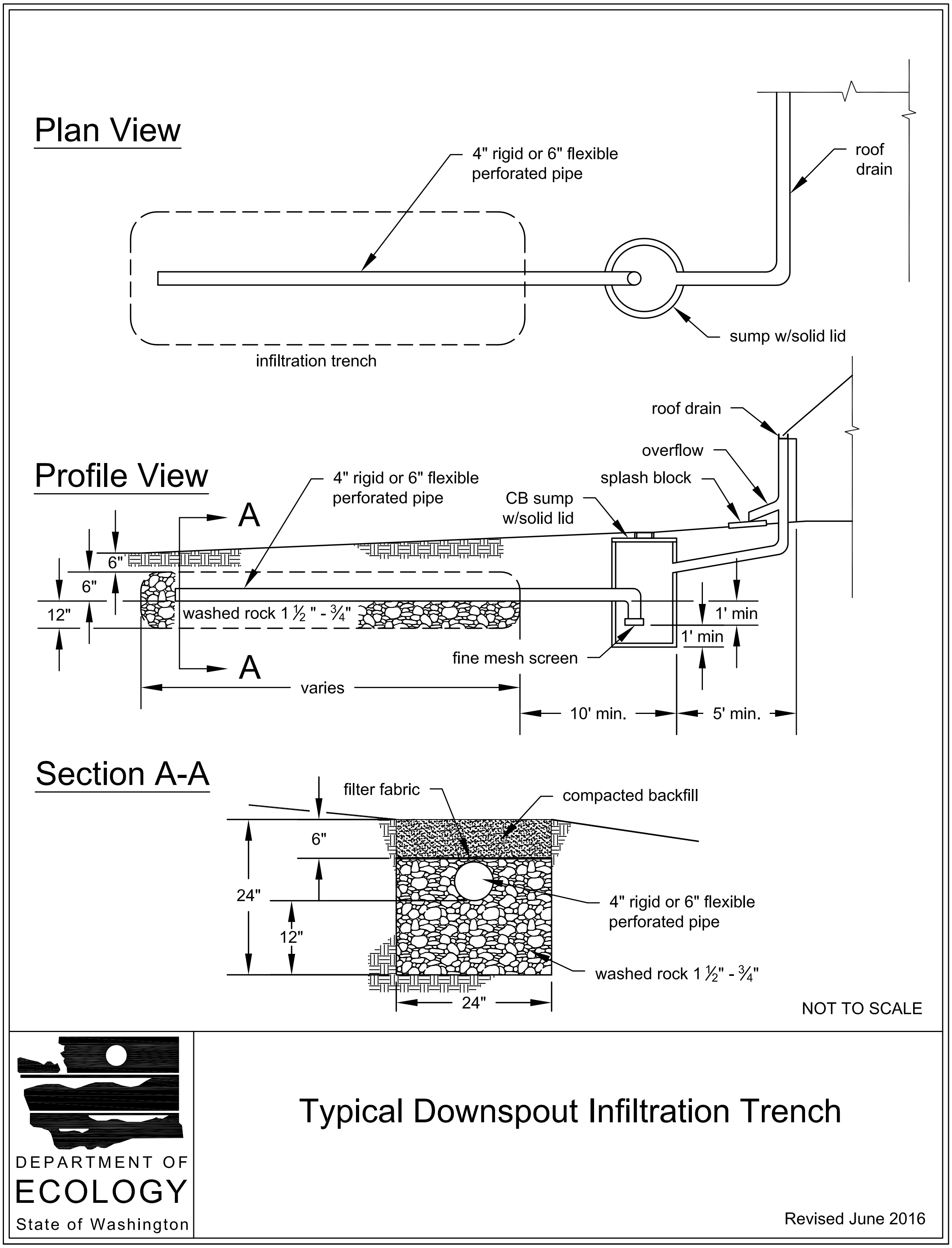
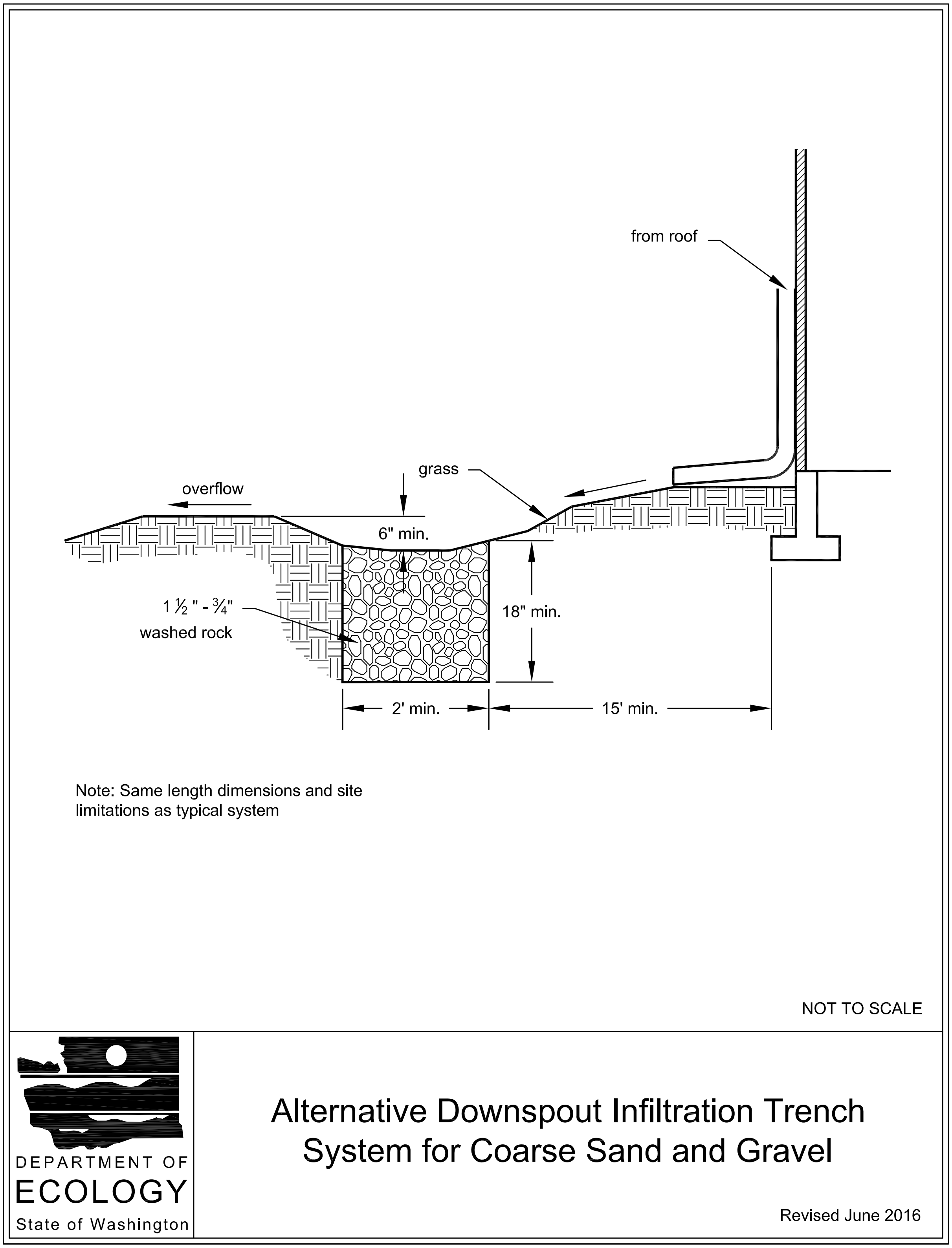


Figure 6.21: Alternative Downspout Infiltration Trench System for Coarse Sand and Gravel

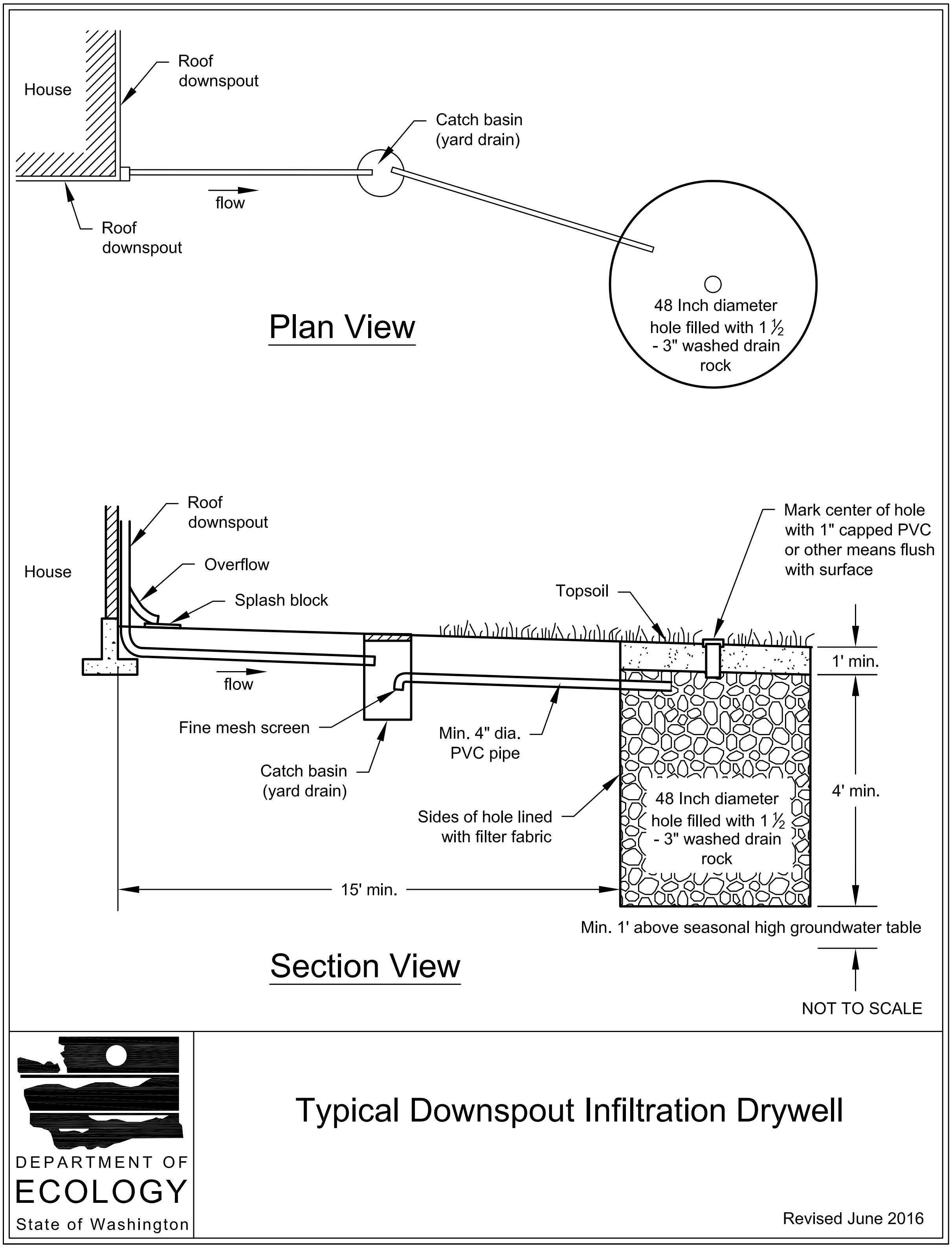


Infiltration Drywells

Figure 6.22: Typical Downspout Infiltration Drywell shows a typical downspout infiltration drywell system. These systems are designed as specified below.

1. Drywell bottoms must be a minimum of 1 foot above the seasonal high groundwater level or impermeable soil layers.
2. When located in course sands and cobbles, drywells must contain a volume of gravel equal to or greater than 60 cubic feet per 1000 square feet of impervious surface served. When located in medium sands, drywells must contain at least 90 cubic feet of gravel per 1,000 square feet of impervious surface served.
3. Drywells must be at least 48 inches in diameter (minimum) and deep enough to contain the gravel amounts specified above for the soil type and impervious surface served.
4. Filter fabric (geotextile) must be placed on top of the drain rock and on drywell sides prior to backfilling.
5. Spacing between drywells must be a minimum of 10 feet.
6. Downspout infiltration drywells must not be built on slopes greater than 25% (4:1). Drywells may not be placed on or above a landslide hazard area or on slopes greater than 15% without evaluation by a licensed engineer in the state of Washington with geotechnical expertise or a licensed geologist, hydrogeologist, or engineering geologist, and with jurisdiction approval.

Figure 6.22: Typical Downspout Infiltration Drywell



Runoff Model Representation

Roof areas served by downspouts that drain to infiltration dry wells or infiltration trenches that are sized in accordance with the guidance in this BMP do not have to be entered into the runoff model. They are presumed to fully infiltrate the roof runoff.

BMP T5.10B: Downspout Dispersion Systems

Downspout dispersion systems are splash blocks or gravel filled trenches, which serve to spread roof runoff over vegetated pervious areas. Dispersion attenuates peak flows by slowing the runoff entering into the conveyance system, allowing some infiltration, and providing some water quality benefits.

Design Criteria

1. Use downspout trenches designed as shown in Figure 6.23: Typical Downspout Dispersion Trench and Figure 6.24: Standard Dispersion Trench with Notched Grade Board for all downspout dispersion applications except where splash blocks are allowed below.

2. Splash blocks shown in Figure 6.25: Typical Downspout Splashblock Dispersion may be used for downspouts discharging to a vegetated flow path at least 50 feet in length as measured from the downspout to the downstream property line, structure, slope over 15%, stream, wetland, or other impervious surface. Sensitive area buffers may count toward flow path lengths.

3. The vegetated flow path must consist of well-established lawn or pasture, landscaping with well-established groundcover, native vegetation with natural groundcover, or an area that meets BMP F6.61: Post-Construction Soil Quality and Depth. The groundcover shall be dense enough to help disperse and infiltrate flows and to prevent erosion.

4. If the vegetated flow path (measured as defined above) is less than 25 feet, BMP T5.10C: Perforated Stub-out Connections may be used in lieu of downspout dispersion. BMP T5.10C: Perforated Stub-out Connections may also be used where implementation of downspout dispersion might cause erosion or flooding problems, either on site or on adjacent lots. For example, this provision might be appropriate for lots constructed on steep hills where downspout discharge could culminate and might pose a potential hazard for lower lying lots, or where dispersed flows could create problems for adjacent off-site lots. This provision does not apply to situations where lots are flat and on-site downspout dispersal would result in saturated yards.

   Note: For all other types of projects, the use of a perforated stub-out in lieu of downspout dispersion shall be as determined by the Local Plan Approval Authority.

5. For sites with septic systems, the discharge point of all dispersion systems must be downslope of the primary and reserve drainfield areas. This requirement may be waived if site topography clearly prohibits flows from intersecting the drainfield or where site conditions (soil permeability, distance between systems, etc.) indicate that this is unnecessary.

6. No erosion or flooding of downstream properties may result.

7. For purposes of maintaining adequate separation of flows discharged from adjacent dispersion devices, the vegetated flowpath segment for the splashblock (or the outer edge of the vegetated flowpath segment for the dispersion trench) must not overlap with other flowpath segments, except those associated with sheet flow from a non-native pervious surface.
8. Have a geotechnical engineer or a licensed geologist, hydrogeologist, or engineering geologist evaluate runoff discharged towards landslide hazard areas. Do not place the discharge point from splashblocks or dispersion trenches on or above slopes greater than 15% or above erosion hazard areas without evaluation by a licensed engineer in the state of Washington with geotechnical expertise or a licensed geologist, hydrogeologist, or engineering geologist, and approval by the Local Plan Approval Authority.

Design Criteria for Dispersion Trenches

1. A vegetated flow path of at least 25 feet in length must be maintained between the outlet of the dispersion trench and any property line, structure, stream, wetland, or impervious surface. A vegetated flow path of at least 50 feet in length must be maintained between the outlet of the trench and any slope steeper than 15%. Sensitive area buffers may count towards flow path lengths.
2. Trenches serving up to 700 square feet of roof area may be 10-foot-long by 2-foot wide gravel filled trenches as shown in Figure 6.23: Typical Downspout Dispersion Trench.

   For roof areas larger than 700 square feet, a dispersion trench with notched grade board as shown in Figure 6.24: Standard Dispersion Trench with Notched Grade Boardor alternative material approved by the Local Plan Approval Authority may be used. The total trench length must not exceed 50 feet and must provide atleast10 feet of trench length per 700 square feet of roof area.
3. Maintain a setback of at least 5 feet between any edge of the trench and any structure or property line.

Figure 6.23: Typical Downspout Dispersion Trench

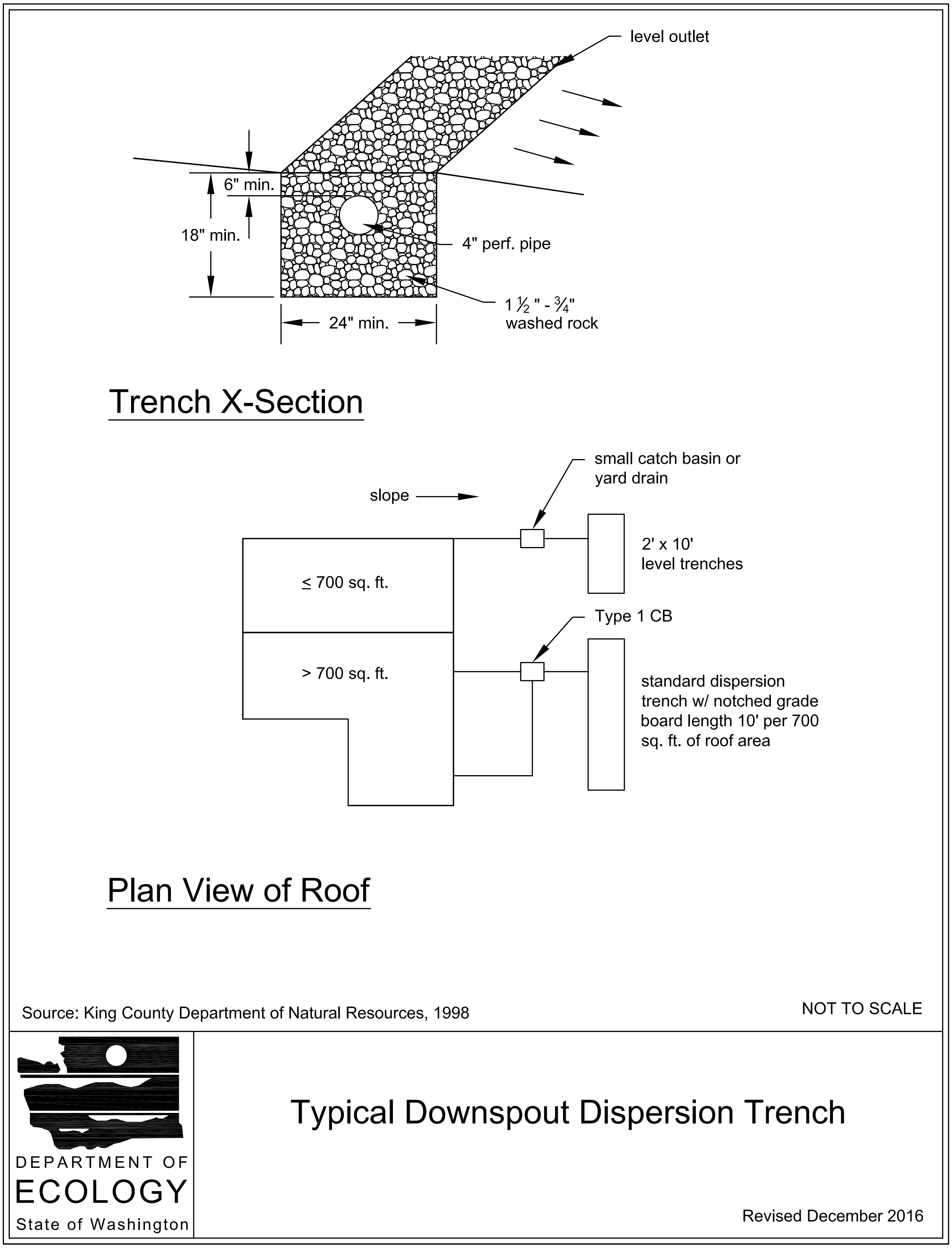
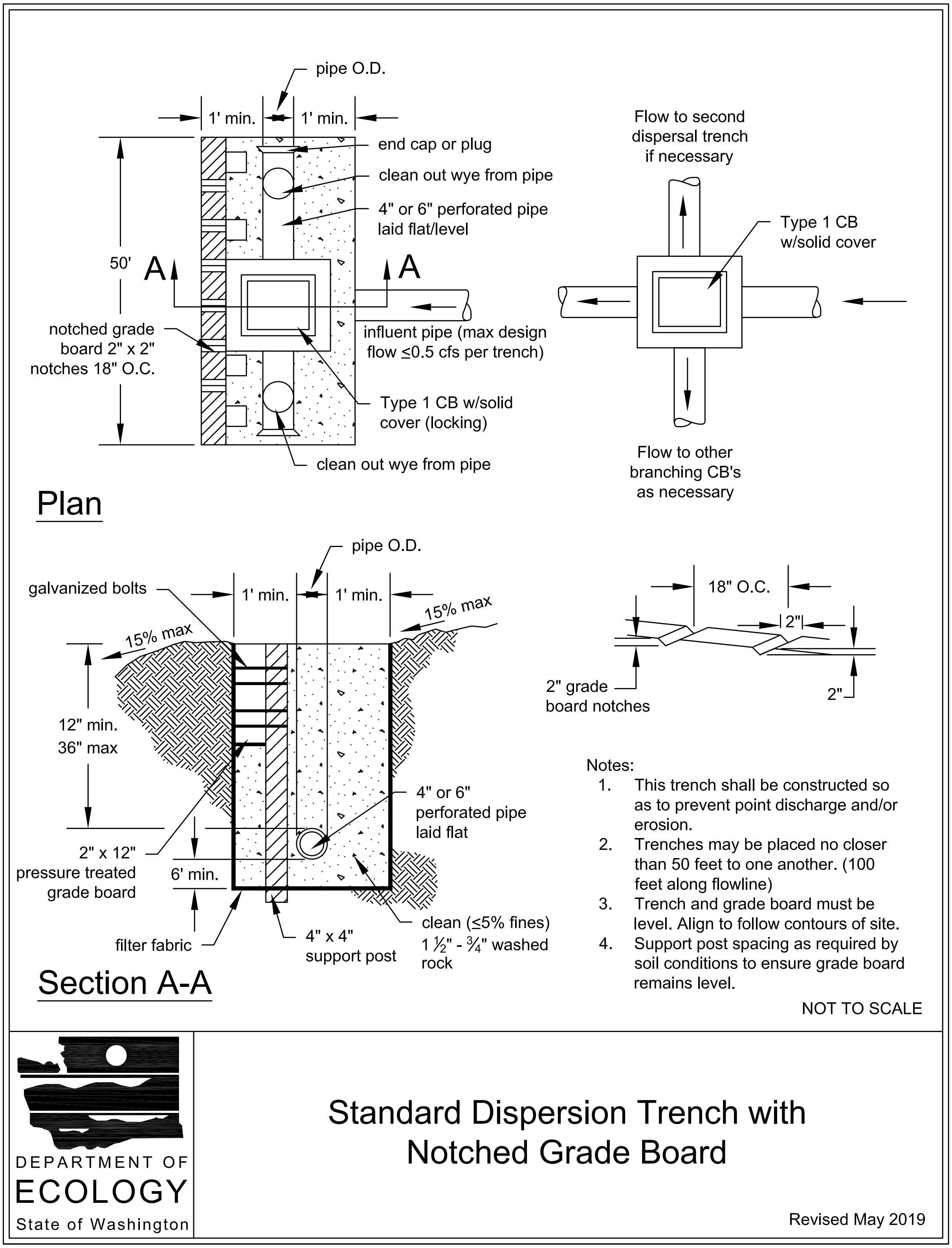


Figure 6.24: Standard Dispersion Trench with Notched Grade Board



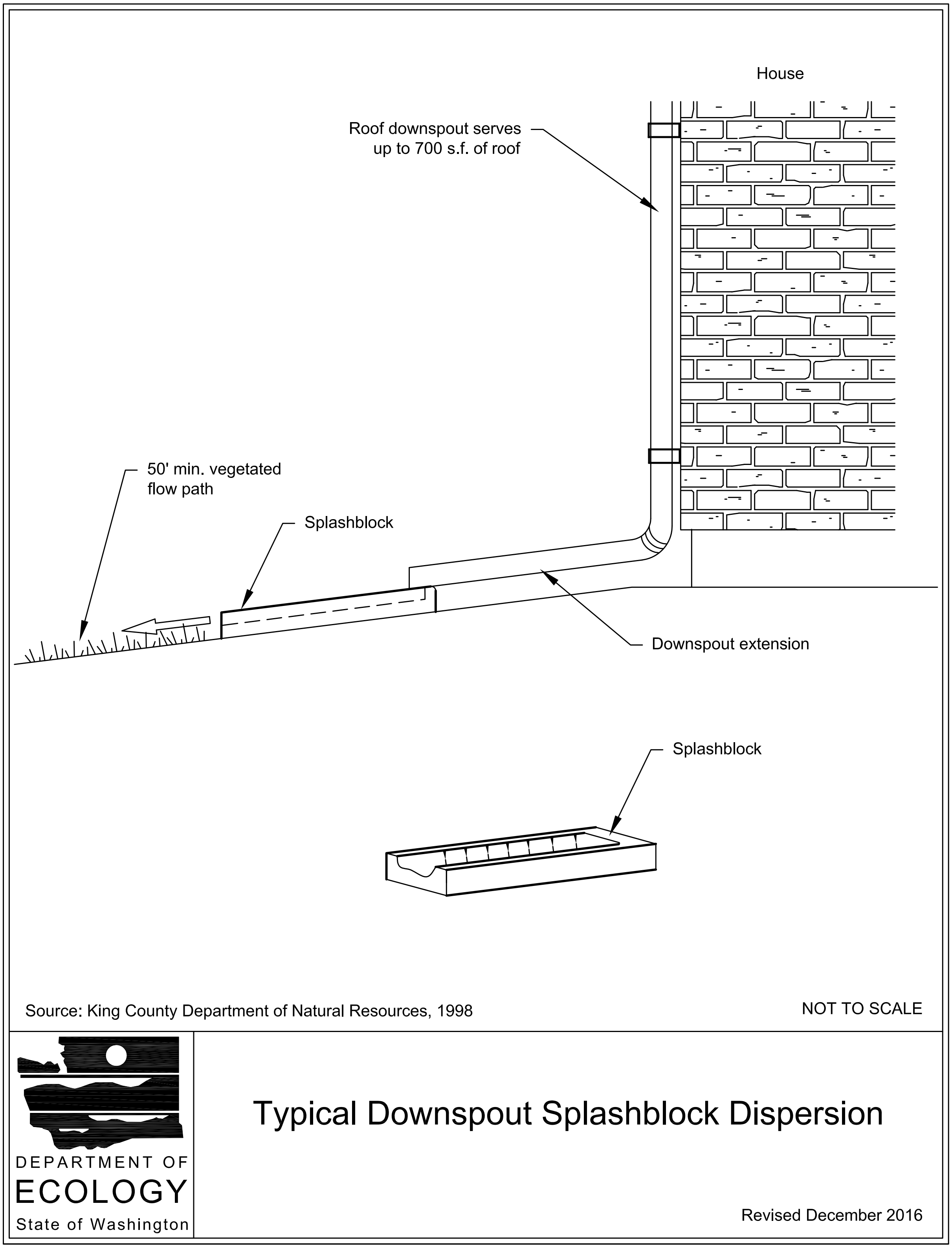
Design Criteria for Splashblocks

A typical downspout splashblock is shown in Figure 6.25: Typical Downspout Splashblock Dispersion. In general, if the ground is sloped away from the foundation and there is adequate vegetation and area for effective dispersion, splashblocks will adequately disperse storm runoff. If the ground is fairly level, if the structure includes a basement, or if foundation drains are proposed, splashblocks with downspout extensions may be a better choice because the discharge point is moved away from the foundation. Downspout extensions can include piping to a splashblock/discharge point a considerable distance from the downspout, as long as the runoff can travel through a well-vegetated area as described below.

The following apply to the use of splashblocks:

1. Maintain a vegetated flow path of at least 50 feet between the discharge point and any property line, structure, slope steeper than 15%, stream, wetland, lake, or other impervious surface. Sensitive area buffers may count toward flow path lengths.
2. A maximum of 700 square feet of roof area may drain to each splashblock.
3. Place a splashblock or a pad of crushed rock (2 feet wide by 3 feet long by 6 inches deep) at each downspout discharge point.

Figure 6.25: Typical Downspout Splashblock Dispersion



Runoff Model Representation

The designer has the following options to model the amount of Flow Control presumed to be provided by this BMP:

- When splashblocks or dispersion trenches are used per the guidance above, and the length of the vegetated flow path is at least 50 feet:
  - Ecology allows the roof area to be modeled as a landscaped area (grass).
  - When calculating the runoff curve number to include in calculations described in 4.6 SCS Curve Number Equations, the curve number may be determined by considering the roof area as landscaped area (grass).
- When dispersion trenches are used per the guidance above, and the length of the vegetated flow path is 25 - 50 feet:
  - Ecology allows the roof area to be modeled as 50%landscaped / 50%impervious.
  - When calculating the runoff curve number to include in calculations described in 4.6 SCS Curve Number Equations, the curve number may be determined by considering the roof area as 50%landscaped / 50%impervious.

BMP T5.10C: Perforated Stub-out Connections

A perforated stub out connection is a length of perforated pipe within a gravel filled trench that is placed between roof downspouts and a stub out to the local drainage system. Figure 6.26: Perforated Stub-Out Connection illustrates a perforated stub out connection. These systems are intended to provide some infiltration during drier months. During the wet winter months, they may provide little or no Flow Control.

Applications & Limitations

Perforated stub-outs are not appropriate when the seasonal water table is less than one foot below the trench bottom.

Select the location of the connection to allow a maximum amount of runoff to infiltrate into the ground (ideally a dry, relatively well drained, location). To facilitate maintenance, do not locate the perforated pipe portion of the system under impervious or heavily compacted (e.g., driveways and parking areas) surfaces. Use the same setbacks as for infiltration trenches in BMP T5.10A: Downspout Full Infiltration.

Have a licensed geologist, hydrogeologist, or engineering geologist evaluate potential runoff discharges towards landslide hazard areas. Do not place the perforated portion of the pipe on or above slopes greater than 20% or above erosion hazard areas without evaluation by a licensed engineer in the state of Washington with geotechnical expertise or qualified geologist and jurisdiction approval.

For sites with septic systems, the perforated portion of the pipe must be downgradient of the drainfield primary and reserve areas. This requirement can be waived if site topography will clearly prohibit flows from intersecting the drainfield or where site conditions (soil permeability, distance between systems, etc.) indicate that this is unnecessary.

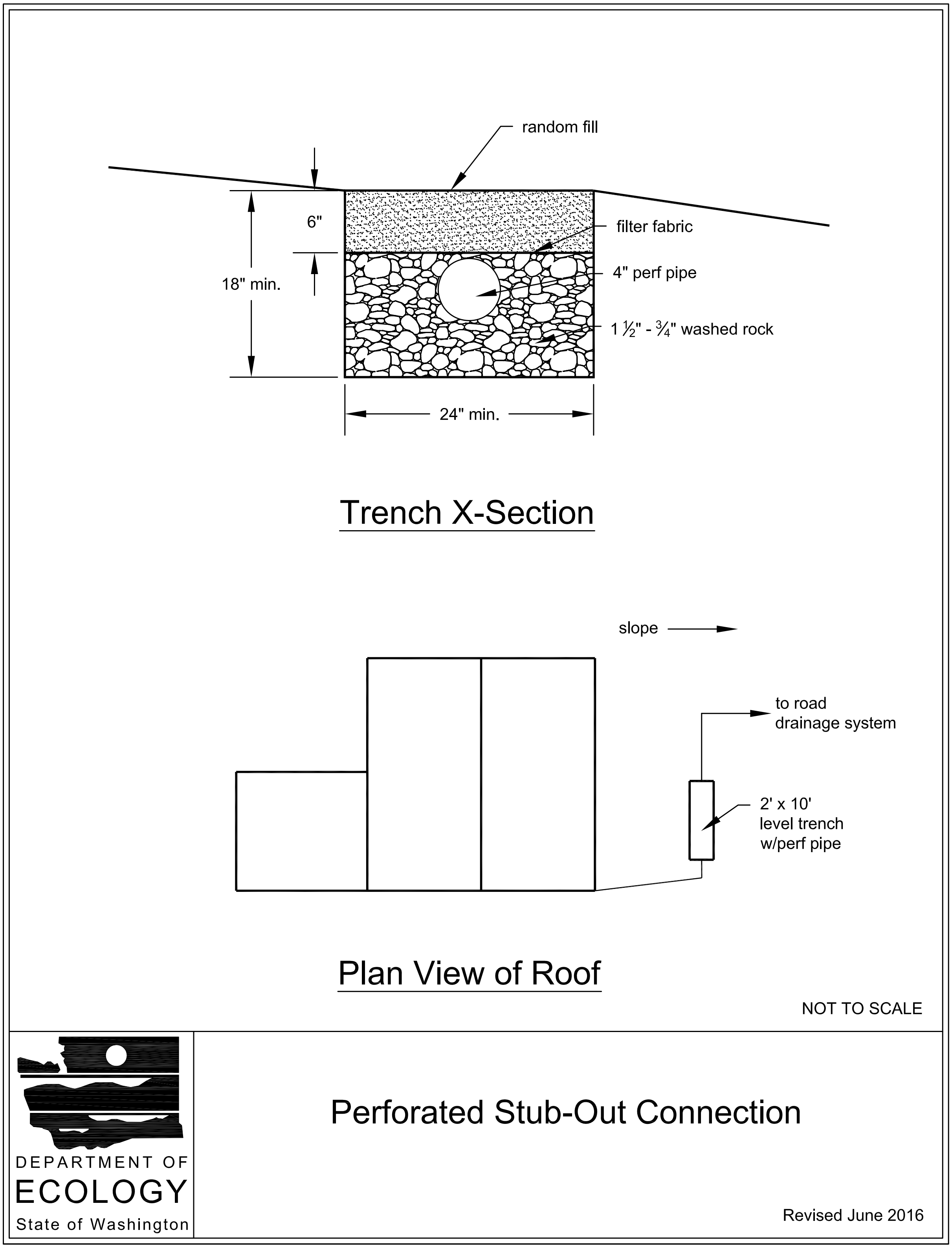
Design Criteria

Perforated stub out connections consist of at least 10 feet of perforated pipe per 5,000 square feet of roof area laid in a level, 2 foot wide trench backfilled with washed drain rock. Extend the drain rock to a depth of at least 8 inches below the bottom of the pipe and cover the pipe. Lay the pipe level and cover the rock trench with filter fabric and 6 inches of fill (see Figure 6.26: Perforated Stub-Out Connection).

Runoff Model Representation

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.

Figure 6.26: Perforated Stub-Out Connection



6.5 Infiltration BMPs

6.5.1 Introduction to Infiltration BMPs

Purpose

An infiltration BMP is typically an open basin (pond), trench, buried perforated pipe, or permeable pavement used for distributing stormwater runoff into the underlying soil.

Some infiltration BMPs are considered underground injection control (UIC) wells, and must comply with the UIC Program requirements. See Chapter 5 - UIC Program Guidelines for details.

Infiltration BMPs are used as Flow Control BMPs, and in some cases can also be used as Runoff Treatment BMPs.

- Infiltration BMPs used as Flow Control BMPs convey stormwater runoff from new development or redevelopment to the ground and groundwater after appropriate Runoff Treatment.
- Infiltration BMPs used as Runoff Treatment BMPs rely either on the soil profile or on a treatment layer within the BMP to provide Runoff Treatment.

Infiltration BMPs can have multiple benefits including:

- Flow Control.
- Runoff Treatment.
- Groundwater recharge.
- Discharge of uncontaminated or properly treated stormwater to dry-wells in compliance with Ecology's UIC regulations (Chapter 173-218 WAC).
- Retrofits in limited land areas. Infiltration BMPs can be considered for residential lots, commercial areas, parking lots, and open space areas.
- Flood control.
- Streambank erosion control.

Infiltration refers to the use of the filtration, adsorption, and biological properties of native soils, with or without amendments, to remove pollutants as stormwater soaks into the ground. One condition that can limit the use of infiltration is the potential adverse impact on groundwater quality. You must understand the difference between infiltrating in soils that are suitable for Runoff Treatment and soils only suitable for Flow Control to protect groundwater. Sufficient organic content and sorption capacity to remove pollutants must be present for soils to provide Runoff Treatment. See 6.5.6 Site Suitability Criteria (SSC) for details. Examples of suitable soils are silty and sandy loams. Coarser soils, such as gravelly sands, can provide Flow Control but are not suitable for providing Runoff Treatment. The use of coarser soils to provide Flow Control for runoff from pollutant generating surfaces must always be preceded by Runoff Treatment to protect groundwater quality. Thus, there will be instances when soils are suitable for Runoff Treatment but not Flow Control, and vice versa.

Companion practices, such as street sweeping, catch basin inserts, and similar BMPs can provide additional benefit and reduce the cleaning and maintenance needs for the infiltration BMP. The hydraulic design goal should be to mimic the natural hydrologic balance between surface and groundwater.

Due to the multiple hydrologic benefits of infiltration, Ecology encourages infiltration to the maximum extent practicable. Sites that can fully infiltrate are not required to provide additional Runoff Treatment or Flow Control BMPs. Hard surfaces that are not fully infiltrated should be partially infiltrated to the maximum extent practicable.

Infiltration BMPs used for Runoff Treatment are typically installed:

- Where the native soils meet the criteria for Runoff Treatment as described in 6.5.6 Site Suitability Criteria (SSC)
- As off-line systems, or on-line for small contributing areas
- As a polishing treatment for street/highway runoff after pretreatment for TSS and oil
- As part of a treatment train
- As retrofits at sites with limited land areas, such as residential lots, commercial areas, parking lots, and open space areas.
- With appropriate pretreatment for oil and silt control to prevent clogging. Appropriate pretreatment devices are described in 6.10 Pretreatment BMPs.

Application

Infiltration BMPs may be used for Flow Control where Runoff Treatment is not required (e.g. for runoff from non pollution generating surfaces), or for flows greater than the Water Quality Design Flow Rate, or where appropriate Runoff Treatment is provided prior to discharge.

6.5.2 Infiltration BMP Design Steps

Designers should follow the steps below if an infiltration BMP is proposed for the project site.

1. Select a Location for the Infiltration BMP

Select the location based on the ability to convey flow to the location and the expected soil conditions at the location. Conduct a preliminary surface and sub-surface characterization study (see 6.5.5 Site Characterization Criteria for Infiltration). Also do a preliminary check of the criteria in 6.5.6 Site Suitability Criteria (SSC) and 6.5.7 Screening Criteria for Infiltration BMPs to initially estimate feasibility of locating an infiltration BMP on the site.

2. Estimate the Volume of Stormwater Runoff to be Infiltrated

Estimate the volume of stormwater runoff to be infiltrated. The volume to be infiltrated will depend on the performance goals the infiltration BMP is designed to meet. Refer to 2.4.5 CE5: Runoff

Treatment and/or 2.4.6 CE6: Flow Control for guidance on various performance standards for Runoff Treatment and/or Flow Control.

3. Develop Trial Infiltration BMP Geometry

To develop the trial BMP geometry, assume a design infiltration rate based on previously available data, or a default design infiltration rate of 0.3 inches/hour. Use this trial BMP geometry to help locate the BMP and for planning purposes in developing the geotechnical subsurface investigation plan.

4. Complete a More Detailed Site Characterization Study and Consider the Site Suitability Criteria

Information gathered during initial geotechnical and surface investigations is necessary to know whether infiltration is feasible. The geotechnical investigation evaluates the suitability of the site for infiltration, establishes the infiltration rate for design, and evaluates slope stability, foundation capacity, and other geotechnical design information needed to design and assess constructability of the BMP.

See 6.5.5 Site Characterization Criteria for Infiltration and 6.5.6 Site Suitability Criteria (SSC) for details.

5. Determine the Design Infiltration Rate

Refer to 6.5.4 Determining the Design Infiltration Rate of the Native Soils.

6. Size the Infiltration BMP

The maximum ponded water depth should be between 2 and 6 feet with at least one foot of freeboard.

Size should be determined by using the method(s) outlined with each BMP, based on the requirement of infiltrating the water quality design storm volume within 72 hours after cessation of flow.

7. Groundwater Mounding Analysis

On projects where an infiltration BMP has a contributing drainage area exceeding 1 acre and has less than fifteen feet depth to seasonal high groundwater (as measured from the elevation at which infiltration into the native soil begins) or other low permeability stratum, determine the final design infiltration rate using an analytical groundwater model to investigate the effects of the local hydrologic conditions on BMP performance.

These larger projects can use the design infiltration rate determined in 6.5.4 Determining the Design Infiltration Rate of the Native Soils to do an initial sizing of the infiltration BMP. Then complete the groundwater modeling (mounding analysis) of the proposed infiltration BMP. Use MODRET or an equivalent model unless the local government approves an alternative analytic technique.

Export the full output hydrograph of the developed condition and use it as input to MODRET. Note that an iterative process may be required beginning with an estimated design rate, sizing of the BMP , then groundwater model testing.

8. Construct the Infiltration BMP and Conduct Performance Testing

Test and monitor the constructed BMP to demonstrate that the BMP performs as designed. Use the same test method for saturated hydraulic conductivity as used in the planning stages so that results are comparable. Perform the testing after stabilizing the construction site.

Submit the results and comparisons to the pre-project measured (initial) and design infiltration rates to the local stormwater authority that approved the project design. If the post project measured rates are lower than the design saturated hydraulic conductivity, the applicant shall implement measures to improve infiltration capability within the footprint of the constructed BMP and re-test.

If less intensive measures prove unsuccessful, replacement of the top foot of soil – or more if visual observation indicates deeper fouling of the bed with fine sediment – with a soil meeting the design needs (i.e. Runoff Treatment, Flow Control, or both) shall be provided. Longer-term monitoring of drawdown times and periodic testing of the BMP should provide an indication of when the BMP needs maintenance to restore infiltration rates.

6.5.3 General Design Criteria for Infiltration BMPs

This section provides design, construction and maintenance criteria that apply to all types of infiltration BMPs. The designer should refer to this section, as well as the design criteria provided for the individual BMP when designing the infiltration BMP.

Sizing Infiltration BMPs

The size of the infiltration BMP can be determined by calculating the footprint required to fully infiltrate the required volume within the time allowed (i.e. 72 hours), based on the design infiltration rate(s) (i.e. the most limiting rate of either the native soils or engineered soil layers).

To prevent the onset of anaerobic conditions, an infiltration BMP designed for Runoff Treatment purposes (either by a layer within the infiltration BMP, as in BMP F6.23: Bioretention, or by treatment through native soils that meet the criteria for Runoff Treatment per 6.5.6 Site Suitability Criteria (SSC)) must be designed to drain the Water Quality Design Volume within 72 hours (see explanation under SSC-4 Soil Infiltration Rate/Drawdown Time).

In general, an infiltration BMP has two discharge modes. The primary mode of discharge is infiltration into the ground. However, when the infiltration capacity of the BMP is reached, additional runoff to the BMP will cause the BMP to overflow. Overflows from an infiltration BMP must comply with the Flow Control performance standard(s) they are designed to meet. These standards are typically to meet 2.4.6 CE6: Flow Control. Infiltration BMPs used for Runoff Treatment may allow flows that exceed the Water Quality Design Volume (see 6.1.5 Sizing Your Runoff Treatment BMPs) to overflow.

Size should be determined by using the method(s) outlined with each BMP, based on the requirement of infiltrating the water quality design storm volume within 72 hours after cessation of flow.

Inflow to infiltration BMPs is calculated according to the methods described in Chapter 4 - Hydrologic Analysis and Design. The storage volume in the pond, drywell, perforated pipe, or voids in the gravel, is used to detain runoff prior to infiltration. The infiltration rate and size of the infiltration area are used in conjunction with the size of the storage area to design the facility.

Treatment Prior to Infiltration BMPs

Presettling and Oil Reduction Prior to Infiltration BMPs

It may be possible for a project site to propose an infiltration BMP (e.g. to comply with 2.4.6 CE6: Flow Control), but not require Runoff Treatment prior to the runoff entering the infiltration BMP. Examples of when this may happen are:

- The native soils (or an engineered soil layer) below the infiltration BMP are providing the required level of Runoff Treatment to protect groundwater.
- The project is a new/redevelopment project, complying with the Core Elements, and the project does not include any pollution-generating surfaces (and therefore not triggering Runoff Treatment requirements).

In these cases, Ecology advises to include a presettling chamber of some kind prior to the infiltration BMP, with the intent to reduce potential plugging of the soils and prolong the life of the infiltration BMP.

Ecology does not have a specific performance goal for the recommended presettling chamber. Some examples of how this recommended presettling can be achieved are:

- A Pretreatment BMP, as described in 6.10 Pretreatment BMPs
- A Basic, Oil Control, Metals, or PhosphorusTreatment BMP, as described in 6.1.2 Choosing Your Runoff Treatment BMPs.
- A detention BMP with any amount of settling storage.
- A catch basin or other presettling device with a down-turned elbow on the outlet pipe that traps small quantities of oils and solids. This type of presettling will not capture as many oils and solids as the previous examples listed above, and may require more frequent inspections and/or maintenance.

Note that some infiltration BMPs will accomplish an acceptable level of presettling or Runoff Treatment as an initial accessible layer within the infiltration BMP, and do not need an additional upstream presettling chamber to reduce plugging of the void spaces below. Examples include:

- BMP F6.23: Bioretention. Presettling happens in the ponded area above the BSM, and Runoff Treatment happens via filtering through the BSM layer prior to infiltration to the native soils. When maintenance is required to replace the BSM, it is accessible from the surface.
- BMP F6.24: Permeable Pavement. The wearing course in permeable pavement BMPs will not allow large solids through. Regular maintenance of the permeable pavement, including suction sweeping, will remove the solids from the voids.

In BMPs such as BMP F6.22: Infiltration Trenches where a reduction in infiltration capability can have significant maintenance or replacement costs, selection of a reliable Pretreatment or Basic

Treatment BMP with high solids removal capability is preferred to provide the presettling prior to the infiltration BMP. For infiltration BMPs that allow easier access for maintenance and less costly maintenance activity (e.g. BMP F6.21: Infiltration Ponds with gentle side slopes), there is a trade-off between using the minimum presettling chamber (with no performance goal and lower solids removal capability) or using a Basic (or higher level) Runoff Treatment BMP. Generally, Basic (or higher level) Runoff Treatment BMPs are more capable at solids removal than a minimal presettling chamber or a Pretreatment BMP. Though Basic (or higher level) Runoff Treatment BMPs may be higher in initial cost and space demands, the infiltration BMP that it is protecting from oil and sediment build up should have lower maintenance costs.

Runoff Treatment Prior to Infiltration BMPs

In an effort to protect groundwater, projects must determine and apply the appropriate level of Runoff Treatment whenever infiltration is proposed. There are various regulations with Runoff Treatment requirements that might apply to a project site. It is up to the designer to understand and apply the appropriate requirements, including federal and local jurisdiction requirements. See 1.2 Relationship of This Manual to Regulations and Programs.

This manual includes guidance for two different regulations that might require Runoff Treatment prior to infiltration:

1. **Infiltration BMP(s) that are NOT Underground Injection Control (UIC) wells, proposed as part of a new/redevelopment project within a jurisdiction covered by Ecology's Municipal Stormwater Permit (Phase I or Phase II)**

   These projects must comply with the Core Elements, as described in Chapter 2 - Core Elements for New Development and Redevelopment. 2.4.5 CE5: Runoff Treatment has Runoff Treatment requirements that may be required, depending on the type and amount of work proposed for the project.

2. **Projects installing an Underground Injection Control (UIC) well**

   - Projects that are proposing a UIC well with **no discharge** to an MS4 will refer to Chapter 5 - UIC Program Guidelines for design guidance, including Runoff Treatment requirements.

     Note that some types of UIC wells, even with no discharge to an MS4, will refer to the new/redevelopment requirements from Ecology's Municipal Stormwater Permits. See Chapter 5 - UIC Program Guidelines for details.

     To show that there is no discharge to the MS4, the designer must provide calculations to show that the 100-yr, 3-hr storm OR the 100-yr, 72-hr storm, whichever is larger, is fully infiltrated.

   - Projects that are proposing a UIC well **that will have a discharge** to an MS4 within a jurisdiction covered by an Ecology Municipal Stormwater Permit are directed to comply with the Runoff Treatment requirements per Ecology's Municipal Stormwater Permit.

     These projects must comply with the Core Elements, as described in Chapter 2 - Core Elements for New Development and Redevelopment. 2.4.5 CE5: Runoff

Treatment and 2.4.8 CE8: Wetlands Protection have Runoff Treatment requirements that may be required, depending on the type and amount of work proposed for the project.

Note that these projects must still follow the registration requirements for the UIC well. See Chapter 5 - UIC Program Guidelines for details.

Additional Design Criteria

- The slope of the base of the infiltration BMP should be as flat as possible, generally < 3%.
- Construct a nonerodible outlet or spillway with a firmly established elevation to discharge overflow. Calculate ponding depth, drawdown time, and storage volume from that reference point.
- For infiltration BMPs providing Runoff Treatment, side-wall seepage is not a concern if seepage occurs through the same stratum as the bottom of the BMP. However, for soils with very low permeability, the potential to bypass the treatment soil through the side-walls may be significant. In those cases, line the side-walls with at least 18 inches of treatment soil to prevent seepage of untreated flows through the side walls.
- The project design should consider whether there would be any adverse effects caused by seepage zones on nearby building foundations, basements, roads, parking lots or sloping sites.

Cold Climate Considerations

Infiltration BMPs can be effective in cold climates, but may be restricted by groundwater quality concerns related to infiltration of chlorides associated with street deicing compounds. Frozen ground may inhibit the infiltration capacity of the ground. Grasses or other vegetation used in BMPs may also be dormant or ineffective at providing treatment mechanisms (e.g. filtration, pollutant uptake, etc.) during the winter. For vegetated BMPs, plants should be selected to be tolerant of cold and freezing climates. See 6.1.8 Cold Weather Considerations for additional cold weather considerations.

Arid and Semi-arid Climate Considerations

For vegetated BMPs in arid/semiarid portions of eastern Washington, plants should be selected to be drought tolerant and not require watering after establishment (2 to 3 years). In more arid environments, watering may be needed during prolonged dry periods after plants are established. See Table 6.6: Recommended Stormwater Treatment BMPs Based on Climate Type (continued) for additional considerations based on average annual rainfall.

Construction Criteria

- Conduct initial excavation for the infiltration BMP to within 1-foot of the final elevation of the BMP floor. Excavate to final grade only after all disturbed areas in the upgradient project drainage area have been permanently stabilized. The final phase of excavation should remove all accumulation of silt in the infiltration BMP before putting it in service. After construction completion, prevent sediment from entering the infiltration BMP by first conveying the runoff water through an appropriate pretreatment BMP.

- Generally, do not use infiltration BMPs as temporary sediment traps during construction. If an infiltration BMP will be used as a temporary sediment trap, do not excavate to final grade until after stabilizing the upgradient drainage area. Remove any accumulation of silt in the BMP prior to putting it into service.
- Relatively light-tracked equipment is recommended for use during construction of infiltration BMPs to avoid compaction of the infiltration BMP floor. Consider the use of draglines and trackhoes for constructing infiltration BMPs. Flag or mark the infiltration area to keep heavy equipment away.

Maintenance Criteria

Make provisions for regular and perpetual maintenance of the infiltration BMP, including replacement and/or reconstruction of any media relied upon for Runoff Treatment purposes.

An Operation and Maintenance Plan, approved by the local jurisdiction, should ensure maintaining the desired infiltration rate.

Include adequate access for operation and maintenance in the design of infiltration BMPs.

Conduct removal of accumulated debris/sediment in the infiltration BMP every 6 months or as needed to prevent clogging. Indications that the BMP is not infiltrating adequately include:

- Overflows occur more frequently than planned. For example, off-line infiltration BMPs should not have any overflows. Infiltration BMPs designed to completely infiltrate all flows should not overflow.
- Water remains pooled in the infiltration BMP for more than 72 hours.
- Water remains in the BMP for greater than 24 hours after the end of most moderate rainfall events.

For more detailed information on maintenance, see Appendix 6-A: BMP Maintenance Tables.

Verification of Performance

During the first 1 to 2 years of operation, verification monitoring is strongly recommended along with a maintenance program that results in achieving expected performance levels. A professional engineer, professional geologist, licensed hydrogeologist, or designee under their supervision should monitor the construction of the infiltration BMP to ensure that the work is completed in compliance with the designer’s intent and the plans and specifications. Following construction, the BMP should be visually monitored quarterly over a 2-year period to assess its performance as designed. Operating and maintaining groundwater monitoring wells is also strongly encouraged. Water levels within installed groundwater monitoring wells should be monitored on a periodic interval, particularly prior to, during, and following storm events, to evaluate groundwater mounding impacts below and adjacent to the BMP.

6.5.4 Determining the Design Infiltration Rate of the Native Soils

A crucial element to infiltration BMP design is the long term (design) infiltration rate of the native soils. In order to determine the design infiltration rate, the designer must first determine the measured (initial) saturated hydraulic conductivity (K_{sat}) of the native soils. Detailed below are several methods for determining initial K_{sat}. Ecology then offers a simplified approach and a detailed approach to use the initial K_{sat} to determine the design infiltration rate of the native soils. The design infiltration rate is used to size the infiltration BMP, including verifying compliance with the maximum drawdown time of 72 hours.

Determining the Measured (Initial) K_{sat}

Ecology recommends using in-situ field measurements (i.e. PIT tests, further described below) to determine the initial K_{sat} rate of the native soil.

For sites with soils unconsolidated by glacial advance, Ecology also supports using a laboratory method (i.e. soil grain size analysis, further described below) to determine the initial K_{sat} rate of the native soil.

Local governments may approve additional testing methods. Ecology has provided details on additional testing methods below, for reference purposes.

K_{sat} Determination Option 1: Large Scale Pilot Infiltration Test (PIT)

The large scale Pilot Infiltration Test (PIT) is a large-scale in-situ infiltration measurement, and is the preferred method for estimating the initial K_{sat} of the soil profile beneath the proposed infiltration BMP. The PIT reduces some of the scale errors associated with relatively small-scale double ring infiltrometer or “stove-pipe” infiltration tests. It is not a standard test but rather a practical field procedure recommended by Ecology’s Technical Advisory Committee.

Table 6.16: Large Scale PIT Test: Advantages, Disadvantages, and Applicability

Advantages	Disadvantages	Applicability
• Larger-scale test that reduces scale error associated with site hetero-geneity • Sufficient infilt-ration period to promote adequate soil presoaking and a stabilized infilt-ration rate	• Requires significantly greater effort, time, and space than the small-scale PIT • Logistical constraints (e.g. little or no water for testing, depth of the proposed infiltration system, difficult access, etc.) • Difficult to provide a water source to	• Infiltration BMP design • Large-scale permeable pavement installations where the stormwater from adjacent impervious surfaces is directed to the permeable pavement surface (high hydraulic load)

Table 6.16: Large Scale PIT Test: Advantages, Disadvantages, and Applicability (continued)

Advantages	Disadvantages	Applicability
	maintain a sufficient head in permeable sands and gravels	
Large-scale pilot infiltration test (PIT): Field test method involving an excavated test pit with a bottom surface area of approximately 100 square feet (sf). Involves filling with clean water and measuring water level during a constant-head and drawdown period.		

Large Scale PIT: Infiltration Test Method

Notes:

- Testing should occur between December 1 and April 1.
- The horizontal and vertical locations of the PIT shall be surveyed by a licensed land surveyor and accurately shown on the design drawings.

Steps:

1. Excavate the test pit to the estimated elevation of the proposed infiltration into the native soil. Note that for some proposed BMPs, such as BMP F6.23: Bioretention and BMP F6.24: Permeable Pavement, this will be below the proposed finished grade. If the native soils will have to meet a minimum subgrade compaction requirement (for example, the road subgrade if using BMP F6.24: Permeable Pavement), compact the native soil to that requirement prior to testing. Lay back the slopes sufficiently to avoid caving and erosion during the test. Alternatively, consider shoring the sides of the test pit.
2. The horizontal surface area of the bottom of the test pit should be approximately 100 square feet. Document the size and geometry of the test pit.
3. Install a vertical measuring rod (long enough to measure the ponded water depth, minimum 5-ft. long) marked in half-inch increments in the center of the pit bottom.
4. Use a rigid 6-inch diameter pipe with a splash plate on the bottom to convey water to the test pit and reduce side-wall erosion or excessive disturbance of the test pit bottom. Excessive erosion and bottom disturbance will result in clogging of the infiltration receptor and yield lower than actual infiltration rates.
5. Pre-soak Period: Add water to the pit at a rate that will maintain a water level between 6 and 12 inches above the bottom of the pit. Various meters can be used to measure the flow rate into the pit, including (but not limited to) rotameters and magnetic meters.

   Note: The depth should not exceed the proposed maximum depth of water expected in the completed BMP. For infiltration BMPs serving large drainage areas, designs with multiple feet of ponding depth can have infiltration tests with greater than 1 foot of standing water.

6. Every 15 to 30 minutes, record the cumulative volume and instantaneous flow rate in gallons per minute necessary to maintain the water level at the same point on the measuring rod.
7. Keep adding water to the pit until one hour after the flow rate into the pit has stabilized (constant flow rate; a goal of 5% or less variation in the total flow) while maintaining the same pond water level. The total of the pre-soak time plus one hour after the flow rate has stabilized should be no less than 6 hours.
8. After the flow rate has stabilized for at least one hour, turn off the water and record the rate of infiltration (the drop rate of the standing water) in inches per hour from the measuring rod data, until the pit is empty. Consider running this falling head phase of the test several times to estimate the dependency of the infiltration rate with head.
9. At the conclusion of testing, over-excavate the pit to see if the test water is mounded on shallow restrictive layers or if it has continued to flow deep into the subsurface. The depth of excavation varies depending on soil type and depth to the hydraulic restricting layer, and is determined by the engineer or certified soils professional. Mounding is an indication that a mounding analysis is necessary.

Large Scale PIT: Data Analysis

1. Calculate and record the initial K_{sat} rate in inches per hour in 30-minute or one-hour increments until one hour after the flow has stabilized.
2. Use statistical/trend analysis to obtain the hourly flow rate when the flow stabilizes. This would be the lowest hourly flow rate.

Large Scale PIT: Example

The area of the bottom of the test pit is 8.5-ft. by 11.5-ft. (97.75 sq. ft.).

Water flow rate was measured and recorded at intervals ranging from 15 to 30 minutes throughout the test. Between 400 minutes and 1,000 minutes the flow rate stabilized between 10 and 12.5 gallons per minute or 600 to 750 gallons per hour, or 80.2 to 100 ft^3 per hour. Dividing this rate by the surface area gives an initial K_{sat} of 9.8 to 12.3 inches per hour.

K_{sat} Determination Option 2: Small Scale Pilot Infiltration Test (PIT)

A small-scale PIT can be substituted for Ksat Determination Option 1: Large Scale Pilot Infiltration Test (PIT) in any of the following instances:

- The drainage area to the infiltration BMP is less than 1 acre.
- The testing is for BMP F6.23: Bioretention or BMP F6.24: Permeable Pavement that either serve small drainage areas and/or are widely dispersed throughout a project site.
- The site has a high infiltration rate (>4 in/hr), making a large scale PIT difficult, and the site geotechnical investigation suggests uniform subsurface characteristics.

Table 6.17: Small Scale PIT Test: Advantages, Disadvantages, and Applicability

Advantages	Disadvantages	Applicability
• Reduces cost and test time compared to the large-scale PIT method • Feasible for sites with high infiltration rates (which makes large-scale PIT method difficult) • Sufficient infiltration period to promote adequate soil presoaking and a stabilized infiltration rate	• Only applicable to small contributing areas (less than 1 acre) or for infilt-ration BMPs that either serve small contributing areas or are widely dispersed • Logistical constraints (e.g. little or no water for testing, depth of the proposed infiltration system, difficult access, etc.) • Difficult to provide a water source to maintain a sufficient head in permeable sand and gravel	• Infiltration BMP designs with relatively low hydraulic loadings • Sites with high infiltration rate and uniform subsurface characteristics
Small-scale pilot infiltration test (PIT): Field test method involving an excavated test pit with a bottom surface area of approximately 12 to 32 sf. Involves filling with clean water and measuring water level during a constant-head and drawdown period.		

Small Scale PIT: Infiltration Test Method

Use the same procedures described above in Ksat Determination Option 1: Large Scale Pilot Infiltration Test (PIT), with the following changes:

- The side slopes may be laid back sufficiently to avoid caving and erosion during the test. However, the side slopes for the depth of ponding 6 to 12 inches during the test should be vertical.
- The horizontal surface area of the bottom of the test pit should be 12 to 32 square feet. It may be circular or rectangular. Document the size and geometry of the test pit.
- The rigid pipe with a splash plate used to convey water to the pit may be a 3-inch diameter pipe for pits on the smaller end of the recommended surface area, or a 4-inch pipe for pits on the larger end of the recommended surface area.
- 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. In gravel soils, if standing water cannot be measured after 30 minutes and while maintaining a flow rate ≥ 50 gallons per minute, the presoak period can be terminated early.
- At the end of the pre-soak period, add water to the pit at a rate that will maintain a 6-12 inch water level above the bottom of the pit over a full hour. The depth should not exceed the proposed maximum depth of water expected in the completed facility.

- Every 15 minutes, record the cumulative volume and instantaneous flow rate in gallons per minute necessary to maintain the water level at the same point (between 6 inches and 1 foot) on the measuring rod. The specific depth should be the same as the maximum designed ponding depth (usually 6 – 12 inches).
- After one hour, turn off the water and record the rate of infiltration (the drop rate of the standing water) in inches per hour from the measuring rod data, until the pit is empty.
- A self-logging pressure sensor may also be used to determine water depth and drain-down.
- At the conclusion of testing, over-excavate the pit to see if the test water is mounded on shallow restrictive layers or if it has continued to flow deep into the subsurface. The depth of excavation varies depending on soil type and depth to the hydraulic restricting layer, and is determined by the engineer or certified soils professional. The soils professional should judge whether a mounding analysis is necessary.

Small Scale PIT: Data Analysis

See the data analysis guidance for Ksat Determination Option 1: Large Scale Pilot Infiltration Test (PIT).

K_{sat} Determination Option 3: Soil Grain Size Analysis

The soil grain size analysis method is a laboratory test-based method that estimates initial saturated hydraulic conductivity (K_{sat}) using empirical relationships to grain size. It is used in place of in-situ testing where allowed. The soil grain size analysis method described herein was developed using data from soils that generally are unconsolidated by glacial advance. Application of this method to consolidated glacial soil, such as till, requires correction (Massmann, 2008), (WSDOT, 2017b).

The following grain size analysis may be used to determine initial K_{sat} if the site has soils unconsolidated by glacial advance. This method uses the ASTM soil size distribution test procedure (ASTM D422), which considers the full range of soil particle sizes, to develop soil size distribution curves.

Table 6.18: Soil Grain Size Analysis: Advantages, Disadvantages, and Applicability

Advantages	Disadvantages	Applicability
• Used in place of in-situ measurement where allowed • Well-documented correlations between grain size and saturated hydraulic conductivity	• Does not address in-situ soil characteristics, such as density and stratification, that affect hydraulic conductivity • Empirical equation assumes minimal compaction; must be adjusted if soils are overconsolidated or compacted by glacial advance or due to heavy equipment • Lower precision than in-situ field measurements	Infiltration BMP design for sites with soils unconsolidated by glacial advance

Table 6.18: Soil Grain Size Analysis: Advantages, Disadvantages, and Applicability (continued)

Advantages	Disadvantages	Applicability
Soil grain size analysis method: Laboratory test method that estimates initial saturated hydraulic conductivity using established relationship to grain size.		

Soil Grain Size Analysis: Calculation Method

- Conduct an adequate number of grain size analyses to characterize each defined layer below the top of the final subgrade of the infiltration Best Management Practice (BMP) area to a depth of at least 3 times the maximum ponding depth of the infiltration BMP, but no less than 10 feet. For large infiltration BMPs serving drainage areas of 10 acres or more, soil grain size analyses should be performed on layers up to 50 feet deep (or no more than 10 feet below the water table).
- Estimate the saturated hydraulic conductivity (K_{sat}) of each applicable soil layer using the procedure specified in Section 2 of (Massmann, 2008), which is summarized below:

  Equation: Saturated Hydraulic Conductivity (Soil Grain Size Analysis Method)

  $$log_{10}(K_{sat}) = -1.57 + 1.90 * d_{10} + 0.015 * d_{60} - 0.013 * d_{90} - 2.08 * f_{fines}$$

  where:

  K_{sat} = saturated hydraulic conductivity (centimeters per second [cm/sec])

  d_{10} = grain size for which 10% of the sample is finer (millimeters [mm])

  d_{60} = grain size for which 60% of the sample is finer (mm)

  d_{90} = grain size for which 90% of the sample is finer (mm)

  f_{fines} = fraction of the soil (by weight) that passes a No. 200 sieve

- If the estimate using Equation: Saturated Hydraulic Conductivity (Soil Grain Size Analysis Method) is greater than than 0.01 cm/sec, recalculate K_{sat} using Equation: Saturated Hydraulic Conductivity for Coarse-Grained Soils (Soil Grain Size Analysis Method) and use the greater of the two values:

  Equation: Saturated Hydraulic Conductivity for Coarse-Grained Soils (Soil Grain Size Analysis Method)

  $$log_{10}(K_{sat}) = -1.32 + 1.225 * d_{10} - 0.376 * f_{fines}$$

  where:

  K_{sat} = saturated hydraulic conductivity (cm/sec)

  d_{10} = grain size for which 10% of the sample is finer (mm)

f_{fines} = fraction of the soil (by weight) that passes a No. 200 sieve

- If the estimate using Equation: Saturated Hydraulic Conductivity (Soil Grain Size Analysis Method) is less than 0.01 cm/s, recalculate K_{sat} using Equation: Saturated Hydraulic Conductivity for Fine-Grained Soils (Soil Grain Size Analysis Method):

  Equation: Saturated Hydraulic Conductivity for Fine-Grained Soils (Soil Grain Size Analysis Method)

  $$log_{10}(K_{sat}) = -2.89 + 7.57 * d_{10} - 0.527 * d_{60} + 0.030 * d_{90} + 0.142 * f_{fines}$$

  where:

  K_{sat} = saturated hydraulic conductivity (cm/sec)

  d_{10} = grain size for which 10% of the sample is finer (mm)

  d_{60} = grain size for which 60% of the sample is finer (mm)

  d_{90} = grain size for which 90% of the sample is finer (mm)

  f_{fines} = fraction of the soil (by weight) that passes a No. 200 sieve

Soil Grain Size Analysis: Data Analysis

- If the licensed professional conducting the investigation determines that deeper layers will influence the rate of infiltration for the infiltration BMP area, soil layers at greater depths should be considered when assessing the site's initial K_{sat}.
- Machinery or material stockpiles and associated compaction should not be allowed in infiltration areas. Equation: Saturated Hydraulic Conductivity (Soil Grain Size Analysis Method) through Equation: Saturated Hydraulic Conductivity for Fine-Grained Soils (Soil Grain Size Analysis Method) assume minimal compaction consistent with the use of tracked (e.g. low to moderate ground pressure) excavation equipment. If the soil layer being characterized has been exposed to heavy compaction, the hydraulic conductivity for the layer could be approximately an order of magnitude less than what would be estimated based on grain size characteristics alone (Pitt et al., 1995), (Massmann, 2008). In such cases, compaction effects should be taken into account when estimating hydraulic conductivity unless mitigated as determined by a licensed professional. Methods for correcting K_{sat} for compaction effects are provided by (Massmann, 2008) and (WSDOT, 2017b).
- Use the layer with the lowest saturated hydraulic conductivity to determine the measured hydraulic conductivity.
- If greater certainty is desired, the in-situ saturated hydraulic conductivity of a specific layer can be obtained through the use of a pilot infiltration test (PIT), as described above.

K_{sat} Determination Option 4: Borehole Method

Although not recommended by Ecology, local governments may approve this additional testing method within their jurisdiction. Ecology has provided this guidance for this additional testing method for reference purposes.

This test method is applicable for determining permeabilities for use in the design of standard and nonstandard systems using drywells. Note: Design deviation is required for all nonstandard subsurface infiltration systems.

Table 6.19: Borehole Method: Advantages, Disadvantages, and Applicability

Advantages	Disadvantages	Applicability
• Short-duration test (minimum of 1 hour, maximum of 1.5 hours) • Low cost and relatively easy to implement • Multiple tests can be performed at the same time • Preliminary assessment when performed in conjunction with grain-size distribution correlations • Can test material at depth without excavating	• Saturates a small amount of soil at the test location (i.e., small in scale) • May require multiple borings in areas with variable soils • Measures short-term infiltration rate; correction factors need to be applied for long-term (design) infiltration rates • Does not work well for areas with interbedded fine-grained sediments and/or changes in hydraulic conductivity below the tested area • May underestimate infiltration rate when drilling process creates borehole skin effect (i.e., smearing of sidewalls)	Infiltration BMP design
Borehole percolation test (e.g., California Test 750; U.S. EPA, 1980): Field test method originally developed for sizing septic systems that involves installation of a small-diameter (e.g. 6-inch) borehole and casing (e.g. slotted pipe or well screen), filling with clean water, and collecting measurements during a constant-head and drawdown period.		

Borehole Method: Infiltration Test Steps

1. Using a hollow-stem auger, advance a 6-inch-diameter or greater borehole to a depth of 2 to 5 feet below the anticipated elevation of the proposed drainage structure. Use care not to contaminate the sides of the hole with fines.
2. Install a slotted pipe or well screen into the hole having a minimum diameter of 2 inches and a minimum 20% open area through the hollow-stem portion of the auger-string. Install the pipe as nearly as is practical to the bottom of the hole. Wrapping the pipe with a highly

porous, nonwoven, geotextile fabric is an allowable practice.

3. During auger removal, install a gravel-pack of uniform, clean, dry, pervious fine gravel around the slotted pipe. Omission of this step is an allowable practice. However, calculations for permeability must be based on the original diameter of the borehole, therefore omission of the gravel pack is not recommended.
4. Introduce clean water near the bottom of the hole through the slotted pipe using an in-line, commercially available, flow meter. Prior to the test, field check the accuracy of the flow meter using a suitable container of known volume (i.e., 5-gallon bucket, etc.).
5. Raise the water level in the hole until a level consistent with the operating head anticipated in the proposed drainage structure is achieved. Based on the soil permeability, the subsurface soil profile, and the water supply system available, head levels lower than those anticipated in the drainage structure are permitted.
6. Adjust the flow rate as needed to maintain the constant-head level in the hole. Minimum required time for this step is 1 hour.
7. Monitor and record the flow rate required to maintain the constant-head level at appropriate intervals. In no case shall the interval > 10 minutes.
8. Continue maintaining a constant-head level until a stabilized flow rate has been achieved. Consider the flow rate stable when the incremental flow rate required to maintain the head does not vary by > 5% between increments. The intent of this step is to achieve a relatively steady-state flow condition between the minimum time of 1 hour and a maximum time of 1.5 hours for this step. At the discretion of the qualified professional, the time for this step may be extended beyond the 1.5-hour maximum.
9. Upon completion of the constant-head period, discontinue flow, and monitor the decrease in head level in the borehole at appropriate intervals over ≥ 30-minute falling-head period.
10. Compute the permeability for the constant-head portion of the test using methods outlined in U.S. Bureau of Reclamation (USBR) Procedure 73000-89, Performing Field Permeability Testing by the Well Permeameter Method; and USBR Procedure 7305-89, Field Permeability Test (Shallow-Well Permeameter Method). Note: Use stabilized flow rates observed near the end of the constant-head period in the permeability calculations.
11. At a minimum, the test report shall include a description of the equipment used to conduct the test (including type of flow meter used and the results of the on-site accuracy check of the flow meter); difficulties encountered during drilling and testing; a subsurface log of the soils encountered; depth and diameter of the borehole; type of gravel-pack used (including visual description); type of slotted pipe used; raw data for both constant- and falling-head periods including flow meter readings, incremental flow rates and observed head levels; and calculations showing how the reported permeability rates were computed.

K_{sat} Determination Option 5: Single-Ring Infiltrometer Method

Although not recommended by Ecology, local governments may approve this additional testing method within their jurisdiction. Ecology has provided this guidance for this additional testing method for reference purposes.

This test method is applicable for estimating infiltration and permeability rates for surficial soils in conjunction with nonstandard, subsurface infiltration systems incorporating infiltration ponds.

Note: Design deviation is required for all nonstandard subsurface infiltration systems.

Table 6.20: Single-Ring Infiltrometer Method: Advantages, Disadvantages, and Applicability

Advantages	Disadvantages	Applicability
• Small-scale test • Compatible with nonstandard subsurface disposal systems • Can be used to verify that infiltration rates used for design have not been significantly reduced from compaction	• Increased scale errors compared to other test methods • Measures the rate of infiltration near the soil surface • Impacted by site heterogeneity - results can be highly variable within a site • Poor connection between the ring wall in the soil can cause a leakage of water along the ring wall; may overestimate infiltration rate in these cases • Only saturates a small amount of soil at the test location • Does not work well for areas with interbedded fine-grained sediments and/or changes in hydraulic conductivity below the tested area; may overestimate infilt-ration rate in these cases	• Infiltration swale design • Detention pond design • Infiltration BMP design
Single-ring infiltrometer test: Field test method that involves driving a plastic or metal ring into the soil and measuring water level during a constant-head period.		

Single-Ring Infiltrometer Method: Infiltration Test Steps

1. Drive, jack, or hand-advance a short section of steel or polyvinyl chloride (PVC) pipe having a minimum inside diameter of approximately 12 inches, and a beveled leading edge into the soil surface to a depth of about 8 inches. If after installation the surface of the soil surrounding the wall of the ring shows signs of excessive disturbance such as extensive cracking or heaving, reset the ring at another location using methods that will minimize the disturbance. If the surface of the soil is only slightly disturbed, tamp the soil surrounding the inside and outside wall of the ring until it is as firm as it was prior to disturbance.

2. Introduce clean water into the ring using an in-line, commercially available, flow meter. Prior to the test, field check the accuracy of the flow meter using a suitable container of known volume (i.e., 5-gallon bucket, etc.). Use some form of splash-guard or diffuser apparatus such as a highly porous, nonwoven, geotextile fabric or a sheet of thin aluminum plate to prevent erosion of the surface of the soil during filling and testing.

3. Raise the water level in the ring until a head-level of ≥ 6 inches above the soil surface is achieved.
4. Adjust the flow rate as needed to maintain the constant-head level in the ring. Minimum required time for this step is 2 hours.
5. Monitor and record the flow rate required to maintain the constant-head level at appropriate intervals. In no case shall the interval > 10 minutes.
6. Continue maintaining the constant-head level until a stabilized flow rate has been achieved. Consider the flow rate stable when the incremental flow rate required to maintain the head does not vary by > 5% between increments. The intent of this step is to achieve a relatively steady-state flow condition between the minimum 2-hour test time and a maximum test time of 2.5 hours. At the discretion of the qualified professional, the test may be extended beyond the 2.5-hour maximum.
7. Upon completion of the constant-head period, discontinue flow, and monitor the decrease in head level in the ring at appropriate intervals over ≥ 30-minute falling-head period.
8. Compute the surface infiltration rate using the equation:

   Equation 6.4: Surface Infiltration Rate (Single-Ring Infiltrometer)

   $$I = Q/A$$

   where:

   I = surface infiltration rate(inches per hour [in/hr])

   Q = flow rate required to maintain the constant-head (cubic inches per hour)

   A = surface area of the soil inside the infiltrometer ring (square inches)

   Use stabilized flow rates observed near the end of the constant-head period to compute the rate.
9. Compute the permeability rate using the following equation:

   Equation 6.5: Permeability Rate (Single-Ring Infiltrometer)

   $$K = \frac{Q * L}{A * H}$$

   where:

   k = permeability (in/hr)

   Q = flow rate required to maintain a constant-head level (cubic inches/hour)

   L = length of soil column contained within the ring (inches)

   A = area of the ring (square inches)

   H = head level measured from the base of the ring to the free water surface (inches)

This equation is based on information presented in the U.S. Bureau of Reclamation *Drainage Manual*(USBR, 1993). Use stabilized flow rates observed near the end of the constant-head period to compute the rate.

10. At a minimum, the test report shall include a description of the equipment used to conduct the test (including type of flow meter used and the results of the on-site, flow meter accuracy check); a subsurface log of the soils encountered (if test was conducted in the bottom of a test pit), difficulties encountered during testing; raw data for both constant and falling-head periods including flow meter readings, incremental flow rates, and observed head levels; and calculations showing how the infiltration and permeability rates were computed.

K_{sat} Determination Option 6: Full-Scale Drywell Test Method

Although not recommended by Ecology, local governments may approve this additional testing method within their jurisdiction. Ecology has provided this guidance for this additional testing method for reference purposes.

This test method is applicable for confirmation of design outflow rates for newly installed standard and nonstandard drywells.

Table 6.21: Full-Scale Drywell Test Method: Advantages, Disadvantages, and Applicability

Advantages	Disadvantages	Applicability
Postconstruction verification to ensure that a drywell has been designed and constructed properly	• Relatively time consuming (minimum test length of 2.5 hours) • Could require significant flow rate and volume of water depending on outflow capacity of drywell • Can be difficult to correlate performance of an existing drywell to long-term capacity of a new drywell depending on the condition of the drywell	• Postconstruction verification of the condition and capacity of a drywell • Site suitability assessment for additional drywell installation
Full-scale drywell test: Field test method that involves filling a drywell with clean water and includes a period of constant-head and drawdown measurements.		

Full-Scale Drywell Test Method: Infiltration Test Steps

1. Inspect the drywell and make a thorough report of its condition. At a minimum include information on any silt buildup; if there is any standing water in the drywell; whether it is interconnected to other drywells or catch basins by pipes; the overall depth of the drywell from finished grate elevation to bottom; the distance from finished grate elevation to the invert elevation of any interconnecting pipes; the length of the active barrel section. The active barrel section is defined as the length of ported sections from the bottom of the drywell up to the elevation of the base of the solid cone section. Include additional

information as is applicable (i.e., age of the drywell, if it appears to have been heavily impacted by unusual factors such as construction practices, etc.).

2. Introduce clean water into the drywell using a calibrated, in-line commercially available flow meter.
3. Raise the water level in the drywell until it reaches the top of the active barrel section and then maintain it at that elevation. In the case of drywells interconnected by pipes, raise the water level to the invert elevation of the connecting pipe, or use an expandable pipe plug to seal the connecting pipe.
4. Adjust the flow rate as needed to maintain the constant-head level in the hole. Minimum required time for this step is 1 hour. Test time begins after the water level in the drywell has reached the top of the active barrel section, or the invert elevation of any interconnecting pipes.
5. Monitor the flow rate required to maintain the constant-head level in the drywell at appropriate intervals. In no case shall the interval > 10 minutes.
6. Continue maintaining the constant-head level in the drywell until a stabilized flow rate has been achieved. Consider the flow rate stable when the incremental flow rate required to maintain the head does not vary by > 5% between increments. The intent of this step is to achieve a relatively steady-state flow condition between the minimum 1 hour time and a maximum time of 2 hours for this step. At the discretion of the qualified professional, the time for this step may be extended beyond the 2-hour maximum.
7. Upon completion of the constant-head period, discontinue flow and monitor the decrease in head level in the drywell at appropriate intervals for a 30-minute falling-head period.
8. Report test data in a format that includes time of day, flow meter readings, incremental flow rates, observed head levels and water depths in the drywell, and total flow volumes.

How to Calculate the Design Infiltration Rate of the Native Soils

Once the initial K_{sat} for a site has been determined using one of the methods above, use one of the methods below to determine the design infiltration rate.

The Simplified Approach to Calculating the Design Infiltration Rate of the Native Soils

The simplified approach was derived from high groundwater and shallow pond sites, and in general will produce conservative designs. This approach can be used when determining the trial geometry of the infiltration BMP and for small BMPs serving short plats or commercial developments less than 1 acre of contributing area. Designs of infiltration BMPs for larger projects should use the detailed approach (as described below) and may have to incorporate the results of a groundwater mounding analysis as described in 6.5.2 Infiltration BMP Design Steps. Note: A groundwater mounding analysis is advisable for BMPs with drainage areas smaller than 1 acre if the depth to a low permeability layer (e.g., less than 0.1 inches per hour) is less than 10 feet.

Using the simplified approach, estimate the design (long-term) infiltration rate as follows:

- Use any of the three options above, or other method approved by the local jurisdiction (as appropriate for the site) to estimate the initial K_{sat}.
- Assume that the K_{sat} is the measured (initial) infiltration rate for the native soils.
- Determine the design infiltration rate by adjusting the initial infiltration rate using the appropriate correction factors, as detailed below.

  Correction factors account for site variability, number of tests conducted, uncertainty of the test method, and the potential for long-term clogging due to siltation and bio-buildup. Table 6.22: Correction Factors for In-Situ Ksat Measurements to Estimate Long-Term Design Infiltration Rates of Subgrade Soils (continued) summarizes the typical range of correction factors to account for these issues. The specific correction factors used shall be determined based on the professional judgment of the licensed engineer in the state of Washington or other site professional, considering all issues that may affect the infiltration rate over the long term, subject to the approval of the local jurisdictional authority.

  - **Site variability and number of locations tested (CF_v)**: The number of locations tested must be capable of producing a picture of the subsurface conditions that fully represents the conditions throughout the proposed location of the infiltration BMP. The partial correction factor used for this issue depends on the level of uncertainty that adverse subsurface conditions may occur. If the range of uncertainty is low - for example, conditions are known to be uniform through previous exploration and site geological factors - one pilot infiltration test (or grain size analysis location) may be adequate to justify a partial correction factor at the high end of the range.

    If the level of uncertainty is high, a partial correction factor near the low end of the range may be appropriate. This might be the case where the site conditions are highly variable due to conditions such as a deposit of ancient landslide debris, or buried stream channels. In these cases, even with many explorations and several pilot infiltration tests (or several grain size test locations), the level of uncertainty may still be high.

    A partial correction factor near the low end of the range could be assigned where conditions have a more typical variability, but few explorations and only one pilot infiltration test (or one grain size analysis location) is conducted. That is, the number of explorations and tests conducted do not match the degree of site variability anticipated.

  - **Uncertainty of test method (CF_t)**: Accounts for uncertainties in the testing methods. These values are intended to represent the difference in each test's ability to estimate the actual saturated hydraulic conductivity. The assumption is the larger the scale of the test, the more reliable the result.

  - **Degree of influent control to prevent siltation and bio-buildup (CF_m)**: Even with a pre-settling basin or a basic treatment BMP for pre-treatment, the soil's initial infiltration rate will gradually decline as more and more stormwater, with some amount of suspended material, passes through the soil profile. The maintenance schedule calls for removing sediment when the BMP is infiltrating at only 90% of its design capacity. Therefore, a correction factor, CF_m, of 0.9 is called for.

Note that the CF_m correction factor is "1.0" for BMP F6.23: Bioretention, because correction factors are applied to the bioretention soil mix (BSM) layer to account for the influence of siltation.

Note that the CF_m correction factor is "1.0" for BMP F6.24: Permeable Pavement, because the wearing course provides excellent protection for the underlying native soil from sedimentation. Accordingly, the underlying subgrade soil profile does not require a correction factor for sediment input from sources above the pavement.

- **Quality of pavement aggregate base material (CF_b)**: This correction factor is used for BMP F6.24: Permeable Pavement only. All other infiltration BMPs may use "1.0" as the CF_b correction factor when calculating the design infiltration rate of the native soils.

  For BMP F6.24: Permeable Pavement, "1.0" may be used for CF_b if a licensed engineer in the state of Washington determines that the aggregate base material is clean washed material with less than 1% fines passing the No. 200 sieve. If more than 1% of fines pass the No. 200 sieve, "0.9" may be an appropriate value for CF_b .

Table 6.22: Correction Factors for In-Situ Ksat Measurements to Estimate Long-Term Design Infiltration Rates of Subgrade Soils

Site Analysis Issue or Method	Partial Correction Factor
Site variability and number of locations tested	CF_v = 0.33 to 1.0
Test method • Large-scale PIT • Small-scale PIT • Other small-scale (e.g. Double ring, falling head) • Grain Size Method (Massmann, 2008) ○ Percent passing the U.S. No. 200 sieve is > 10 ○ Percent passing the U.S. No. 200 sieve is < 10 but > 5 ○ Percent passing the U.S. No. 200 sieve is < 5	CF_t = • 0.75 • 0.50 • 0.40 • As follows: ○ 0.40 ○ 0.50 ○ 0.75
Degree of influent control to prevent siltation and bio-buildup	CF_m = 0.9 (for all BMPs other than bioretention and permeable pavement) CFm = 1.0 for bioretention and permeable pavement
Quality of pavement aggregate base	CF_b = 0.9 to 1.0 (for permeable pavement)

Table 6.22: Correction Factors for In-Situ Ksat Measurements to Estimate Long-Term Design Infiltration Rates of Subgrade Soils (continued)

Site Analysis Issue or Method	Partial Correction Factor
material	CF_b = 1.0 for all BMPs other than permeable pavement

Total Correction Factor, $CF_T = CF_v \times CF_t \times CF_m \times CF_b$

The design infiltration rate (K_{sat}design) is calculated by multiplying the initial K_{sat} by the total correction factor:

$$K_{sat}\text{ design} = K_{sat}\text{ initial} \times CF_T$$

The Detailed Approach to Calculating the Design Infiltration Rate of the Native Soils

This detailed approach was obtained from (Massman, 2003).

Using the detailed approach, estimate the design (long-term) infiltration rate as follows:

1. Use any of the three options above, or other method approved by the local jurisdiction (as appropriate for the site) to estimate the initial K_{sat}.
2. Calculate the steady state hydraulic gradient as follows:

$$gradient = i \approx \frac{D_{wt}+D_{pond}}{138.62(K^{0.1})}CF_{size}$$

Where:

D_{wt} is the depth from the base of the infiltration facility to the water table in feet,

K is the initial saturated hydraulic conductivity in feet/day,

D_{pond} is one-quarter of the maximum depth of water in the facility in feet, and

CF_{size}, is the correction for pond size. The correction factor was developed for ponds with bottom areas between 0.6 and 6 acres in size. For small ponds (i.e. ponds with a bottom area less than 0.6 acres), the correction factor is equal to 1.0. For large ponds (i.e. ponds with a bottom area greater than 6 acres), the correction factor is 0.2.

$$CF_{size} = 0.73(A_{pond})^{-0.76}$$

Where:

A_{pond} is the area of pond bottom in acres.

This equation generally will result in a calculated steady state hydraulic gradient of less than 1.0 for moderate to shallow groundwater depths (or to a low permeability layer) below the BMP, and conservatively accounts for the development of a groundwater mound. A more detailed groundwater mounding analysis using a program such as MODFLOW will usually result in a gradient that is equal to or greater than the gradient calculated using the equation above.

If the calculated steady state hydraulic gradient is greater than 1.0, the water table is considered to be deep, and a maximum gradient of 1.0 must be used. Typically, a depth to groundwater of 100 feet or more is required to obtain a gradient of 1.0 or more using this equation.

Since the gradient is a function of depth of water in the BMP, the gradient will vary as the pond fills during the season. The gradient could be calculated as part of the stage-discharge calculation used in continuous runoff modeling software. As of the date of this update, no Ecology approved continuous runoff models have that capability. However, updates to those models may incorporate the capability. Until that time, calculate the steady-state hydraulic gradient using the equation above assuming a ponded depth of ¼ of the maximum ponded depth – as measured from the pond floor to the overflow.

3. Determine the pond aspect ratio adjustment factor as follows:

$$CF_{aspect} = 0.02A_r + 0.98$$

Where:

A_r is the aspect ratio for the pond (length/width of the bottom area).

In no case shall CF_{aspect} be greater than 1.4.

4. Determine C_{FT}, as described above in The Simplified Approach to Calculating the Design Infiltration Rate of the Native Soils.

5. The design infiltration rate (K_{sat}design) is calculated by multiplying the initial K_{sat} by the steady state hydraulic gradient, the aspect ratio adjustment factor, and the total correction factor:

$$K_{sat}\text{ design} = K_{sat}\text{ initial} \times i \times CF_{aspect} \times CF_T$$

6.5.5 Site Characterization Criteria for Infiltration

One of the first steps in siting and designing infiltration BMPs is to conduct a characterization study that includes surface and subsurface features characterization, as described below.

Information gathered during initial geotechnical investigations can be used for the site characterization.

Surface Features Characterization

Review applicable geologic maps of the site area, to identify geologic conditions that could impact the feasibility of infiltration systems. This may include outcropping/shallow low-permeability bedrock, surficial low-permeability sediment, borrow pits, and/or shallow groundwater conditions.

Include a surface reconnaissance of surrounding properties, particularly in the anticipated downgradient groundwater flow direction, to assess potential impact of additional groundwater.

The characterization study should document the following surface features:

1. Topography within 500 feet of the proposed infiltration BMP.
2. Anticipated site use (street/highway, residential, commercial, high-use site).
3. Location of water supply wells within 500 feet of the proposed infiltration BMP.
4. Location of groundwater protection areas and/or 1, 5 and 10 year time of travel zones for municipal well protection areas (if available).
5. Location of areas known to have contaminated soils.
6. A description of local site geology, including soil or rock units likely to be encountered, the groundwater regime, and geologic history of the site.

Subsurface Characterization

The characterization study should document the following subsurface data:

1. Site explorations should consist of one exploratory test pit or boring per every 15,000 square feet (sf) of the infiltration area or 200 linear feet of roadway, but not less than three explorations. The explorations should be completed on the site and specifically in the planned infiltration area.

   Complete subsurface explorations (test holes or test pits) to a depth below the base of the infiltration BMP of at least 5 times the maximum design depth of ponded water proposed for the infiltration BMP, but not less than 10 feet below the base of the BMP. However, at sites with shallow groundwater (less than 15 feet from the estimated base of the infiltration BMP), if a groundwater mounding analysis is necessary, determine the thickness of the saturated zone.

   Deeper site exploration (up to 50 feet in depth) may be needed if subsurface information, such as existing water well or resource protection well logs, is not available.

   Continuous sampling (representative samples from each soil type and/or unit within the infiltration receptor) to a depth below the base of the infiltration BMP of 2.5 times the maximum design ponded water depth, but not less than 10 feet. For large infiltration BMPs serving drainage areas of 10 acres or more, perform soil grain size analyses on layers up to 50 feet deep (or no more than 10 feet below the water table). These samples provide information on the treatment capabilities of the soils.

   The depth and number of test holes or test pits, and samples should be increased, if in the judgment of a licensed engineer in the state of Washington (P.E.) with geotechnical expertise, a licensed geologist, engineering geologist, hydrogeologist, or other licensed professional acceptable to the local jurisdiction, the conditions are highly variable and such increases are necessary to accurately estimate the performance of the infiltration BMP.

Samples recovered from the site exploration work may be tested to assess gradational characteristics to help verify the soil classification for comparison with the mapped soil unit.

2. If proposing to estimate the infiltration rate using the soil grain size analysis method (see 6.5.4 Determining the Design Infiltration Rate of the Native Soils), obtain samples adequate for the purposes of that gradation/classification testing.

   - For BMP F6.21: Infiltration Ponds, at least one test pit or test hole per 5,000 ft^2 of BMP infiltrating surface (in no case less than two per BMP).

   - For BMP F6.22: Infiltration Trenches, at least one test pit or test hole per 200 feet of trench length (in no case less than two per trench).

   The depth and number of test holes or test pits, and samples should be increased, if in the judgment of a licensed engineer in the state of Washington (P.E.) with geotechnical expertise, a licensed geologist, engineering geologist, hydrogeologist, or other licensed professional acceptable to the local jurisdiction, the conditions are highly variable and such increases are necessary to accurately estimate the performance of the infiltration BMP.

   The exploration program may be decreased if, in the opinion of the licensed engineer in the state of Washington or other professional, the conditions are relatively uniform and the borings/test pits omitted will not influence the design or successful operation of the BMP.

   In high water table sites, the subsurface exploration sampling need not be conducted lower than two (2) feet below the groundwater table.

3. Prepare detailed logs for each test pit or test hole and a map showing the location of the test pits or test holes. Logs must include at a minimum, depth of pit or hole, soil descriptions, depth to water, presence of stratification.

   Logs must substantiate whether stratification does or does not exist. The licensed professional may consider additional methods of analysis to substantiate the presence of stratification that will significantly impact the design of the infiltration BMP.

4. Provide groundwater monitoring wells (or driven well points if there is shallow depth to groundwater) to locate the groundwater table and establish its gradient, direction of flow, and seasonal variations, considering both confined and unconfined aquifers. For infiltration BMPs with a contributing basin that is less than an acre, establish that the depth to groundwater or other hydraulic restriction layer will be at least 10 feet below the base of the BMP. Use subsurface explorations or information from nearby wells.

   In general, a minimum of three wells per infiltration BMP, or three hydraulically connected surface or groundwater features, are needed to determine the direction of flow and gradient. If in the assessment of the site professional, the surrounding site conditions indicate that gradient and flow direction are not critical (e.g., there is low risk of down-gradient impacts) one monitoring well may be sufficient. Alternative means of establishing the groundwater levels may also be considered. If the groundwater in the area is known to be greater than 50 feet below the proposed infiltration BMP, detailed investigation of the groundwater regime is not necessary.

Monitoring through at least one wet season is required, unless substantially equivalent site historical data regarding groundwater levels is available.

5. If using the soil Grain Size Analysis Method for estimating infiltration rates: Complete laboratory testing as necessary to establish the soil gradation characteristics and other properties, to complete the infiltration facility design. At a minimum, conduct one-grain size analysis per soil stratum in each test hole within 2.5 times the maximum design water depth, but not less than 10 feet. When assessing the hydraulic conductivity characteristics of the site, soil layers at greater depths must be considered if the licensed professional conducting the investigation determines that deeper layers will influence the rate of infiltration for the BMP, requiring soil gradation/classification testing for layers deeper than indicated above.

Soil Testing Data

Perform laboratory testing to determine Unified Soil Classification Group Symbol and Group Name of the site soils (e.g., ASTM C136/D442; ASTM C117/D1140; and ASTM D4318).

Soil characterization for each soil unit (soils of the same texture, color, density, compaction, consolidation and permeability) encountered should include:

- Grain-size distribution (ASTM D422 or equivalent AASHTO specification), if using the grain size analysis method to estimate infiltration rates
- Visual grain size classification
- Percent clay content (include type of clay, if known)
- Color/mottling
- Variations and nature of stratification

If the infiltration BMP will provide Runoff Treatment as well as Flow Control, the soil characterization should also include:

- Cation exchange capacity (CEC) and organic matter content for each soil type and strata where distinct changes in soil properties occur, to a depth below the base of the BMP of at least 2.5 times the maximum design water depth, but not less than 6 feet.
- For soils with low CEC and organic content, deeper characterization of soils may be warranted (refer to 6.5.6 Site Suitability Criteria (SSC)).

Infiltration Receptor Data

Infiltration receptor (unsaturated and saturated soil receiving the stormwater) characterization should include:

1. The information obtained from groundwater monitoring in #4 of the Subsurface Characterization above.
2. An assessment of the ambient groundwater quality, if that is a concern.
3. An estimate of the volumetric water holding capacity of the vadose zone. This is the soil layer below the infiltration BMP and above the seasonal high-water mark, bedrock, hardpan, or other low permeability layer. Conduct this analysis at a conservatively high infiltration rate based on vadose zone porosity, and the Water Quality Design Volume to be infiltrated. This, along with an analysis of groundwater movement, will be useful in determining if there are volumetric limitations that would adversely affect drawdown, and if a groundwater mounding analysis should be conducted.
4. Determination of:
    - Depth to groundwater table and to bedrock/impermeable layers.
    - Seasonal variation of groundwater table based on well water levels and observed mottling.
    - Existing groundwater flow direction and gradient.
    - Lateral extent of infiltration receptor.
    - Horizontal hydraulic conductivity of the saturated zone to assess the aquifer’s ability to laterally transport the infiltrated water.
    - Impact of the infiltration rate and volume at the BMP site on groundwater mounding, flow direction, and water table; and the discharge point or area of the infiltrating water. Conduct a groundwater mounding analysis at all sites where the depth to seasonal groundwater table or low permeability stratum is less than 15 feet from the estimated bottom elevation of the infiltration BMP, and the contributing basin to the infiltration BMP is more than one acre.

Summary Report

Provide a summary report, describing the results of the work. Include a vicinity map, an exploration site plan, and laboratory test results. Include information regarding the depth to groundwater and the presence of any limiting layers which may control groundwater flow. Consider feasibility and limitations for infiltration. Include information on how the field permeability testing was performed and the assumptions made for determining the recommended infiltration rate. The report shall be prepared by or under the direction of a licensed engineer, geologist, or hydrogeologist in the state of Washington with geotechnical expertise and appropriately signed and sealed.

6.5.6 Site Suitability Criteria (SSC)

This section specifies the Site Suitability Criteria (SSC) that must be considered for siting infiltration BMPs. When a site investigation reveals that any of the applicable SSC cannot be met, appropriate mitigation measures must be implemented so that the infiltration BMP will not pose a threat to safety, health, or the environment.

For site selection and design decisions, a geotechnical and hydrogeologic report should be prepared by a licensed engineer in the state of Washington with geotechnical and hydrogeologic experience, or a licensed geologist, hydrogeologist, or engineering geologist. The designer may utilize a team of certified or registered professionals in soil science, hydrogeology, geology, and other related fields.

SSC-1 Setback Criteria

Setback requirements are generally required by local regulations, Uniform Building Code requirements, or other state regulations.

The following list contains examples of setback requirements that may be required by the entities listed above:

- Infiltration BMPs should be set back at least 100 feet from drinking water wells, septic tanks or drainfields, and springs used for public drinking water supplies.

  Infiltration BMPs upgradient of drinking water supplies and within 1, 5, and 10-year time of travel zones of a public drinking water well must comply with Health Department requirements (DOH, 2010) and local ordinances.

  To locate wellhead protection areas and the associated water purveyors in each county, see the Washington State Department of Health Source Water Assessment Program maps at the following website:

  https://fortress.wa.gov/doh/eh/dw/swap/maps/

  Information related to sole source aquifers and critical aquifer recharge areas, including requirements, is managed by the local jurisdiction.

- Infiltration BMPs that qualify as Underground Injection Control Wells must comply with the setback requirements within Chapter 173-218 WAC and the guidance in Chapter 5 - UIC Program Guidelines.
- Additional setbacks must be considered if roadway deicers or herbicides are likely to be present in the influent to the infiltration BMP.
- From building foundations: ≥ 20 feet downslope and ≥ 100 feet upslope
- From a Native Growth Protection Easement (NGPE): ≥ 20 feet
- From the top of slopes >15%: ≥ 50 feet.
- Evaluate on-site and off-site structural stability due to extended subgrade saturation and/or head loading of the permeable layer, including the potential impacts to downgradient properties, especially on hills with known side-hill seeps.
- Infiltration BMPs should be located outside the sanitary control area of public drinking water systems and > 100 feet from drinking water wells, septic tanks, and drain fields.

SSC-2 Groundwater Protection Areas

A site is not suitable for an infiltration BMP if the infiltrated stormwater will cause a violation of Ecology's Groundwater Quality Standards (Chapter 173-200 WAC). Local jurisdiction staff and local ordinances should be consulted for applicable pretreatment requirements if the project site is located in an aquifer sensitive area, sole source aquifer, wellhead protection area, or critical aquifer recharge area.

SSC-3 High Vehicle Traffic Areas

An infiltration BMP may be considered for runoff from high vehicle traffic areas, including areas that require an oil control BMP per 6.1.2 Choosing Your Runoff Treatment BMPs. For such applications, provide the oil control BMP upstream of the infiltration BMP to ensure that groundwater quality standards will not be violated and that the infiltration BMP is not adversely affected.

SSC-4 Soil Infiltration Rate/Drawdown Time

Infiltration Rates: measured (initial) and design (long-term)

For infiltration BMPs used for Runoff Treatment purposes, the measured (initial) soil infiltration rate should be 9 in/hr or less (For BMP F6.24: Permeable Pavement, this rate can be 12 in/hr or less). Design (long-term) infiltration rates up to 3 in/hr can also be considered, if the infiltration receptor is not a sole-source aquifer, and in the judgment of the licensed professional, the treatment soil has characteristics comparable to those specified in SSC-6 Soil Physical and Chemical Suitability for Treatment to adequately control the target pollutants. Project sites with infiltration rates lower than those identified in the infeasibility criteria may be used for infiltration of stormwater, if the local jurisdiction approves the design.

The design infiltration rate should also be used for maximum drawdown time and routing calculations.

Drawdown Time

Document that the maximum ponded depth from the infiltration BMP can infiltrate through the infiltration BMP surface within 72 hours. This can be calculated by multiplying the horizontal projection of the infiltration BMP mid-depth dimensions by the estimated design infiltration rate, and multiplying the result by 72 hours.

This drawdown restriction is intended to meet the following objectives:

- Restore hydraulic capacity to receive runoff from the next storm.
- Maintain infiltration rates.
- Aerate vegetation and soil to keep the vegetation healthy.
- Prevent anoxic conditions in treatment soils.
- Enhance the biodegradation of pollutants and organics in the soil.

Note: This is a check procedure, not a method for determining infiltration BMP size. If the design fails the check procedure, redesign the infiltration BMP.

SSC-5 Depth to Bedrock, Water Table, or Impermeable Layer

The base of BMP F6.21: Infiltration Ponds or BMP F6.22: Infiltration Trenches shall be ≥ 5 feet above the seasonal high-water mark, bedrock (or hardpan) or other low permeability layer. A separation down to 3 feet may be considered if the groundwater mounding analysis, volumetric holding capacity, and the design of the overflow and/or bypass structures are judged by the licensed professional to be adequate to prevent overtopping and to meet the other SSC specified in this section.

SSC-6 Soil Physical and Chemical Suitability for Treatment

This SSC applies to infiltration BMPs that intend to use the native soil to provide Runoff Treatment. If the native soils do not meet the criteria below, Runoff Treatment must be provided prior to infiltration either by a layer within the infiltration BMP (such as is the case for BMP F6.23: Bioretention), a Runoff Treatment BMP upstream of the infiltration BMP, or by a layer of engineered soil that meets the criteria below. Refer to 6.5.3 General Design Criteria for Infiltration BMPs for guidance to determine the appropriate level of Runoff Treatment, based on land use and project type, that is necessary to precede the infiltration BMP.

Consider the soil texture and design infiltration rates along with the physical and chemical characteristics specified below to determine if the soil is adequate for removing the target pollutants. Perform the analysis of the soils below the bottom of the proposed infiltration BMP, regardless of the depth of the BMP. If an applicant proposes to use a deep UIC well, the soils analysis should show the adequacy of the deep soils. The following soil properties must be carefully considered in making such a determination:

- Cation exchange capacity (CEC) of the treatment soil must be ≥ 5 milliequivalents CEC/100 g dry soil (USEPA, 1986). Consider empirical testing of soil sorption capacity, if practicable. Ensure that soil CEC is sufficient for expected pollutant loadings, particularly heavy metals. CEC values of > 5 meq/100g are expected in loamy sands (Buckman and Brady, 1969). Lower CEC content may be considered if it is based on a soil loading capacity determination for the target pollutants that is accepted by the local jurisdiction.

- Depth of soil used for infiltration Runoff Treatment must be a minimum of 18 inches, excepted as noted below.

  Note: Depth of soil used for infiltration Runoff Treatment below BMP F6.24: Permeable Pavement that is a pollution-generating hard surface may be reduced to one foot if the permeable pavement does not accept run-on from any other surfaces.

- Organic Content of the treatment soil (ASTM D 2974): Organic matter can increase the sorptive capacity of the soil for some pollutants. A minimum of 1% organic content is necessary.

- Waste fill materials shall not be used as infiltration soil media, nor shall such media be placed over uncontrolled or non-engineered fill soils.

Engineered soils may be used to meet these design criteria. Field performance evaluation(s), using protocols cited in this manual, would be needed to determine feasibility and acceptability by the local jurisdiction.

Local jurisdictions may establish preapproved soil types for treatment suitability. Check locally for specific allowances and requirements.

SSC-7 Seepage Analysis and Control

Determine whether there would be any adverse effects caused by seepage zones on nearby building foundations, basements, roads, parking lots or sloping sites.

SSC-8 Cold Climate and Impact of Roadway Deicing Chemicals

Consider the potential impact of roadway deicing chemicals dissolved within infiltrated stormwater on potable water wells in the siting determination. Implement mitigation measures if the infiltration of roadway deicing chemicals could cause a violation of groundwater quality standards.

SSC-9 Previously Contaminated Soils or Unstable Soils

Infiltration of stormwater is not recommended on or upgradient of contaminated sites where infiltration of even clean water can cause contaminants to mobilize. If the site is known or suspected to contain contaminated soils, the design professional should investigate whether the soil under the proposed infiltration BMP contains contaminants that could be transported by infiltrated water from the BMP. If so, measures should be taken for remediation of the site prior to construction of the BMP, or an alternative location should be chosen. The design professional should also determine if the site history, regional geology or local geology indicates that the soil beneath the proposed infiltration BMP could be unstable, due to improper placement of fill, subsurface geologic features, etc. If so, further investigation and planning should be undertaken prior to siting of the BMP.

6.5.7 Screening Criteria for Infiltration BMPs

The following screening criteria describe conditions that make infiltration BMPs infeasible or inefficient. If a project triggers any of the below-listed screening criteria, yet the project proponent wishes to use infiltration BMPs, they may propose a functional design that effectively mitigates these issues to the local jurisdiction. These screening criteria should be evaluated based on site-specific conditions by a licensed professional.

Note: For bioretention, criteria with setback distances are as measured from the bottom edge of the bioretention soil mix.

- Where professional geotechnical evaluation recommends infiltration not be used due to reasonable concerns about erosion, slope failure, or downgradient flooding.
- Within an area where groundwater drains into an erosion hazard, or landslide hazard area.
- Where the only area available for siting would threaten the safety or reliability of preexisting underground utilities, preexisting underground storage tanks, preexisting structures, or preexisting road or parking lot surfaces.
- Where the only area available for siting does not allow for a safe overflow pathway.

- Where there is a lack of usable space for infiltration BMPs at redevelopment sites, or where there is insufficient space within the existing public right-of-way on public road projects.
- Where infiltrating water would threaten existing below grade basements.
- Where infiltrating water would threaten shoreline structures (such as bulkheads).
- Where treatment soils containing compost amendments for treatment prior to infiltration would exacerbate phosphorus loading to phosphorus-sensitive receiving waters.
- Within setbacks from structures as established by the local jurisdiction.
- Where they are not compatible with the surrounding drainage system as determined by the local jurisdiction (e.g. project drains to an existing drainage system where the elevation or location precludes connection to a properly functioning bioretention BMP).
- Where land for infiltration BMPs is within area designated as an erosion hazard, or landslide hazard.
- Within 50 feet from the top of slopes that are greater than 20% and greater than 10 feet of vertical relief.
- For properties with known soil or groundwater contamination (typically federal Superfund sites or state cleanup sites under the Model Toxics Control Act (MTCA):
    - Within 100 feet of an area known to have deep soil contamination
    - Where groundwater analysis indicates infiltration will likely increase or change the direction of the migration of pollutants in the groundwater
    - Wherever surface soils have been found to be contaminated unless those soils are removed within 10 horizontal feet from the infiltration area
    - Any area where these BMPs are prohibited by an approved cleanup plan under the state MTCA or federal Superfund Law, or an environmental covenant under Chapter 64.70 RCW
- Within 100 feet of a closed or active landfill.
- Within 100 feet of a drinking water well, within the sanitary control area of a public drinking water well, within 200 feet of a spring used for drinking water supply, or within a wellhead protection area.
- Within 10 feet of a small on-site sewage disposal drain field, including reserve areas, and grey water reuse systems. For setbacks from a “large on-site sewage disposal system”, see Chapter 246-272B WAC.
- Within 10 feet of an underground storage tank and connecting underground pipes when the capacity of the tank and pipe system is 1,100 gallons or less. As used in these criteria, an underground storage tank means any tank used to store petroleum products, chemicals, or liquid hazardous wastes of which 10% or more of the storage volume [including volume in the connecting piping system] is beneath the ground surface.

- Within 100 feet of an underground storage tank and connecting underground pipes when the capacity of the tank and pipe system is greater than 1,100 gallons.

BMP T5.21: Infiltration Swales

Purpose and Definition

Infiltration swales are vegetated or rock-lined conveyances designed for removal of stormwater pollutants by percolation into the ground.

Vegetated infiltration swales, also known as grassed percolation areas, combine grasses (or other vegetation) and soils to remove stormwater pollutants by percolation into the ground. Their pollutant removal mechanisms include filtration, soil sorption, and uptake by vegetated root zones.

Rock-lined infiltration swales require the native soils (or an engineered soil layer) beneath the swale surface to meet the requirements for Runoff Treatment per 6.5.6 Site Suitability Criteria (SSC). Pollutant removal is provided by the native or engineered soil layer.

In general, infiltration swales are used for treating stormwater runoff from roofs, roads, and parking lots. For Flow Control, flows greater than the Water Quality Design Flow Rate are typically overflowed to the subsurface through an appropriate conveyance BMP such as BMP F6.20: Drywells, or to surface water through an overflow channel.

Note that the Underground Injection Control (UIC) regulations do not apply to infiltration swales; however, the UIC regulations do apply to any drywell (or other BMP considered a UIC well) used in connection with the infiltration swale (see Chapter 5 - UIC Program Guidelines).

General Design Criteria

- Use the same sizing guidance, off-line and online guidance, and design procedures as in 6.5.3 General Design Criteria for Infiltration BMPs.
- The maximum drawdown time for the flooded depth should be within 72 hours after cessation of flow.
- A concrete or riprap apron shall be provided at the curb opening to prevent vegetation from blocking the inlet.
- Unless check dams are used, the swale bottom should be relatively flat with a longitudinal slope less than 1%.
- Slopes greater than 2.5% need check dams (riprap) at vertical drops of 12 to 15 inches.
- The maximum flood depth of the swale should be 6 inches, prior to overflow to a drywell or other infiltrative or overflow BMP.
- The volume contained by the swale must be sufficient for the water quality volume to be treated prior to overflow or infiltration.
- Treatment soils:

- For vegetated infiltration swales, the treatment soils (i.e. the native soils or an engineered soil layer) beneath the swale surface must meet the requirements for Runoff Treatment per 6.5.6 Site Suitability Criteria (SSC), with the following exception:
    - The treatment soil depth must be 6 inches or greater.
- For rock-lined infiltration swales, the treatment soils (i.e. the native soils or an engineered soil layer) beneath the swale surface must meet the requirements for Runoff Treatment per 6.5.6 Site Suitability Criteria (SSC).

- Surface layer:
  - For vegetated infiltration swales, native grasses, adapted grasses, or other vegetation with significant root mass should be used per Appendix 6-B: Planting Recommendations. Grasses should be drought tolerant or irrigation should be provided.
  - For rock-lined infiltration swales, select appropriate rock, such as large 3- or 5-inch river rock or crushed basalt, to facilitate maintenance and help with dust and erosion control.

- Presumed level of Runoff Treatment:
  - For vegetated infiltration swales:
    - If the treatment soil depth is less than 18 inches, the vegetated infiltration swale is presumed to meet the Basic Treatment BMP Performance Goal.
    - If the treatment soil depth is 18 inches or greater (per the requirements for Runoff Treatment per 6.5.6 Site Suitability Criteria (SSC)), the vegetated infiltration swale is presumed to meet the Basic, Metals, and Phosphorus BMP Performance Goals.
  - For rock-lined infiltration swales:
    - Per the treatment soil guidance above, the treatment soils beneath the rock-lined swale surface must meet the requirements for Runoff Treatment per 6.5.6 Site Suitability Criteria (SSC). So long as the guidance herein is followed, the rock-lined infiltration swale is presumed to meet the Basic, Metals, and Phosphorus BMP Performance Goals.

  These presumptions are based on the entire Water Quality Design Volume filtering through the treatment soils. See 6.1.5 Sizing Your Runoff Treatment BMPs for more information on the Water Quality Design Volume, and 6.1.2 Choosing Your Runoff Treatment BMPs for more information on the Runoff Treatment Performance Goals.

- For vegetated infiltration swales in areas with arid or semiarid climates, xeriscape landscaping is strongly encouraged to reduce the need for irrigation and better fit the surrounding site context. See Appendix 6-B: Planting Recommendations for additional information on selecting and installing xeriscape and other plantings.

- Pretreatment may be used to prevent the clogging of the treatment soil, vegetation, and/or rock lining by debris, total suspended solids (TSS), and oil and grease.

Identify pollutants, particularly in industrial and commercial area runoff, that could cause a violation of Washington State Department of Ecology's groundwater quality standards (Chapter 173-200 WAC). Include appropriate mitigation measures (pretreatment, source control, etc.) for those pollutants.

Sizing Procedure

There are three different design methods to size infiltration swales. Details for each method are described below.

Method 1 – Prescribed Volume Based on Rainfall and Design Infiltration Rate

This method prescribes a set runoff volume to be used in calculating the treatment volume of the infiltration swale, based on the 2-year 24-hour precipitation at the site and the design infiltration rate. Table 6.23: Infiltration Swale Sizing Table for Design Infiltration Rates in the Range of 0.15 to 0.40 Inches/Hour (continued) and Table 6.24: Infiltration Swale Sizing Table for Design Infiltration Rates in the Range of 0.41 to 1.00 Inches/Hour illustrate the amount of runoff from 1,000 square feet (sf) of contributing area for various regions of eastern Washington for design infiltration rates of 0.15 to 0.40 in/hr and 0.41 to 1.00 in/hr, respectively. The appropriate value for the site may be used to calculate the required volume of the infiltration swale as follows:

Equation 6.6: Infiltration Swale Volume (Method 1)

$$V = A * R/1{,}000$$

where:

V = volume of the infiltration swale (cubic feet [cf])

A = area draining to infiltration swale (sf)

R = runoff volume ratio shown in the third column of Table 6.23: Infiltration Swale Sizing Table for Design Infiltration Rates in the Range of 0.15 to 0.40 Inches/Hour (continued) (for sites with design infiltration rates between 0.15 and 0.40 in/hr) or Table 6.24: Infiltration Swale Sizing Table for Design Infiltration Rates in the Range of 0.41 to 1.00 Inches/Hour (for sites with design infiltration rates between 0.41 and 1.00 in/hr)

Table 6.23: Infiltration Swale Sizing Table for Design Infiltration Rates in the Range of 0.15 to 0.40 Inches/Hour

2-Year 24-Hour Precipitation (inches)		Infiltration Swale Volume per 1,000 Square Feet of Area (R)	Examples of Applicable Sites
From	To		
0.60	0.80	29.2 cubic feet	Moses Lake
0.81	1.00	37.5 cubic feet	Yakima, Kennewick

Table 6.23: Infiltration Swale Sizing Table for Design Infiltration Rates in the Range of 0.15 to 0.40 Inches/Hour (continued)

2-Year 24-Hour Precipitation (inches)		Infiltration Swale Volume per 1,000 Square Feet of Area (R)	Examples of Applicable Sites
From	To		
1.01	1.20	45.8 cubic feet	Wenatchee, Walla Walla
1.21	1.40	55.8 cubic feet	Colfax, Colville
1.41	1.55	61.3 cubic feet	Lowlands Blue Mountains
1.56	> 1.56r	Method 3 required	Eastern and Cascade Mountains

Table 6.24: Infiltration Swale Sizing Table for Design Infiltration Rates in the Range of 0.41 to 1.00 Inches/Hour

2-Year 24-Hour Precip-itation (inches)		Infiltration Swale Volume per 1,000 Square Feet of Area (R)	Examples of Applicable Sites
From	To		
0.60	0.80	19.6 cubic feet	Moses Lake
0.81	1.00	25.4 cubic feet	Yakima, Kennewick
1.01	1.20	27.9 cubic feet	Wenatchee, Walla Walla
1.21	1.40	33.8 cubic feet	Colfax, Colville
1.41	1.55	36.7 cubic feet	Lowlands Blue Mountains
1.56	> 1.56	Method 3 required	Eastern and Cascade Mountains

Method 2 – First 0.5 Inches of Runoff

This method uses the first 0.5 inches of runoff from impervious surfaces to size the infiltration swale. This method is applicable only in Climate Regions 2 and 3.

Equation 6.7: Infiltration Swale Volume (Method 2)

$$V = (A * 0.5 \text{ inch}) / 12 \text{ inches per foot (in/ft)}$$

where:

V = Volume of the infiltration swale (cf)

A = Area needing treatment that drains to the infiltration swale (sf)

This method does not give credit for infiltration through the bottom of the swale.

The swale is sized to store the required runoff volume (using the design storm established by the local jurisdiction) generated by the contributing basin. The swale is sized using the entire swale depth, typically no deeper than 1 foot, in conjunction with a subsurface infiltration BMP such as a drywell.

Method 3 – Hydrologic Analysis

This method uses hydrologic models, such as SCS or Santa Barbara Urban Hydrograph (SBUH), to determine the quantity of runoff from the water quality design storm and then route the flow through the infiltration swale, assuming the long-term infiltration rate is used for the outflow calculations. This method is required in areas with > 1.56 inches of rainfall in the 2-year, 24-hour storm and is allowed in all other areas with the approval of the local jurisdiction.

For more information: See Chapter 4 - Hydrologic Analysis and Design for more information on hydrologic analysis methods.

BMP F6.20: Drywells

Purpose and Definition

Drywells are subsurface concrete structures, typically precast, that convey stormwater runoff into the soil matrix. They can be used as standalone structures, or as part of a larger drainage system (i.e. the overflow for a biofiltration swale).

Note that drywells meet the definition of an Underground Injection Control (UIC) well, and must meet the regulations per Chapter 5 - UIC Program Guidelines. Also note that per Chapter 2 - Core Elements for New Development and Redevelopment if there is overflow to the MS4, then the CoreElements apply and only the registration requirement of the UIC rule applies.

General Criteria

Figure 6.28: Typical Infiltration Drywell – City of East Wenatchee, Figure 6.29: Typical Infiltration Drywell – Spokane County, and Figure 6.27: Typical Infiltration Drywell – City of Kennewick show typical infiltration drywell systems.

These systems are designed as specified below. The following general requirements apply to design of drywells. Check with the local jurisdiction for outflow capacity or other local requirements:

- Drywell bottoms should be a minimum of 5 feet above seasonal high groundwater level or impermeable soil layers. Refer to 6.5.6 Site Suitability Criteria (SSC).
- Drywells are typically a minimum of 48 inches in diameter and approximately 5 to 10 feet deep, or more.
- Filter fabric (geotextile) may need to be placed on top of the drain rock and on trench or drywell sides prior to backfilling to prevent migration of fines into the drain rock, depending on local soil conditions and local jurisdiction requirements.

- Drywells should be no closer than 30 feet center to center or twice the depth, whichever is greater.
- Drywells should not be built on slopes greater than 25% (4H:1V).
- Drywells may not be placed on or above a landslide hazard area or slopes greater than 15% without evaluation by a licensed engineer in the state of Washington with geotechnical expertise or licensed geologist and jurisdiction approval.

Design Procedure

Refer to the guidance earlier in this chapter that is applicable to the design for all infiltration BMPs.

Operation and Maintenance Criteria

The structural life of a drywell is approximately 20 years, although hydraulic failure could potentially occur at any time. Drywell performance is dependent on proper installation, regularly scheduled maintenance, and contaminants reaching the drywell. The following schedule is recommended as a guide; actual schedule may need to be varied based on observed performance.

Table 6.25: Maintenance Criteria for Drywells

Maintenance Interval	Description of Maintenance to Be Performed
Every 3 months	Visually inspect
Every 6 months	Remove debris and sediment
Annually	Check for structural damage
Whichever Is More Frequent: Above Schedule or Below Observed Events:	
Following substantial (> 24-hour) rainfall event	If possible, observe drywells in operation during the rainfall event. Aim to identify and correct problem prior to failure.
Following intense but short-duration event	
Following snowmelt event	It is especially important to observe the drywells if the melt occurred concurrently with frozen ground conditions.

Maintenance Tasks

Visual Inspection

Ensure metal grate and drywell are free of debris and obstructions. Remove any debris from on top of or around drywell and grate. Remove grate and inspect drywell for debris and sediment buildup in the barrel. Debris needs to be removed immediately, if possible. Sediment needs to be cleaned out before depth reaches the lowest row of slots providing outflow from drywell barrel.

Anytime that standing water is noticed in a drywell > 24 hours after an event has ceased, a visual inspection is warranted. When standing water is observed, the inspector should be aware of any signs of illicit discharge. If any of the following are observed, in addition to the sod and topsoil being affected and requiring replacement, if it is evident that discharge was made directly into the drywell, the drywell and affected surrounding drain rock must be replaced as soon as possible: oil sheen, spilled paint, burned area due to battery acid, multicolored appearance of antifreeze, brown to black fuel oil, or any other materials that may be deemed deleterious to water quality. Sod, topsoil and drain rock removed must be handled and disposed of in a manner consistent with a hazardous material.

Remove Debris and Sediment

Remove any large debris that would interfere with the vactoring (suction removal) of the drywell. Sediment must be completely suctioned out of the drywell barrel. Care should be taken to note the depth of the sediment. If it appears that the sediment is increasing with depth at each inspection, this may be a sign that the swale is not functioning properly; stormwater may be ponding and spilling, carrying sediment laden stormwater into the drywell, rather than infiltrating at the design rate.

Check for Structural Damage

Inspect metal frame and grate, adjustment rings, mortar or any other visible parts of the drywell structure. The metal frame and grate should sit flush on the top ring. Any separation of ≥ 0.75 inches must be adjusted and repaired. The drywell should be replaced or repaired to design standards if it has settled > 2 inches or if standing water fails to drain out of the barrel slots. Adjustment rings should be free of cracks. Crack repair should adhere be performed when:

Location of Crack	Maximum Width of Crack
Top ring of drywell	0.25 inches
Drywell barrel	0.5 inches and longer than 3 feet
Drywell floor	0.5 inches and longer than 1 foot

Note: Any crack, regardless of location or width, in which sediment is observed, needs to be repaired as soon as possible. Cracks should be repaired with mortar similar to that used between the adjustment rings. Mortar or grout should be waterproof and of the nonshrink variety.

Figure 6.27: Typical Infiltration Drywell – City of Kennewick

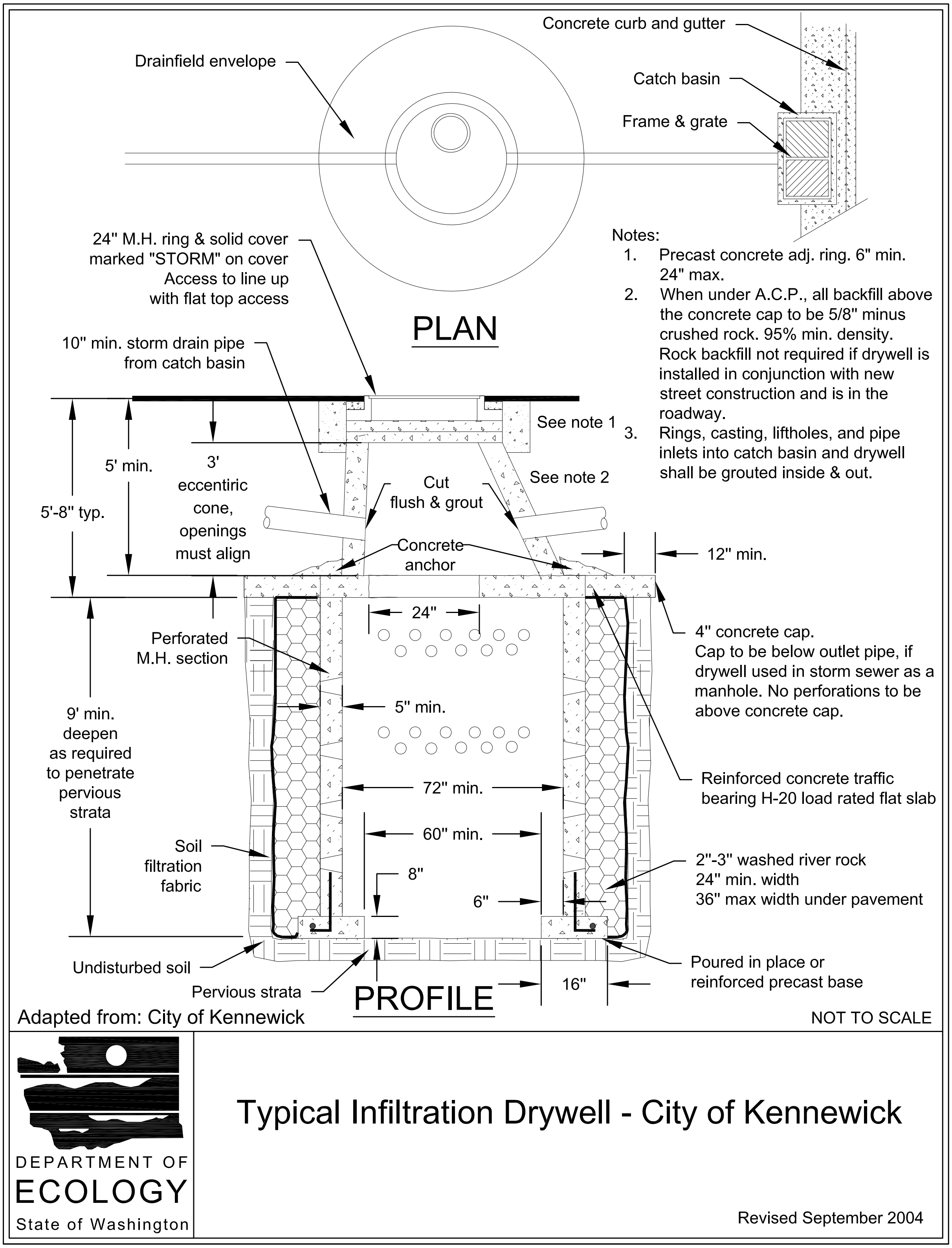
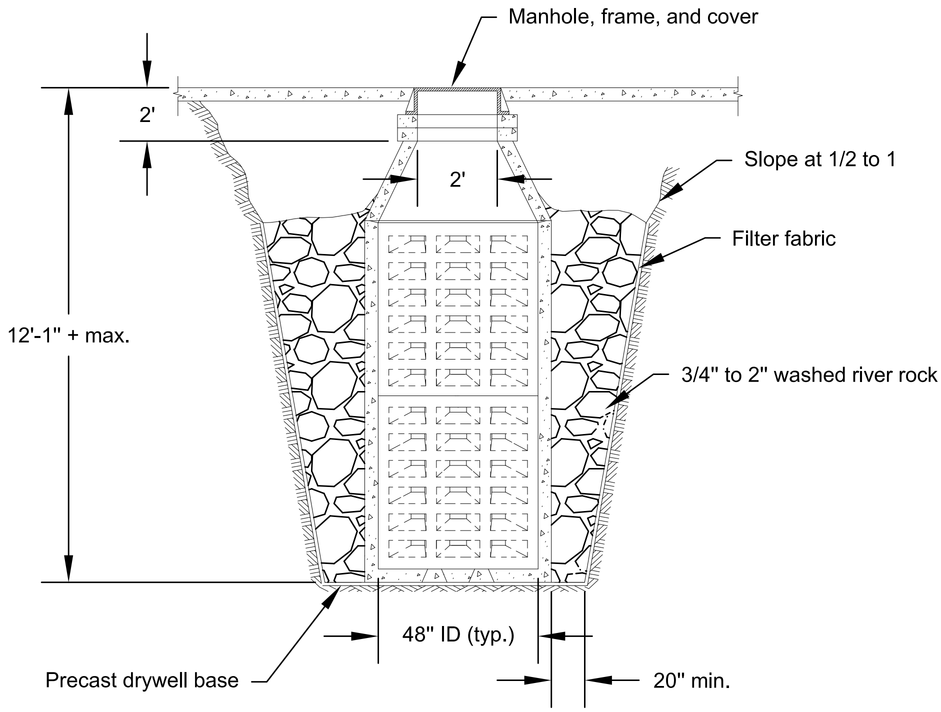


Figure 6.28: Typical Infiltration Drywell – City of East Wenatchee



Notes:

1. Backfill above filter fabric to base of asphalt with crushed surfacing base course.

2. Size and spacing of drywells determined by drainage analysis.

Adapted from: RH2 Engineering, Inc.

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Typical Infiltration Drywell - City of East Wenatchee

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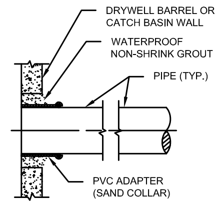
Figure 6.29: Typical Infiltration Drywell – Spokane County

GENERAL NOTES

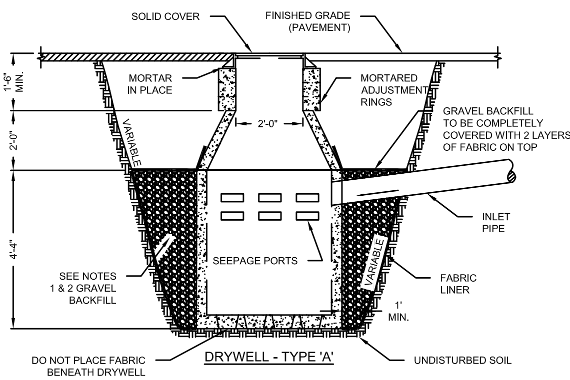
1. GRAVEL BACKFILL QUANTITY FOR DRYWELLS :
   TYPE "A" - 30 CUBIC YARDS MINIMUM / 42 TONS.
   TYPE "B" - 40 CUBIC YARDS MINIMUM / 56 TONS.
   OR AS SPECIFIED ON ROAD PLANS.
2. SPECIAL BACKFILL MATERIAL FOR DRYWELLS SHALL CONSIST OF WASHED GRAVEL GRADED FROM 1" TO 3" WITH A MAXIMUM OF 5% PASSING THE U.S. No. 200 SCREEN, AS MEASURED BY WEIGHT. A MAXIMUM OF 10% OF THE AGGREGATE, AS MEASURED BY WEIGHT, MAY BE CRUSHED OR FRACTURED ROCK. THE REMAINING 90% SHALL BE NATURALLY OCCURRING UN-FRACTURED MATERIAL.
3. FABRIC SHALL BE MODERATE SURVIVABILITY NON WOVEN AS OUTLINED IN STANDARD SPECIFICATIONS 9-33.
4. SEE STANDARD PLANS SHEETS B-2 AND B-3 FOR PRECAST CONCRETE DETAILS.
5. ADJUSTMENT BLOCKS SHALL BE CEMENT CONCRETE.
6. PRECAST RISER MAY BE USED IN COMBINATION WITH OR IN LIEU OF ADJUSTING BLOCKS.
7. WHEN PVC PIPE IS USED A PVC ADAPTER SHALL BE INSTALLED.
8. PIPES SHALL BE GROUTED INTO DRYWELLS WITH NON-SHRINK GROUT.
9. DRYWELLS LOCATED IN SWALES SHALL HAVE A RIM ELEVATION 0.5' ABOVE SWALE FLOOR. USE METAL FRAME TYPE 4 AND GRATE TYPE 4.



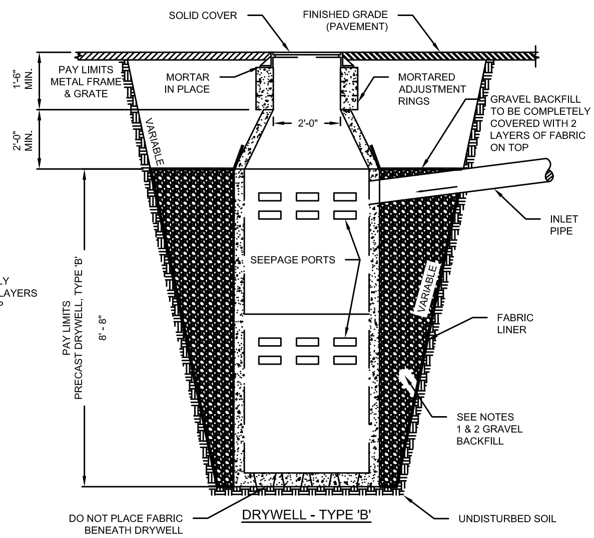
PVC ADAPTER
(SAND COLLAR)

NOTE

PVC PIPE ADAPTERS AND GASKET MAY VARY IN SHAPE AND SIZE AS ILLUSTRATED IN DETAIL BY ACCEPTABLE ALTERNATE IN ACCORDANCE WITH A.S.T.M.-C-428.



DRYWELL - TYPE 'A'



DRYWELL - TYPE 'B'

Source: Spokane County Public Works

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Typical Infiltration Drywell - Spokane County

Revised September 2004

BMP F6.21: Infiltration Ponds

Purpose and Definition

Infiltration ponds are earthen impoundments used for the collection, temporary storage and infiltration of incoming stormwater runoff.

Refer to the guidance earlier in this chapter for information pertinent to all infiltration BMPs. Guidance specific to infiltration ponds is provided below. Check with the local jurisdiction for outflow capacity and other local requirements.

Design Criteria

Infiltration Rate

See 6.5.4 Determining the Design Infiltration Rate of the Native Soils for design infiltration rates.

Access

Provide access for vehicles to easily maintain the forebay (presettling pond) area and minimize disturbance of vegetation or resuspension of sediment. See BMP F6.10: Detention Ponds for design criteria regarding access roads.

Ponding Depth

Size the infiltration pond for a maximum ponding depth of between 2 and 6 feet.

Freeboard

A minimum of 1 foot of freeboard is recommended. Freeboard is measured from the rim of the infiltration BMP to the maximum ponding level or from the rim down to the overflow point if overflow or a spillway is included.

Lining Material

Infiltration ponds can be open or covered with a 6 to 12-inch layer of filter material such as coarse sand, or a suitable filter fabric to help prevent the buildup of impervious deposits on the soil surface. Select a nonwoven geotextile that will function sufficiently without plugging (see 6.1.9.4 Geotextile Specifications). Replace or clean the filter layer when/if it becomes clogged.

Vegetation

Stabilize the embankment, emergency spillways, spoil and borrow areas, and other disturbed areas and plant, preferably with grass. Without healthy vegetation, the surface soil pores will quickly plug.

Seed mixtures should be appropriate for the climate.

Slope

The slope of the infiltration pond bottom should not exceed 3% in any direction.

Runoff Treatment

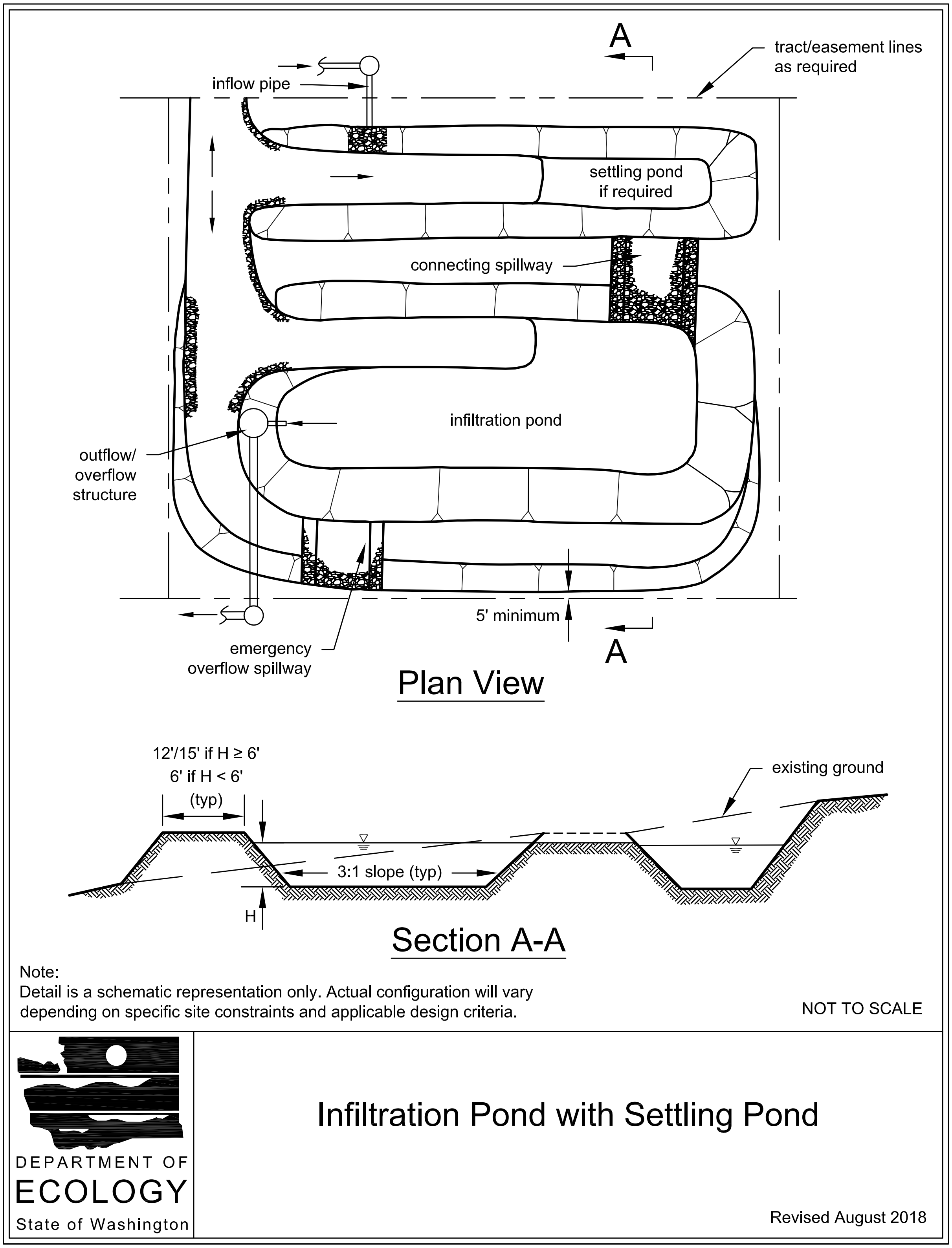
If this BMP is proposed to be used for Runoff Treatment, the design must show that the criteria for Runoff Treatment in 6.5.6 Site Suitability Criteria (SSC) are met.

Infiltration ponds that are providing Runoff Treatment must have sufficient vegetation established on the pond floor and side slopes to prevent erosion and sloughing and to provide additional pollutant removal. Provide erosion protection of inflow points to the pond (see 6.1.10.2 Flow Spreaders). Select suitable vegetative materials to stabilize the pond floor and side slopes.

Maintenance Criteria

- Maintain the infiltration pond floor and side slopes to promote dense turf with extensive root growth. This enhances infiltration, prevents erosion and consequent sedimentation of the basin floor, and prevents invasive weed growth. Immediately stabilize and revegetate bare spots.
- Do not allow vegetation growth to exceed 18 inches in height. Mow the slopes periodically and check for clogging and erosion.
- The use of slow-growing, stoloniferous grasses will permit long intervals between mowing. Mowing twice a year is generally satisfactory for cool season grasses; native warm season grasses should be mowed once every 3 years to stimulate growth.
- Apply fertilizers only as necessary and in limited amounts to avoid contributing to groundwater pollution. Consult the local jurisdiction and local agricultural or gardening resources such as Washington State University Extension for appropriate fertilizer type, including slow release fertilizers, and application rates.
- See additional maintenance recommendations for infiltration ponds in Appendix 6-A: BMP Maintenance Tables.

Figure 6.30: Infiltration Pond With Settling Pond



BMP F6.22: Infiltration Trenches

Infiltration trenches are generally at least 24 inches wide, and are backfilled with a coarse stone aggregate, allowing for temporary storage of stormwater runoff in the voids of the aggregate material. Stored runoff then gradually infiltrates into the surrounding soil. The surface of the trench can be covered with grating and/or consist of stone, gabion, sand, or a grassed or asphalt area with a surface inlet. Perforated rigid pipe of at least 8-inch diameter can also be used to distribute the stormwater in an infiltration trench.

Refer to the guidance earlier in this chapter for information pertinent to all infiltration BMPs. Guidance specific to infiltration trenches is provided below.

Design Criteria

Due to accessibility and maintenance limitations, carefully design and construct infiltration trenches. Contact the local jurisdiction for additional specifications.

Runoff Treatment

If this BMP is proposed to be used for Runoff Treatment, the design must show that the subgrade soils (or an engineered soil layer) meet the criteria for Runoff Treatment in 6.5.6 Site Suitability Criteria (SSC).

Catch basin and tee: A tee section should be provided in the nearest catch basin upstream of the infiltration trench if a catch basin is used. The tee will trap floatable debris and oils.

Infiltration Rate

See 6.5.4 Determining the Design Infiltration Rate of the Native Soils for design infiltration rates. Check with the local jurisdiction for outflow capacity requirements.

Backfill Material

The aggregate material for the infiltration trench should consist of a clean aggregate with a maximum diameter of 1.5 inches and a minimum diameter of 3/8 inches conforming to the Gravel Backfill for Drywells specification in the current version of the WSDOT Standard Specifications. For calculations assume a void space of 30% maximum.

Access Port

Consider including an access port or open or grated top for accessibility to conduct inspections and maintenance.

Geotextile

Geotextile fabric liner – Completely encase the aggregate fill material in an engineering geotextile material. In the case of an aggregate surface, geotextile should surround all of the aggregate fill material except for the top one-foot, which is placed over the geotextile. Carefully select geotextile fabric with acceptable properties to avoid plugging (see 6.1.9.4 Geotextile Specifications).

The bottom sand or geotextile fabric as shown in Figure 6.37: Observation Well Details is optional.

See *Geosynthetic Design and Construction Guidelines* (FHWA, 1998) for design guidance on geotextiles in drainage applications. See the *NCHRP Long-Term Performance of Geosynthetics in Drainage Applications* (NCHRP, 1994), for long-term performance data and background on the potential for geotextiles to clog, blind, or to allow piping to occur and how to design for these issues.

Overflow Channel

Because an infiltration trench is generally used for small drainage areas, an emergency spillway is not necessary. However, provide a non-erosive overflow channel leading to a stabilized watercourse.

Surface Cover

An infiltration trench can be placed under a pervious or impervious surface cover to conserve space.

Observation Well

Install an observation well at the lower end of the infiltration trench to check water levels, drawdown time, sediment accumulation, and conduct water quality monitoring. Figure 6.37: Observation Well Details illustrates observation well details. It should consist of a perforated PVC pipe that is 4 to 6 inches in diameter, and it should be constructed flush with the ground elevation. For larger trenches, a 12-36 inch diameter well can be installed to facilitate maintenance operations such as pumping out the sediment. Cap the top of the well to discourage vandalism and tampering.

Perforated Pipe

A minimum of 8-inch perforated pipe may be included to increase the storage capacity of the infiltration trench and to enhance conveyance of flows throughout the trench area.

Underground Injection Control (UIC) regulations apply to infiltration trenches when perforated pipe is used, unless the perforated pipe is included for the purpose of conveying overflows to surface.

- If the design, operation, and maintenance criteria in this section are met, only the registration requirement of the UIC regulations applies to the infiltration trench.
- Where perforated pipe is not used, the registration requirement does not apply.
- See Chapter 5 - UIC Program Guidelines for details.

Construction Criteria

Trench Preparation

Place excavated materials away from the trench sides to enhance trench wall stability. Take care to keep this material away from slopes, neighboring property, sidewalks, and streets. It is recommended that this material be temporarily covered with plastic. (See BMP C123: Plastic Covering).

Rock Aggregate Placement and Compaction

Place rock aggregate in lifts and compact using plate compactors. In general, a maximum loose lift thickness of 12 inches is recommended. The compaction process ensures geotextile conformity to the excavation sides, thereby reducing potential piping and geotextile clogging, and settlement problems.

Potential Contamination

Prevent natural or fill soils from intermixing with the rock aggregate. Remove all contaminated rock aggregate and replaced with uncontaminated rock aggregate.

Overlapping and Covering

Following the rock aggregate placement, fold the geotextile over the rock aggregate to form a 12 inch minimum longitudinal overlap. When overlaps are required between rolls, the upstream roll should overlap a minimum of 2 feet over the downstream roll in order to provide a shingled effect.

Voids Behind Geotextile

Voids between the geotextile and excavation sides must be avoided. Removing boulders or other obstacles from the trench walls is one source of such voids. Place natural soils in these voids at the most convenient time during construction to ensure geotextile conformity to the excavation sides. This remedial process will avoid soil piping, geotextile clogging, and possible surface subsidence.

Unstable Excavation Sites

Vertically excavated walls may be difficult to maintain in areas where the soil moisture is high or where soft or cohesionless soils predominate. Trapezoidal, rather than rectangular, cross-sections may be needed.

Maintenance Criteria

Monitor sediment buildup in the top foot of stone aggregate or the surface inlet on the same schedule as the observation well.

Figure 6.31: Swale/Trench Design

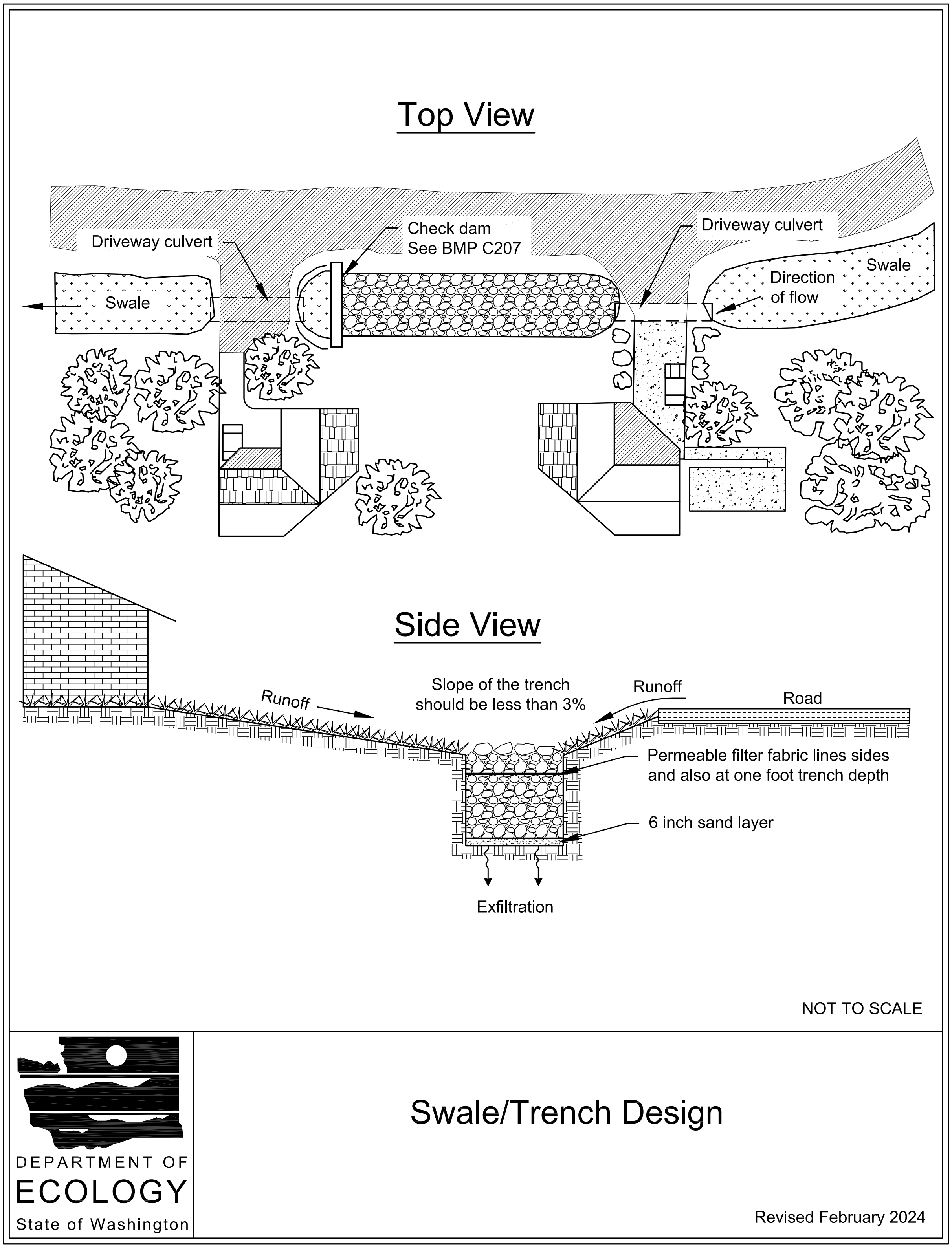
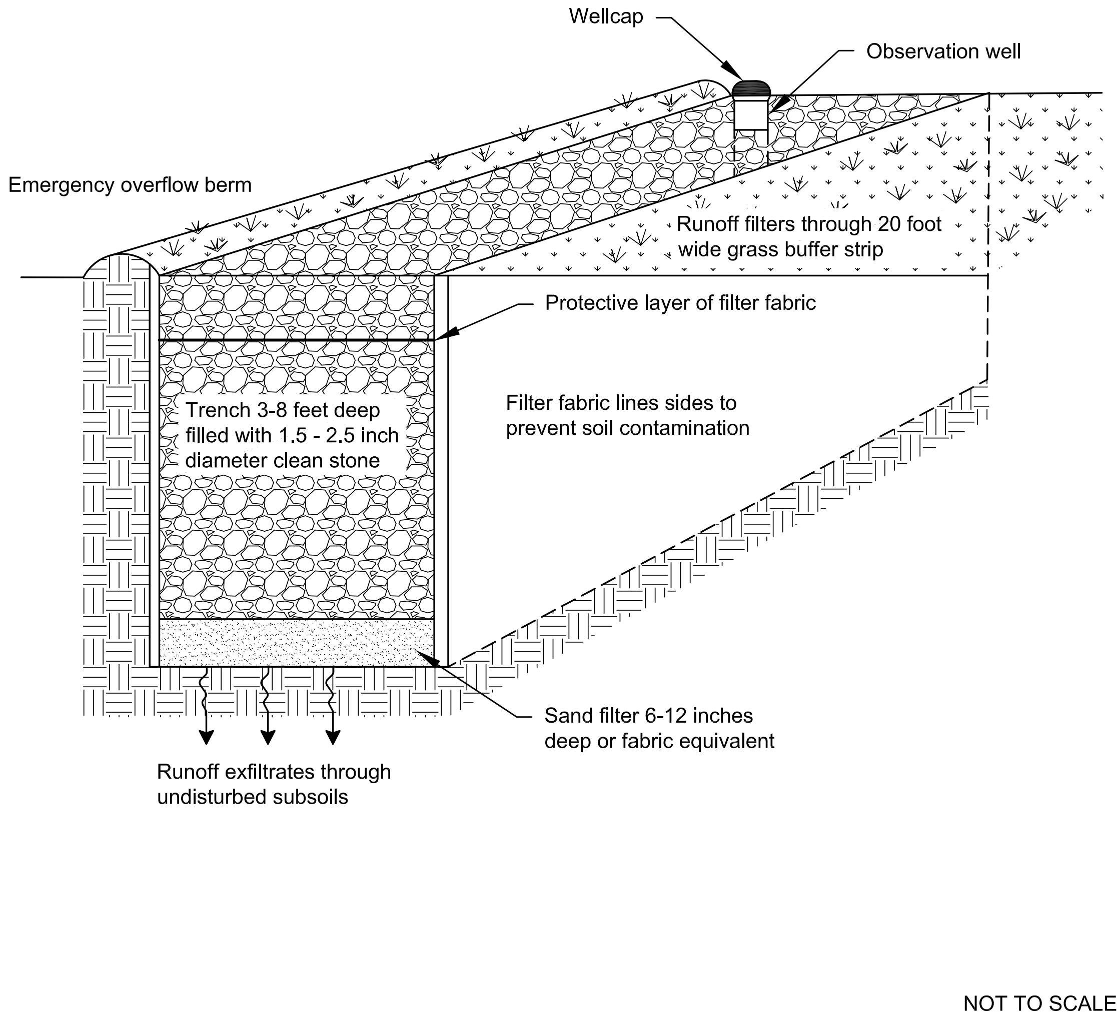


Figure 6.32: Schematic of an Infiltration Trench



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Schematic of an Infiltration Trench

Revised May 2019

Figure 6.33: Parking Lot Perimeter Trench Design

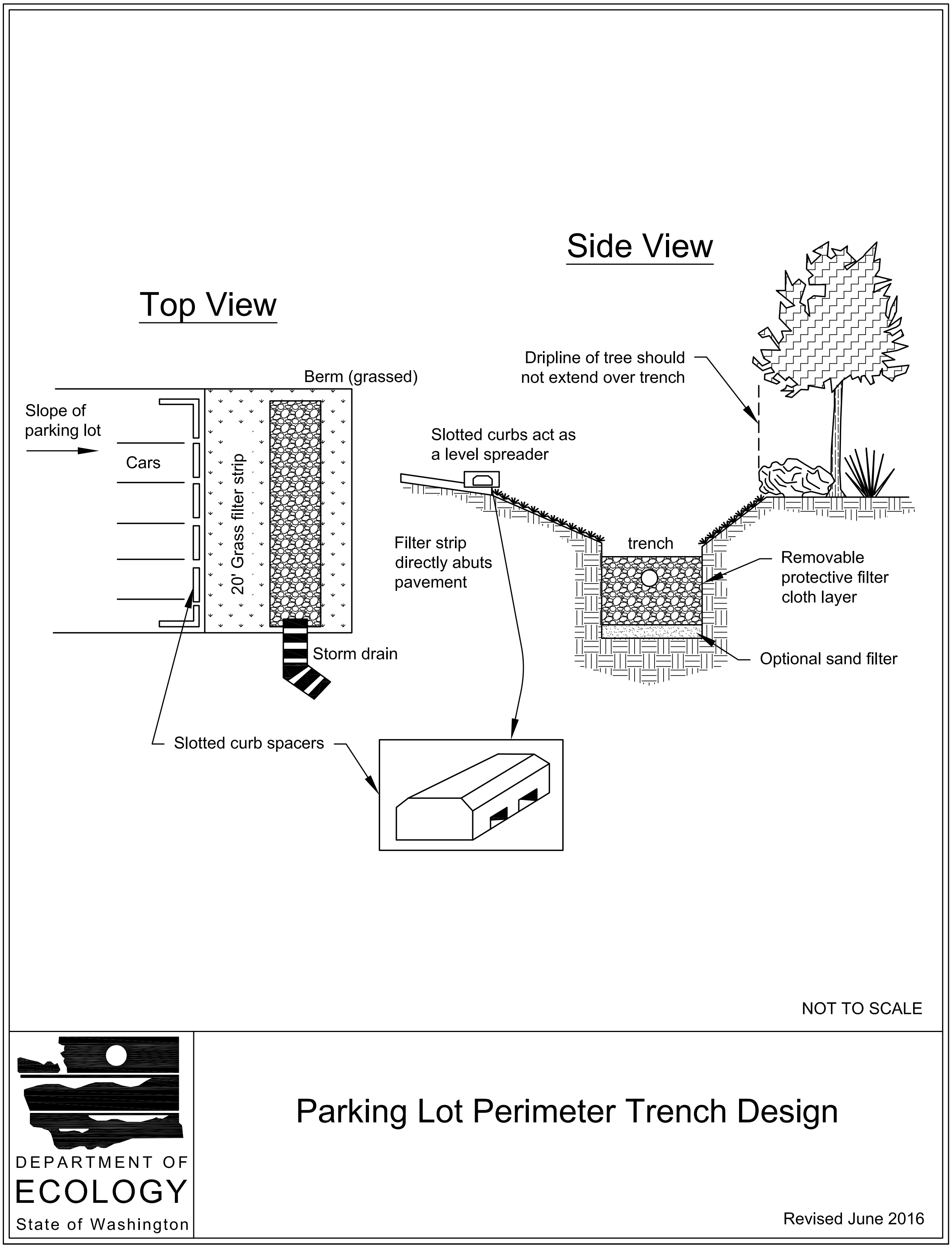


Figure 6.34: Median Strip Trench Design

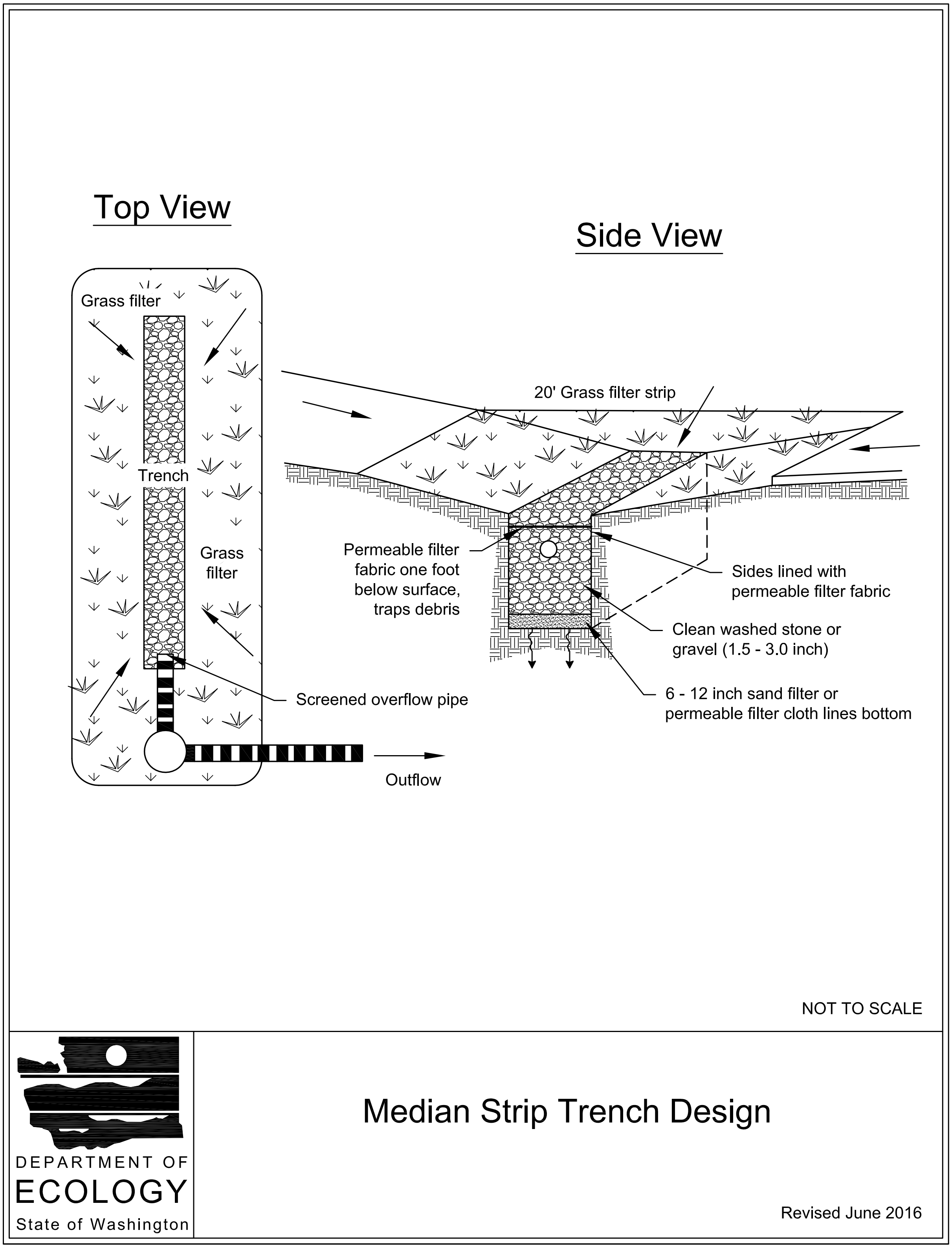


Figure 6.35: Oversized Pipe Trench Design

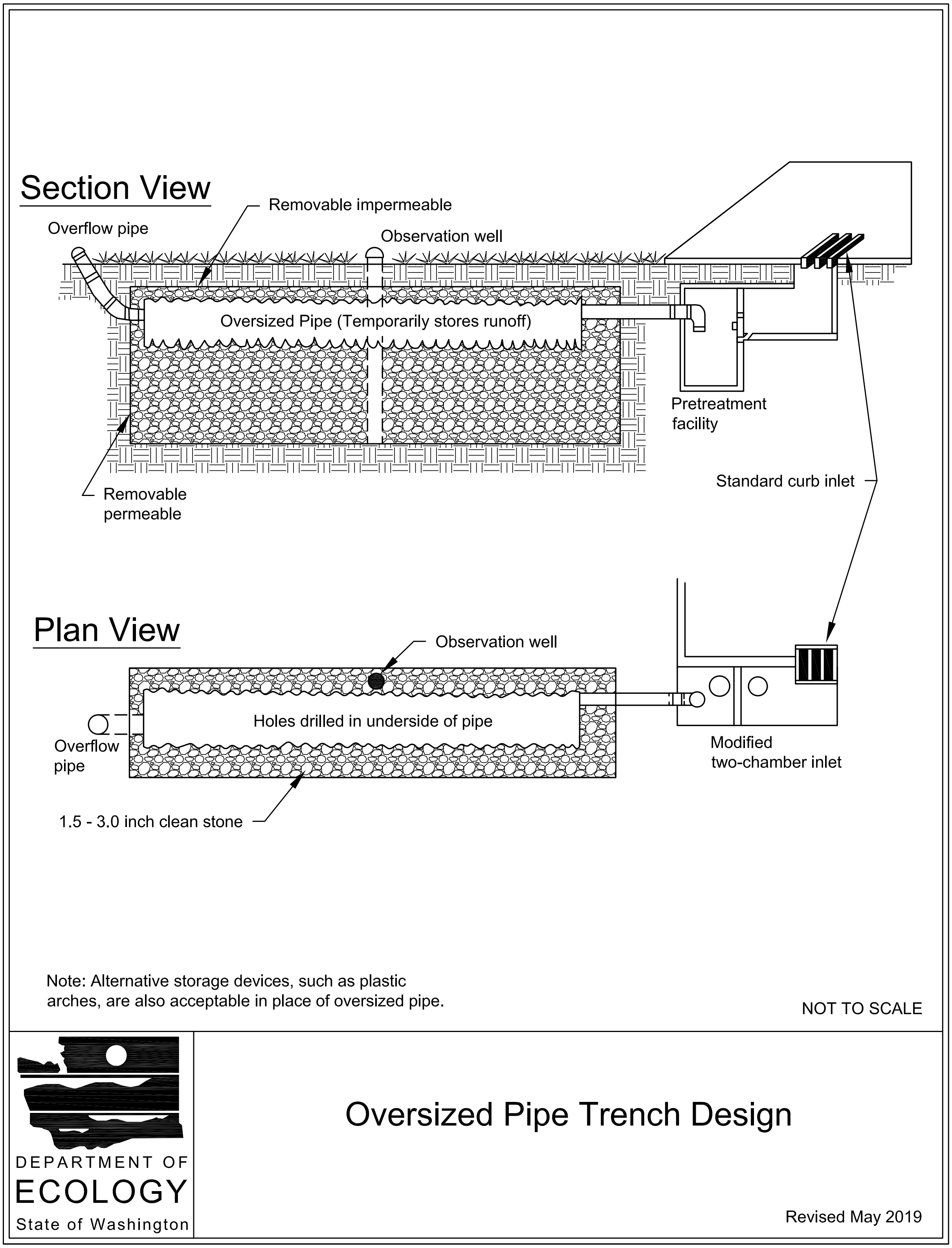


Figure 6.36: Underground Trench with Oil/Grit Chamber

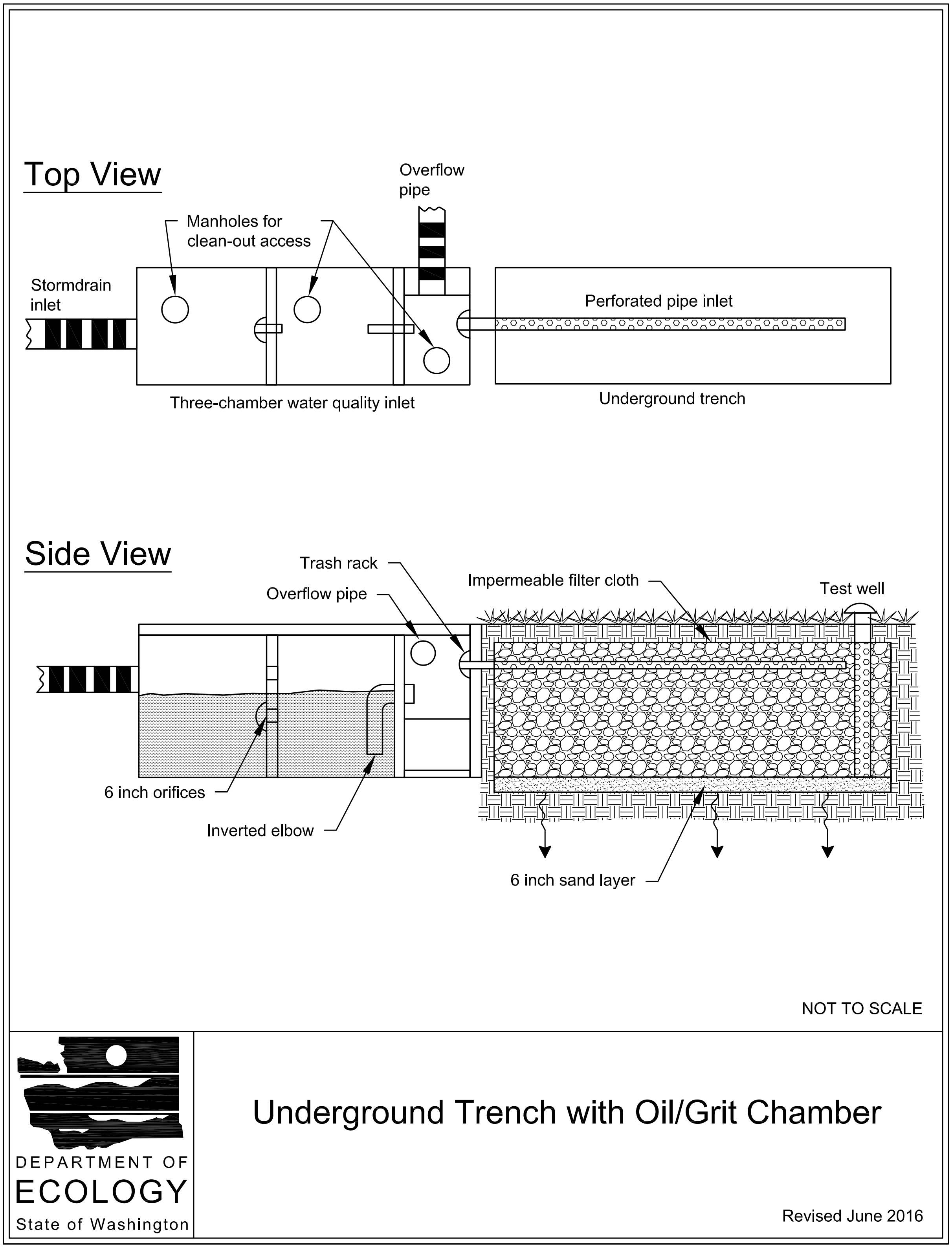
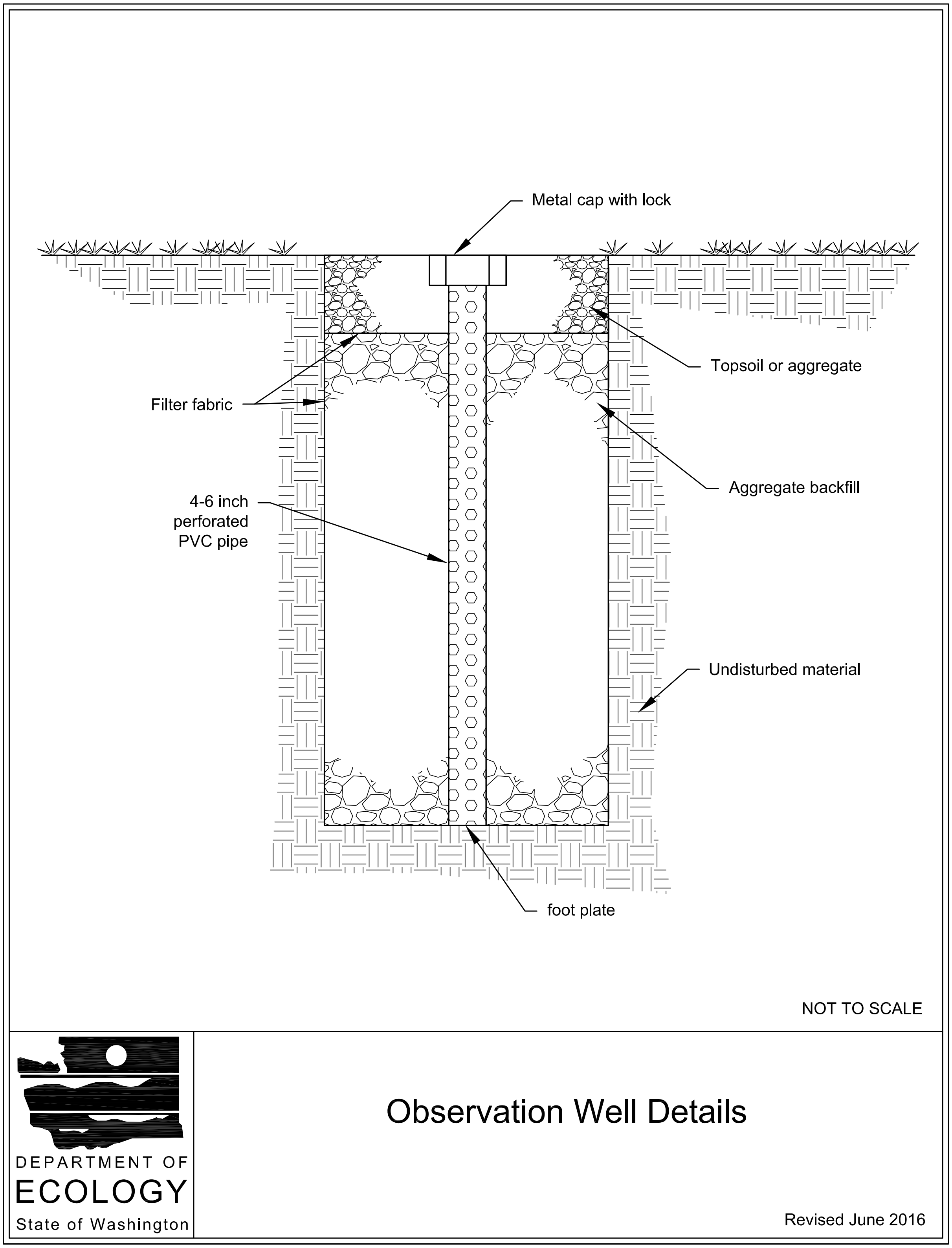


Figure 6.37: Observation Well Details



BMP F6.23: Bioretention

Purpose

Ecology accepts bioretention as having the potential to meet the requirements in 2.4.5 CE5: Runoff Treatment, 2.4.6 CE6: Flow Control, and/or 2.4.8 CE8: Wetlands Protection for the contributing drainage areas depending upon site conditions and sizing.

The purpose of bioretention is to provide effective removal of many stormwater pollutants, and provide reductions in stormwater runoff quantity and surface runoff flow rates. Where the surrounding native soils have adequate infiltration rates, bioretention can provide both Runoff Treatment and Flow Control. Where the native soils have low infiltration rates, underdrain systems can be installed and the bioretention BMP can still be used as a Runoff Treatment BMP. However, designs utilizing underdrains provide significantly less Flow Control benefits.

Description

The term bioretention describes a stormwater management practice that uses the chemical, biological, and physical properties of plants, soil microbes, and the mineral aggregate and organic matter in soils to transform, remove, or retain pollutants from stormwater runoff. Numerous design variations have evolved since the advent of this Best Management Practice (BMP); however, there are fundamental design characteristics that define bioretention BMPs across various settings.

Bioretention BMPs are:

- Shallow landscaped depressions with a designed soil mix and plants adapted to the local climate and soil moisture conditions that typically receive stormwater runoff from small contributing areas;
- Designed to mimic natural forested conditions, where healthy soil structure and vegetation promote the infiltration, storage, filtration, and slow release of stormwater flows; and
- Typically small-scale, dispersed, and integrated into the site as a landscape amenity.

Note that bioretention BMPs are often mis-labeled as BMP T5.14: Rain Gardens. Bioretention and rain gardens have different design specifications and sizing guidance. The designer is able to quantify the amount of Runoff Treatment and/or Flow Control provided by a bioretention BMP due to the specific design, sizing, bioretention soil mix (BSM), and modeling requirements. Although rain gardens are presumed to provide some amount of Runoff Treatment and/or Flow Control, the designer is not able to quantify the amount due to the allowable variations in the installation. Rain garden design also does not require hydrologic modeling. See BMP T5.14: Rain Gardens for further guidance on rain garden BMPs.

The following types of bioretention BMPs are described in this manual:

- **Bioretention cells:** Shallow depressions with a designed planting soil mix and a variety of plant material, including trees, shrubs, grasses, and/or other herbaceous plants. Bioretention cells may or may not have an underdrain and are not designed as a conveyance system.

- **Bioretention swales:** Incorporate the same design features as bioretention cells; however, bioretention swales are designed as part of a system that can convey stormwater when maximum ponding depth is exceeded.
- **Bioretention planters and planter boxes:** Bioretention soil mix and a variety of plant material including trees, shrubs, grasses, and/or other herbaceous plants within a vertical walled container usually constructed from formed concrete, but could include other materials.
  - Planter boxes are completely impervious and include a bottom (must include an underdrain).
  - Planters have an open bottom and allow infiltration to the subgrade.

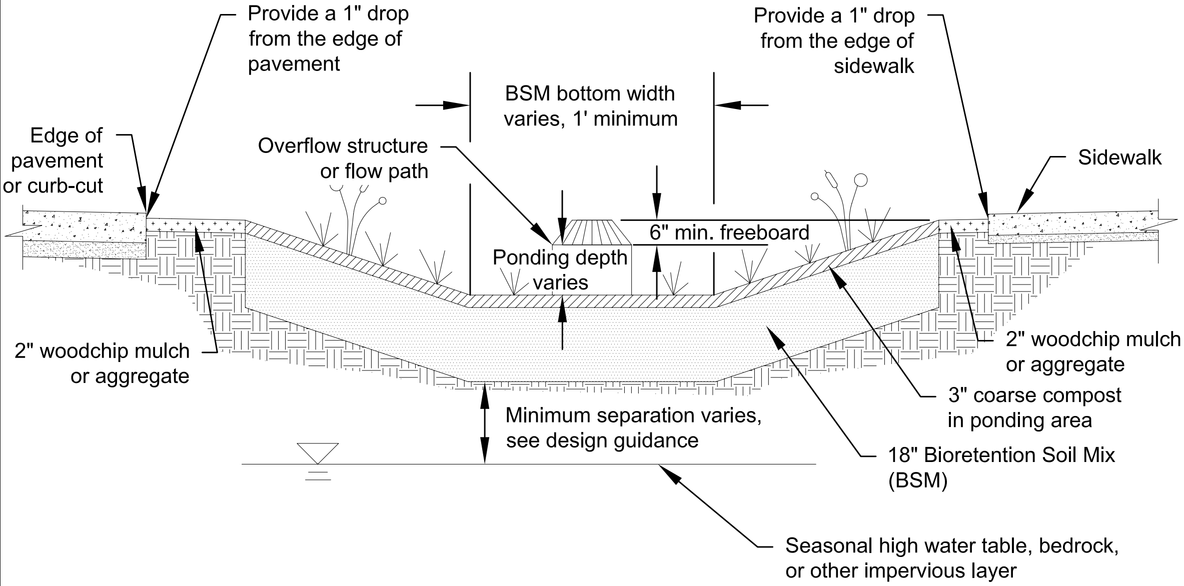
  These designs are often used in ultra-urban settings.

  Stormwater planters in the ROW require urban design and tailoring to street typology and context. NACTO Urban Street Stormwater Guide provides guidance for designing roadside stormwater planters. https://nacto.org/publication/urban-street-stormwater-guide/

See Figure 6.38: Typical Bioretention, Figure 6.39: Typical Bioretention w/Underdrain, Figure 6.40: Typical Bioretention w/Liner (Not LID), Figure 6.41: Example of a Bioretention Planter, and Figure 6.42: Typical Bioretention Planter for examples of various types of bioretention configurations.

Note: Ecology has approved use of certain manufactured treatment devices that use specific, high rate media for treatment. Such systems do not use Bioretention Soil Mix, and are not considered a bioretention BMP (even though marketing materials for these manufactured treatment devices may compare them to bioretention). See 6.11 Manufactured Treatment Devices as BMPs for more information on manufactured treatment devices.

Figure 6.38: Typical Bioretention



Note: See **BMP T7.30: Bioretention** for further details regarding design, installation, and maintenance of bioretention.

NOT TO SCALE

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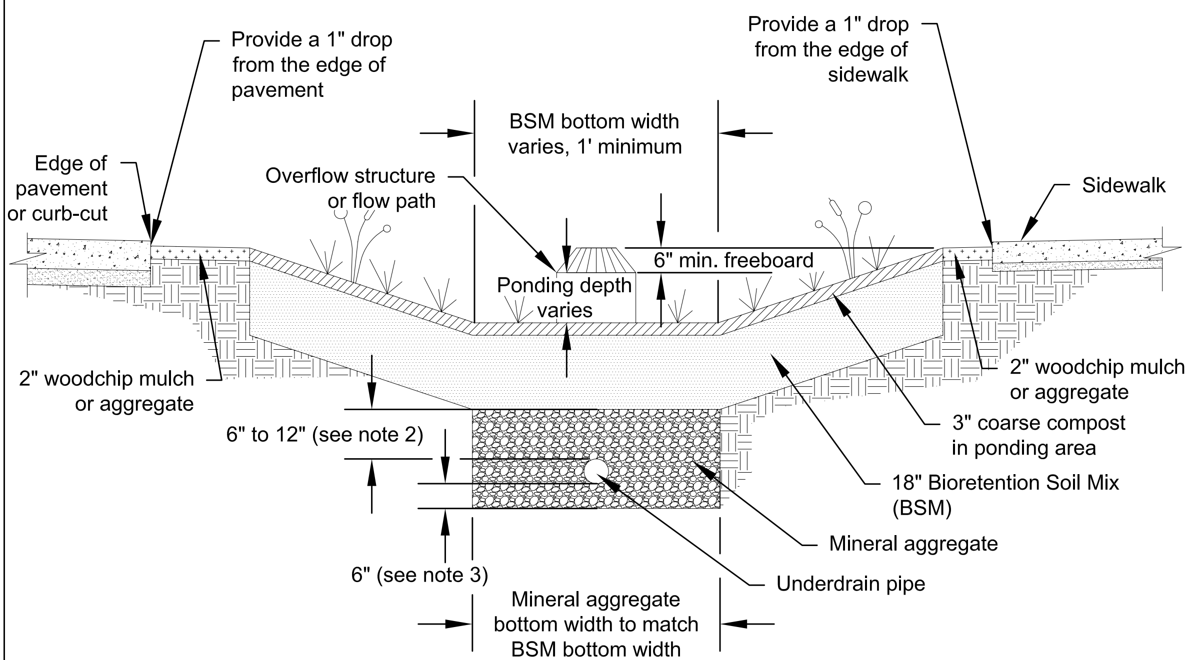
Typical Bioretention

Revised January 2022

Figure 6.39: Typical Bioretention w/Underdrain



Notes:

1. See **BMP T7.30: Bioretention** for further details regarding design, installation, and maintenance of bioretention.
2. Minimum 6" to discourage fines from entering the underdrain from the BSM. Maximum 12" to prevent unnecessary BMP depth from encroaching into the seasonal high ground water.
3. If depth to the seasonal high ground water allows, this distance may be larger.
4. When an underdrain is used, the design must ensure that the seasonal high ground water does not encroach into the BMP (including the mineral aggregate layer surrounding the underdrain pipe).

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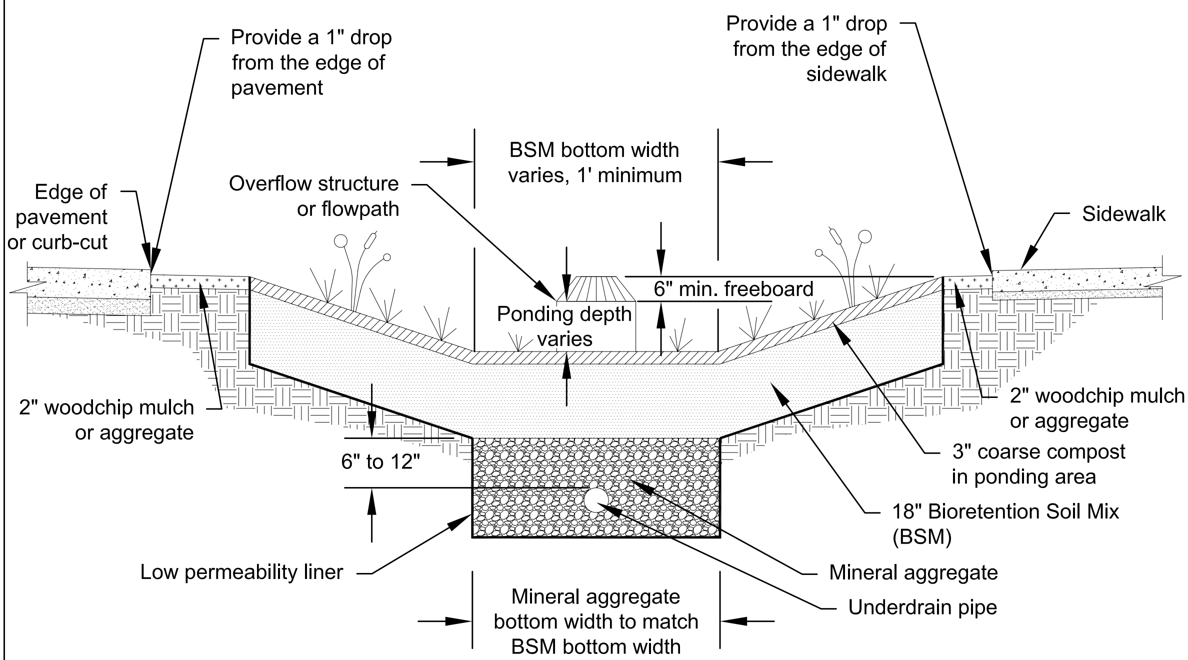
Typical Bioretention w/Underdrain

Revised January 2022

Figure 6.40: Typical Bioretention w/Liner (Not LID)



Note: See the Bioretention BMP text for further details regarding design, installation, and maintenance of bioretention.

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Typical Bioretention w/Liner (Not LID)

Revised February 2024

Figure 6.41: Example of a Bioretention Planter

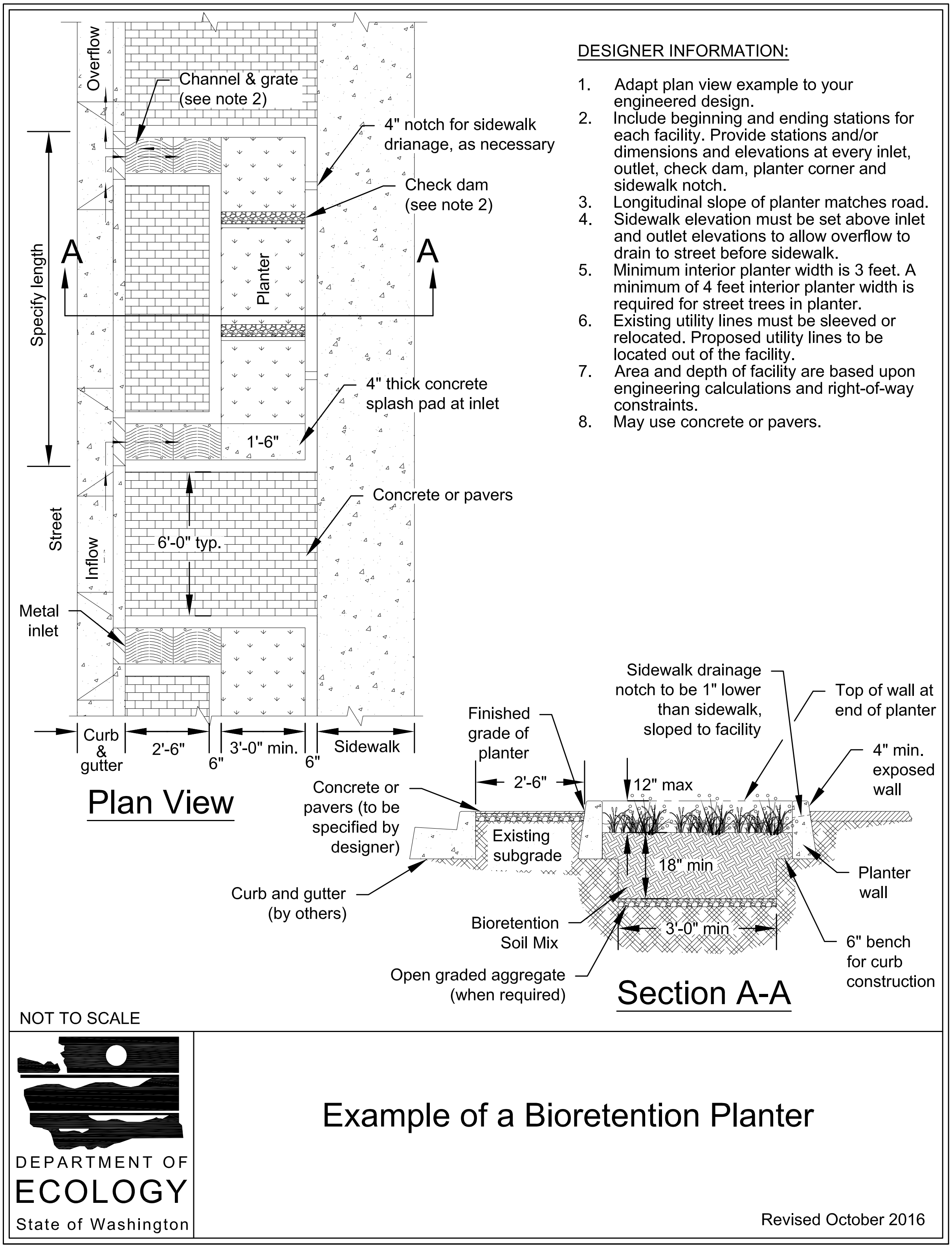
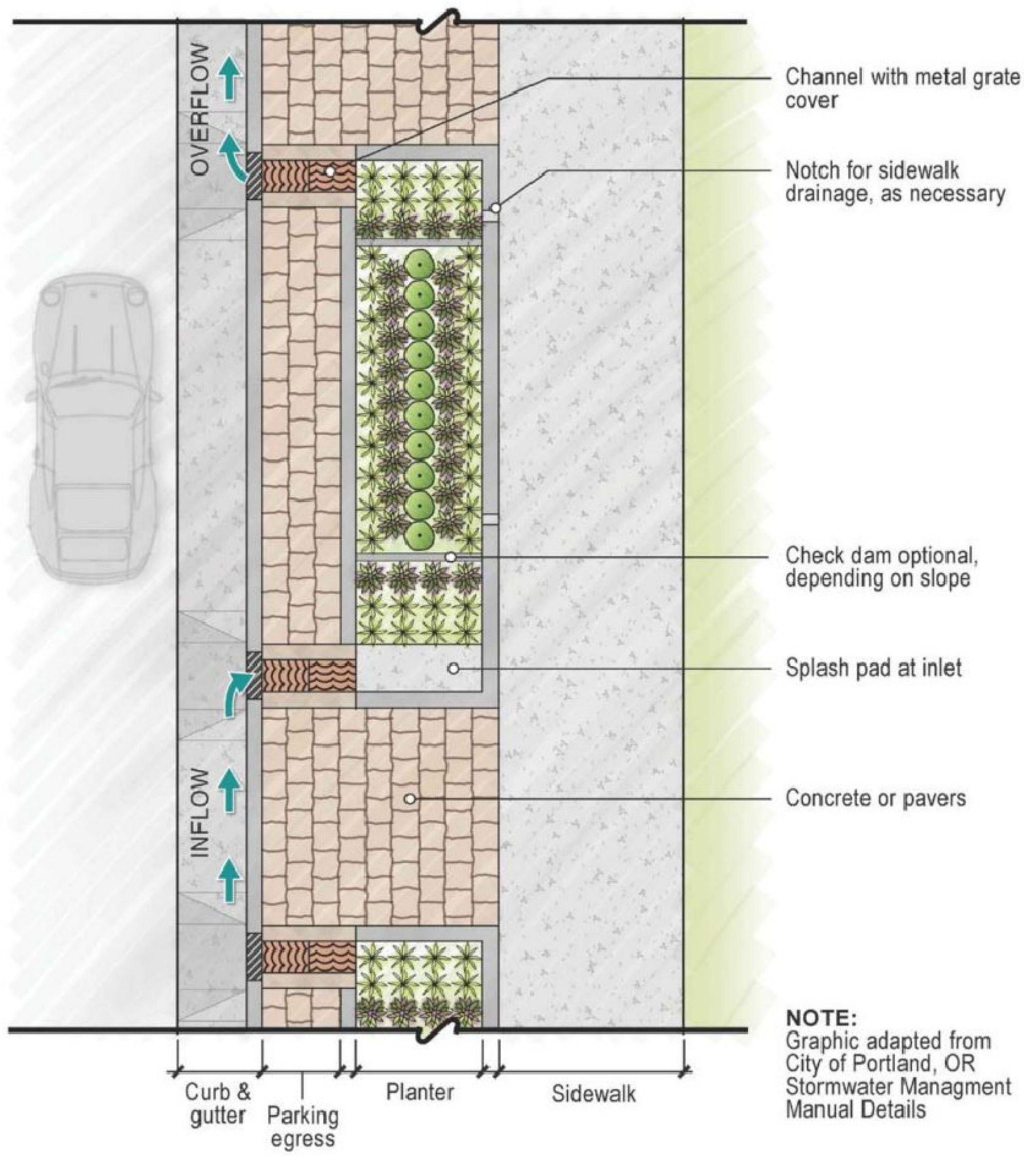


Figure 6.42: Typical Bioretention Planter



Source: Low Impact Development Technical Guidance Manual for Puget Sound (WSU-PSP, 2012)

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Typical Bioretention Planter

Revised June 2013

Applications and Limitations

Because bioretention BMPs use an imported soil mix that has a moderate design infiltration rate, they are best applied for small drainages, and near the source of the stormwater runoff. Bioretention cells may be scattered throughout a subdivision; a bioretention swale may run alongside the access road; or a series of bioretention planter boxes may serve the road. In these situations, they can but are not required to fully meet the Runoff Treatment requirements from pollution-generating surfaces. The amount of stormwater that is predicted to pass through the Bioretention Soil Mix is treated, and may be subtracted from the amount that must be treated per the project requirements (e.g. to meet 2.4.5 CE5: Runoff Treatment). Downstream Runoff Treatment BMPs may be significantly smaller as a result.

Bioretention BMPs that infiltrate into the ground can also provide significant Flow Control. They can, but are not required to fully meet Flow Control requirements. Because they typically do not have an orifice restricting overflow or underflow discharge rates, they may not fully meet 2.4.6 CE6: Flow Control. However, their performance contributes to meeting the standard, and that can result in much smaller additional Flow Control BMPs on the project site.

Bioretention constructed with imported composted material (i.e. for use in either the "Default" BSM or the "Custom" BSM) should not be used within one-quarter mile of phosphorus-sensitive waterbodies if the underlying native soil does not meet the criteria for Runoff Treatment per 6.5.6 Site Suitability Criteria (SSC). Monitoring indicates that new bioretention BMPs using either the "Default" BSM or the "Custom" BSM can add phosphorus to stormwater. Therefore, they should also not be used with an underdrain when the underdrain water would be routed to a phosphorus-sensitive receiving water (Ecology, 2016c). Bioretention BMPs using the "High Performance" BSM may be used, with or without an underdrain, within one-quarter mile of phosphorus-sensitive waterbodies.

Applications with or without underdrains vary extensively and can be applied in new development, redevelopment and retrofits. Typical applications include:

- Individual lots for managing rooftop, driveway, and other on-lot impervious surface.
- Shared facilities located in common areas for multiple lots.
- Areas within loop roads or cul-de-sacs.
- Landscaped parking lot islands.
- Within rights-of-way along roads (often linear bioretention swales and cells). These BMPs may be designed to have traffic-calming functions as well.
- Common landscaped areas in apartment complexes or other multifamily housing designs.
- Infiltration planters are often used in highly urban settings as stormwater management retrofits next to buildings or within streetscapes.
- Stormwater hot spots, or areas where land use or activities generate highly contaminated runoff, such as a gas station. Bioretention can be used to treat stormwater hot spots as long as an impermeable liner is used at the bottom of the treatment media layer (USEPA, 2013), appropriate plants are selected that can tolerate contaminants present at the site, and

inspection and maintenance plans are adequate to identify and address adaptive measures if needed.

- Bioretention systems are applicable to many climatological and geologic situations, with some minor design changes for cold and arid climates (USEPA, 2013).
- In cold climates, bioretention areas can be used as a snow storage area. When used for this purpose, or if used to treat parking lot runoff, the bioretention area should be planted with salt-tolerant and nonwoody plant species.
- Protection of cold water streams, notably trout streams that are extremely sensitive to changes in temperature. Bioretention has been shown to decrease the temperature of runoff from certain land uses, such as parking lots (USEPA, 2013).

While bioretention is one of the more widely applicable Runoff Treatment BMPs, there are some limitations to its use. Although bioretention does not typically consume a large amount of space, incorporating bioretention into site designs could impact other site uses, such as sidewalk or parking spaces. In areas where infiltration is not feasible, underdrains may be needed. Bioretention BMPs with underdrains can provide significant Runoff Treatment benefits, but typically provide less Flow Control than non-underdrained BMPs. Also note that underdrains could add complications with regards to conflicts with existing or future utilities.

See 6.5.7 Screening Criteria for Infiltration BMPs for more discussion of limitations based on the screening criteria for infiltration BMPs.

Infeasibility Criteria

The following screening criteria describe conditions that make bioretention infeasible or inefficient. If a project triggers any of the below-listed criteria, yet the proponent wishes to use bioretention, they may propose a functional design to the local jurisdiction that effectively mitigates these issues .

Criteria with setback distances are as measured from the bottom edge of the Bioretention Soil Mix.

- Citation of any of the following infeasibility criteria must be based on an evaluation of site-specific conditions and a written recommendation from an appropriate licensed professional (e.g. engineer, geologist, hydrogeologist):
    - Where professional geotechnical evaluation recommends infiltration not be used due to reasonable concerns about erosion, slope failure, or down gradient flooding.
    - Within an area whose groundwater drains into an erosion hazard, or landslide hazard area.
    - Where the only 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.
    - Where the only area available for siting does not allow for a safe overflow pathway to the municipal separate storm sewer system or private storm sewer system.

- Where there is a lack of usable space for bioretention BMPs at re-development sites, or where there is insufficient space within the existing public right-of-way on public road projects.
- Where infiltrating water would threaten existing below grade basements.
- Where infiltrating water would threaten shoreline structures such as bulkheads.

- The following infeasibility criteria are based on conditions such as topography and distances to predetermined boundaries. Citation of the following criteria do not need site-specific written recommendations from a licensed professional, although some may require professional services to determine:
  - Within setbacks from structures as established by the local government with jurisdiction.
  - Where they are not compatible with the surrounding drainage system as determined by the local government with jurisdiction (e.g. project drains to an existing stormwater collection system whose elevation or location precludes connection to a properly functioning bioretention BMP).
  - Where land for bioretention is within area designated as an erosion hazard or landslide hazard.
  - Where the site cannot be reasonably designed to locate bioretention BMPs on slopes less than 8%.
  - Within 50 feet from the top of slopes that are greater than 20% and over 10 feet of vertical relief.
  - For properties with known soil or groundwater contamination (typically federal Superfund sites or state cleanup sites under the Model Toxics Control Act (MTCA)):
    - Within 100 feet of an area known to have deep soil contamination;
    - Where groundwater modeling indicates infiltration will likely increase or change the direction of the migration of pollutants in the groundwater;
    - Wherever surface soils have been found to be contaminated unless those soils are removed within 10 horizontal feet from the infiltration area;
    - Any area where these BMPs are prohibited by an approved cleanup plan under the state Model Toxics Control Act or Federal Superfund Law, or an environmental covenant under Chapter 64.70 RCW.
  - Within 100 feet of a closed or active landfill.
  - Within 100 feet of a drinking water well, or a spring used for drinking water supply.
  - Within 10 feet of small on-site sewage disposal drainfield, including reserve areas, and grey water reuse systems. For setbacks from a “large on-site sewage disposal system”, see Chapter 246-272B WAC.

- Within 10 feet of an underground storage tank and connecting underground pipes when the capacity of the tank and pipe system is 1100 gallons or less. (As used in these criteria, an underground storage tank means any tank used to store petroleum products, chemicals, or liquid hazardous wastes of which 10% or more of the storage volume (including volume in the connecting piping system) is beneath the ground surface.

- Within 100 feet of an underground storage tank and connecting underground pipes when the capacity of the tank and pipe system is greater than 1100 gallons.

- Where the minimum vertical separation of 1 foot to the seasonal high water table, bedrock, or other impervious layer would not be achieved below bioretention that would serve a drainage area that is less than:

    1. 5,000 sq. ft. of pollution-generating impervious surface, and

    2. 10,000 sq. ft. of impervious surface, and

    3. three-quarter (3/4) acres of pervious surface.

    Note: Recommended separation distances for bioretention areas with small contributing areas are less than Ecology's recommendation of 3 to 5 feet for conventional infiltration BMPs (see SSC-5 Depth to Bedrock, Water Table, or Impermeable Layer) for two reasons: (1) BSM provides effective pollutant capture; and (2) hydrologic loading and potential for groundwater mounding is reduced when flows are directed to bioretention BMPs from smaller contributing areas.

- Where the minimum vertical separation of 3 feet to the seasonal high water table, bedrock, or other impervious layer would not be achieved below bioretention that would serve a drainage area that meets or exceeds:

    1. 5,000 sq. ft. of pollution-generating impervious surface, or

    2. 10,000 sq. ft. of impervious surface, or

    3. three-quarter (3/4) acres of pervious surface.

    AND

    cannot reasonably be broken down into amounts smaller than those listed in 1-3 (above).

- Where the field testing indicates potential bioretention sites have a measured (a.k.a. initial) native soil saturated hydraulic conductivity less than 0.30 inches per hour.

- A local government may designate geographic boundaries within which bioretention BMPs may be designated as infeasible due to year-round, seasonal or periodic high groundwater conditions, or due to inadequate infiltration rates. Designations must be based upon a preponderance of field data, collected within the area of concern, that indicate a high likelihood of failure to achieve the minimum groundwater clearance or infiltration rates identified in the above infeasibility criteria. The local government must develop a technical report and make it available upon request to Ecology. The report must be authored by (a) professional(s) with appropriate expertise (e.g. registered engineer, geologist, hydrogeologist, or certified soil scientist), and document the location and the pertinent values/observations of data that were used to recommend the designation and boundaries for the geographic area. The types of pertinent data include, but are not limited to:

  - Standing water heights or evidence of recent saturated conditions in observation wells, test pits, test holes, and well logs.
  - Observations of areal extent and time of surface ponding, including local government or professional observations of high water tables, frequent or long durations of standing water, springs, wetlands, and/or frequent flooding.
  - Results of infiltration tests

- In addition, a local government can map areas that meet a specific infeasibility criterion listed above provided they have an adequate data basis. Criteria that are most amenable to mapping are:
  - Where land for bioretention is within an area designated by the local government as an erosion hazard, or landslide hazard
  - Within 50 feet from the top of slopes that are greater than 20% and over 10 feet vertical relief
  - Within 100 feet of a closed or active landfill

Design Steps

Bioretention BMP design uses hydrologic analysis methods, such as the Soil Conservation Service (SCS) or the Santa Barbara Urban Hydrograph (SBUH), to determine the quantity of runoff from the water quality design storm and then route the flow through the bioretention BMP to determine whether the Runoff Treatment requirements for the project site are met (e.g. 2.4.5 CE5: Runoff Treatment). See Chapter 4 - Hydrologic Analysis and Design for more information on hydrologic analysis methods. If designing bioretention for Flow Control to (e.g. to meet 2.4.6 CE6: Flow Control), also see the general guidance for infiltration BMPs earlier in this chapter.

The stepwise procedure for designing bioretention for Runoff Treatment includes the following:

1. Determine the water quality design flow rate. See 6.1.5 Sizing Your Runoff Treatment BMPs.
2. Determine the subgrade's long-term design infiltration rate. See 6.5.4 Determining the Design Infiltration Rate of the Native Soils.
3. Determine the long-term design infiltration rate of the BSM. See Determining the Bioretention Soil Mix Design Infiltration Rate, below.
4. Calculate the required surface area (i.e. the horizontally projected area at the BMP overflow) of the bioretention BMP by dividing the water quality design flow rate by either:

a. the long-term design infiltration rate of the BSM, or

b. the long-term design infiltration rate of the subgrade soils.

If the design proposes to infiltrate the runoff into the subgrade soils: Use whichever of (a) or (b) above that has the lowest infiltration rate.

If the design proposes to utilize an underdrain below the BSM layer to allow filtered runoff to daylight, then use the long-term design infiltration rate of the BSM.

Note that conversions to get consistent units in the flow rates (water quality design flow rate and the long-term design infiltration rate) may be necessary.

5. Define the bioretention BMP geometry, including bottom width, longitudinal slope, side slopes, BSM depth, and ponding area depth (including maximum ponding depth and freeboard).

6. Define the available storage in the bioretention BMP, including storage in the ponding area and in the voids of the BSM. For BMPs with longitudinal slopes > 1%, account for the reduced available storage volume due to slopes. Also account for the effect of weirs or check dams on available storage volume, if applicable.

7. If designs include an underdrain, account for the reduced or eliminated infiltration benefits of the system when analyzing Flow Control and/or Runoff Treatment performance.

   If using level-pool routing per 4.7 Level-Pool Routing Method, the stage-storage-discharge relationship in the level-pool routing analysis would be redefined to include the ponding, Bioretention Soil Mix, and underdrain layers for estimation of the stage-volume relationship. Infiltration would be reduced to account only for infiltration beneath the underdrain pipe invert elevation (or set to zero), and flow through the underdrain would be included in the stage-discharge relationship.

8. Conduct hydrologic analysis to confirm and/or iterate BMP sizing to meet the Runoff Treatment requirements for the project site. Include any orifice or other Flow Control structures and overflow BMPs in the analysis, as applicable. See Chapter 4 - Hydrologic Analysis and Design for hydrologic analysis methods. Check that the design freeboard and maximum drawdown time of 72 hours are met.

Bioretention Soil Mix (BSM) Options and Specifications

Default Bioretention Soil Mix (BSM) Specifications

Projects which use the following requirements for the Bioretention Soil Mix do not have to test the mix for its saturated hydraulic conductivity (K_{sat}). See Determining the Bioretention Soil Mix Design Infiltration Rate.

- **Mineral Aggregate for Default BSM**

  Percentage of fines: A range of 2% to 4% passing the No. 200 sieve is ideal and fines should not be above 5% for a proper functioning specification according to ASTM D422-63.

- **Aggregate Gradation for Default BSM**

The aggregate portion of the BSM should be well-graded. According to ASTM D 2487-98 (Classification of Soils for Engineering Purposes [Unified Soil Classification System]), well-graded sand should have the following gradation coefficients:

- Coefficient of Uniformity ($C_u = D_{60}/D_{10}$) equal to or greater than 4, and
- Coefficient of Curve ($C_c = (D_{30})^2/D_{60} \times D_{10}$) greater than or equal to 1 and less than or equal to 3.

Table 6.26: Guideline for BSM Mineral Aggregate Gradation provides a gradation guideline for the mineral aggregate component of the default BSM (Hinman, 2009). The sand gradation below is often provided by vendors as a well-graded utility or screened sand. With compost, this blend provides enough fines for adequate water retention, hydraulic conductivity within the recommended range, pollutant removal capability, and plant growth characteristics for meeting design guidelines and objectives.

If compost is not available or desired for use on the project, other locally available materials may be used with local jurisdiction approval as long as the blend achieves the desired properties as described in this section. Some experimentation with locally available materials and mix specifications may be needed as demand for bioretention grows and suppliers learn how best to provide mixes that meet designer specifications and provide desired benefits, such as supporting healthy plants and treating and retaining runoff on-site.

Table 6.26: Guideline for BSM Mineral Aggregate Gradation

Sieve Size	Percentage Passing
3/8 inch	100
No. 4	95 to 100
No. 10	75 to 90
No. 40	25 to 40
No. 100	4 to 10
No. 200	2 to 5

Where existing soils meet the above aggregate gradation, those soils may be amended rather than importing mineral aggregate.

- **Compost to Aggregate Ratio, Organic Matter Content, and Cation Exchange Capacity for Default BSM**
  - Compost to aggregate ratio: 60-65 percent mineral aggregate, 35 – 40 percent compost by volume.
  - Organic matter content: 5 – 8 percent by weight.
  - Cation Exchange Capacity (CEC) must be > 5 milliequivalents/100 g dry soil Note:

Soil mixes meeting the above specifications do not have to be tested for CEC. They will readily meet the minimum CEC.

- **Compost for Default BSM**

  To ensure that the BSM will support healthy plant growth and root development, contribute to biofiltration of pollutants, and not restrict infiltration when used in the proportions cited herein, the following compost standards are required:

  - Meets the definition of “composted material” in WAC 173-350-100 and complies with testing parameters and other standards in WAC 173-350-220.

  - Produced at a composting facility that is permitted by the jurisdictional health authority. Permitted compost facilities in Washington are included in a spreadsheet titled *Washington composting facilities and material types – 2017* at the following web address:

    https://ecology.wa.gov/Waste-Toxics/Reducing-recycling-waste/Organic-materials/Managing-organics-compost

  - The compost product must originate a minimum of 65 percent by volume from recycled plant waste comprised of ”yard debris,” “crop residues,” and “bulking agents” as those terms are defined in WAC 173-350-100. A maximum of 35 percent by volume of “post-consumer food waste” as defined in WAC 173-350-100, but not including biosolids or manure, may be substituted for recycled plant waste.

  - Stable (low oxygen use and CO_2 generation) and mature (capable of supporting plant growth) by tests shown below. This is critical to plant success in Bioretention Soil Mixes.

  - Moisture content range: no visible free water or dust produced when handling the material.

  - Tested in accordance with the U.S. Composting Council “Test Method for the Examination of Compost and Composting” (TMECC), as established in the Composting Council’s “Seal of Testing Assurance” (STA) program. Most Washington compost facilities now use these tests.

  - Screened to the following size gradations for Fine Compost when tested in accordance with TMECC test method 02.02-B, Sample Sieving for Aggregate Size Classification.”

    Fine Compost shall meet the following gradation by dry weight:

    - Minimum percent passing 2”: 100%
    - Minimum percent passing 1”: 99%
    - Minimum percent passing 5/8”: 90%
    - Minimum percent passing ¼”: 75%

- ◦ pH between 6.0 and 8.5 (TMECC 04.11-A). “Physical contaminants” (as defined in WAC 173-350-100) content less that 1% by weight (TMECC 03.08-A) total, not to exceed 0.25 percent film plastic by dry weight.
- ◦ Minimum organic matter content of 40% (TMECC 05.07-A “Loss on Ignition")
- ◦ Soluble salt content less than 4.0 dS/m (mmhos/cm) (TMECC 04.10-A “Electrical Conductivity, 1:5 Slurry Method, Mass Basis”)
- ◦ Maturity indicators from a cucumber bioassay (TMECC 05.05-A “Seedling Emergence and Relative Growth") must be greater than 80% for both emergence and vigor.
- ◦ Stability of 7 mg CO2-C/g OM/day or below (TMECC 05.08-B “Carbon Dioxide Evolution Rate”)
- ◦ Carbon to nitrogen ratio (TMECC 05.02A “Carbon to Nitrogen Ratio” which uses 04.01 “Organic Carbon” and 04.02D “Total Nitrogen by Oxidation”) of less than 25:1. The C:N ratio may be up to 35:1 for plantings composed entirely of Puget Sound Lowland native species and up to 40:1 for coarse compost to be used as a surface mulch (not in a soil mix).

For information on using compost, compost benefits, a list of soil laboratories, and more, visit the following websites:

- Soils for Salmon at http://www.soilsforsalmon.org/ ;
- Building Soil – the Foundation for Success at http://www.buildingsoil.org/ ; and
- Washington Stormwater Center at http://www.wastormwatercenter.org/low-impact/.

Custom Bioretention Soil Mix (BSM) Specifications

Projects which prefer to create a custom BSM must demonstrate compliance with the following criteria using the specified test method:

- CEC ≥ 5 meq/100 grams of dry soil; USEPA 9081
- pH between 5.5 and 7.0
- 5 - 8 percent organic matter content before and after the saturated hydraulic conductivity test; ASTM D2974 (Standard Test Method for Moisture, Ash, and Organic Matter of Peat and Other Organic Soils)
- 2-5 percent fines passing the 200 sieve; TMECC 04.11-A
- Measured (Initial) saturated hydraulic conductivity (K_{sat}) of at least 12 inches per hour; ASTM D 2434 (Standard Test Method for Permeability of Granular Soils (Constant Head)) at 85% compaction per ASTM D 1557 (Standard Test Method s for Laboratory Compaction Characteristics of Soil Using Modified Effort). Also, use Recommended Modifications to ASTM D 2434 When Measuring Hydraulic Conductivity for Bioretention Soil Mixes (as detailed above).

- Design (long-term) saturated hydraulic conductivity of more than 1 inch per hour. Note: Design saturated hydraulic conductivity for BSM is determined by applying the appropriate infiltration correction factors as explained above under Determining the Bioretention Soil Mix Design Infiltration Rate.

- If compost is used in creating the custom Bioretention Soil Mix, it must meet all of the specifications listed above in Compost for Default BSM, except for the gradation specification. An alternative gradation specification must indicate the minimum percent passing for a range of similar particle sizes.

  Note: If compost is not used in the custom mix, and the custom mix itself does not leach phosphorus or is installed in series with a phosphorus treatment, then the custom mix may be used near phosphorus sensitive waterbodies.

High Performance Bioretention Soil Mix (HPBSM) Specifications

In 2021, Ecology approved a new, "High Performance" Bioretention Soil Mix (HPBSM). See *Guidance on Using New High Performance Bioretention Soil Mixes* (Ecology, 2024a) for full details on the HPBSM.

HPBSM has the advantage over the "Default" and "Custom" BSMs that include compost, in that it may be used, with or without an underdrain, near and within 1/4 mile of phosphorus sensitive waterbodies.

There are 3 layers used in HPBSM. The level of Runoff Treatment achieved depends on which layers are included in the HPBSM (i.e. HPBSM Type 1, Type 2, or Type 3 as described below). The layers are:

- **HPBSM Compost Surface Layer:**
  - 2" in depth
  - Compost must meet the "Compost for Default BSM" specifications (above)
  - Note: Do not use the HPBSM Compost Surface Layer without the HPBSM Polishing Layer. The HPBSM Polishing Layer is necessary to limit phosphorus and nitrogen export from the HPBSM Compost Surface Layer.
- **HPBSM Primary Layer:**
  - 18 inches in depth
  - 70% sand, 20% coir, and 10% high carbon wood ash (biochar) by volume
- **HPBSM Polishing Layer:**
  - 12 inches in depth
  - 90% sand, 7.5% activated alumina, and 2.5% iron aggregate by volume
  - Note: The HPBSM Polishing Layer, when used, is intended to treat immediately after the HPBSM Surface and Primary Layers, either by being located directly beneath those layers or directly in-series.

See *Guidance on Using New High Performance Bioretention Soil Mixes* (Ecology, 2024a) for further details, including specifications and required media testing.

There are 3 alternative configurations for HPBSM, each resulting in a different level of Runoff Treatment. The Ecology approved configurations for HPBSM are:

- **HPBSM Type 1:** Includes the HPBSM Primary Layer only.

  HPBSM Type 1 meets the basic and metals Runoff Treatment Performance Goals.

- **HPBSM Type 2:** Includes the HPBSM Primary Layer and the HPBSM Polishing Layer.

  HPBSM Type 2 meets the basic, metals, and phosphorus Runoff Treatment Performance Goals.

- **HPBSM Type 3:** Includes the HPBSM Compost Surface Layer, the HPBSM Primary Layer, and the HPBSM Polishing Layer.

  HPBSM Type 3 meets the basic, metals, and phosphorus Runoff Treatment Performance Goals, as well as achieves additional LID objectives (e.g. improves success in plantings due to the compost surface layer).

Blending, Delivery, Protection, and Placement of HPBSM

The blending, handling, and placement of the HPBSM Primary and Polishing Layers needs to be done carefully to ensure a successful installation. The contractor should prepare a Blending, Delivery, Protection, and Placement plan and submit it to the designer for review. The HPBSM Primary Layer and HPBSM Polishing Layer media shall be mechanically blended to produce a homogeneous mix by a blending vendor/contractor with soil blending experience. The blending should occur on an impervious (asphalt or concrete) surface pad that has been thoroughly washed clean (e.g. pressure washed) prior to blending or in purpose-built soil blending equipment that has been washed. The blending pad shall be clean and large enough to be able to turn and mix the media without introducing contamination. The blending pad shall be free of standing water before blending and shall be protected from stormwater run-on from areas off of/adjacent to the pad.

The measurement of the components to be blended shall be by dry weight on scale equipment capable of measuring within 1 pound or in full vessels of a known volume. Estimating the volumes of materials of partially full buckets or vessels shall not be used. Prior to blending, the coconut coir fiber shall be loose and hydrated such that its density is 4-5 pounds per cubic foot. The materials shall be blended until they are in a homogenous mixed state and then protected from contamination or saturation during storage, delivery, stockpiling, and placement.

The HPBSM layers should not be placed if the area is frozen, has standing water, is excessively wet or saturated, or has been subjected to more than 1/2 inch of precipitation within 48 hours before placement, unless approved otherwise by the Engineer. Do not place the HPBSM layers if adequate temporary erosion and sediment control measures are not in place to protect the media from contamination by silt laden run-off.

Place HPBSM layers loosely and evenly, no deeper than these specifications unless otherwise approved by the Engineer, on a properly prepared subgrade. After each lift, rake the surface to a uniform grade. Consolidate the entire surface area of each lift by boot compaction or a lawn roller and rake again to scarify before placing subsequent lifts or planting.

Phosphorus, Nitrogen, and Organic Compound Management Recommendations for BSM

BSM: Phosphorus Management Recommendations

These recommendations are applicable to any bioretention installation, but are critical for bioretention areas that have underdrains and directly release to fresh water or are conveyed to water bodies with TMDLs for nutrients or are specifically designated as phosphorus sensitive by the local jurisdiction. Levels of phosphorus in bioretention areas are generally not a concern for groundwater unless there is groundwater transport of phosphorus through soils with low phosphorus sorption capability and close proximity to surface fresh water. Note that additional research is needed on phosphorus management in Bioretention Soil Mixes; however, current research indicates the following:

- Mature stable compost reduces the leaching of bioavailable phosphorus.
- A healthy plant community provides direct phosphorus uptake, but more importantly promotes the establishment of healthy soil microbial community likely capable of rapid phosphorus uptake.
- Aerobic conditions reduce the reversal of phosphorus sorption and precipitation reactions.
- The "Default" BSM and HPBSM have relatively neutral pH.
- Iron, aluminum, and calcium are metals that can be added to adsorb or precipitate phosphorus. Aluminum is the most applicable for bioretention systems with appropriate adsorption reaction time, relative stability, and pH range for reaction (Lucas and Greenway, 2009).

  Water treatment residuals (WTRs), used for settling suspended material in drinking water intakes, are waste products and sources of aluminum and iron hydroxides. More research is needed in this area, but current trials indicate that WTRs can be added at a rate of 10% by volume to the BSM for sorption of phosphorus. WTRs are fine textured and, if incorporated into the BSM, laboratory analysis is required to verify appropriate hydraulic conductivity. If using WTRs at a rate of 10% by volume, add shredded bark at 15% by volume to compensate for the fine texture of the WTRs (e.g. 60% sand, 15% compost, 15% shredded bark, and 10% WTRs).
- The molar ratio of ammonia-oxalate-extracted phosphorus in relation to the ammonia-oxalate-extracted iron and aluminum in the BSM should be < 0.25.
- A sand or pea gravel bed for the underdrain provides a good filter for fine particulates (see Underdrains (optional) section).
- A two-year bioretention mesocosm study gathered new information on how plants and mulch inoculated with S. rugosoannulata affected bioretention performance to improve stormwater quality. The findings suggested that fungi improved soil

moisture, likely through the biological breakdown of wood mulches. While all the mesocosm (controls, plants, and fungi) reduced most pollutants studied, significant reductions of phosphorus in the mesocosms with fungi, reportedly via fungal translocation. There may be a benefit, particularly during the first year after construction, in using mulch with inoculations to limit ortho-phosphorus export from the Default BSM (McIntyre et al., 2020).

BSM: Nitrogen Management Recommendations

Nitrogen levels in bioretention areas are generally not a concern with groundwater unless there is groundwater transport of nitrogen in close proximity to a sensitive drinking water aquifer. Note that additional research is needed on nitrogen management in bioretention; however, current research indicates the following:

- Mature stable compost reduces leaching of bioavailable nitrate nitrogen.
- A healthy plant community provides direct uptake of nitrate nitrogen but more importantly promotes the establishment of healthy soil microbial community likely capable of rapid uptake of nitrate nitrogen.
- Research suggests that nitrate capture and retention in bioretention areas varies considerably from good retention to export from the compost in the BSM. Where nitrate is a concern, elevated underdrain designs can be used to create a fluctuating anoxic/aerobic zone below the drain pipe. Denitrification within the anaerobic zone is facilitated by microbes using forms of nitrogen (nitrite and nitrate) instead of oxygen for respiration. A suitable carbon source provides a nutrition source for the microbes, enables anaerobic respiration, and can enhance the denitrification process (Kim et al., 2003). Dissolved and particulate organic carbon that migrates from the BSM to the aggregate filter and bedding layer likely provides adequate carbon source for microbes.

Biosolids and manure composts can be higher in bioavailable phosphorus and nitrogen than compost derived from yard or plant waste. Accordingly, the use of biosolids or manure compost in bioretention areas is not allowed, in order to reduce the possibility of exporting bioavailable phosphorus and nitrogen in effluent.

BSM: Organic Compounds Management Recommendations

These recommendations are applicable to any bioretention installation, but may be most useful for bioretention facilities that receive runoff from commercial, industrial, high traffic or other more highly developed areas. Levels of organic compounds such as PCBs, PAHs, phthalates, current or historical pesticides, TPH, or other ubiquitous toxic organic contaminants are believed to be carried in stormwater at generally low but highly variable concentrations (see 1.1.4 Effects of Urbanization on Stormwater and 1.1.6 Stormwater Pollutants and Their Adverse Impacts). A few research studies done at the bench and mescosm scale are indicating that the default BSM alone and with amendments provides some reduction of these compounds. Note that additional research is needed on organic compound management in Bioretention Soil Mixes; however, current research indicates the following:

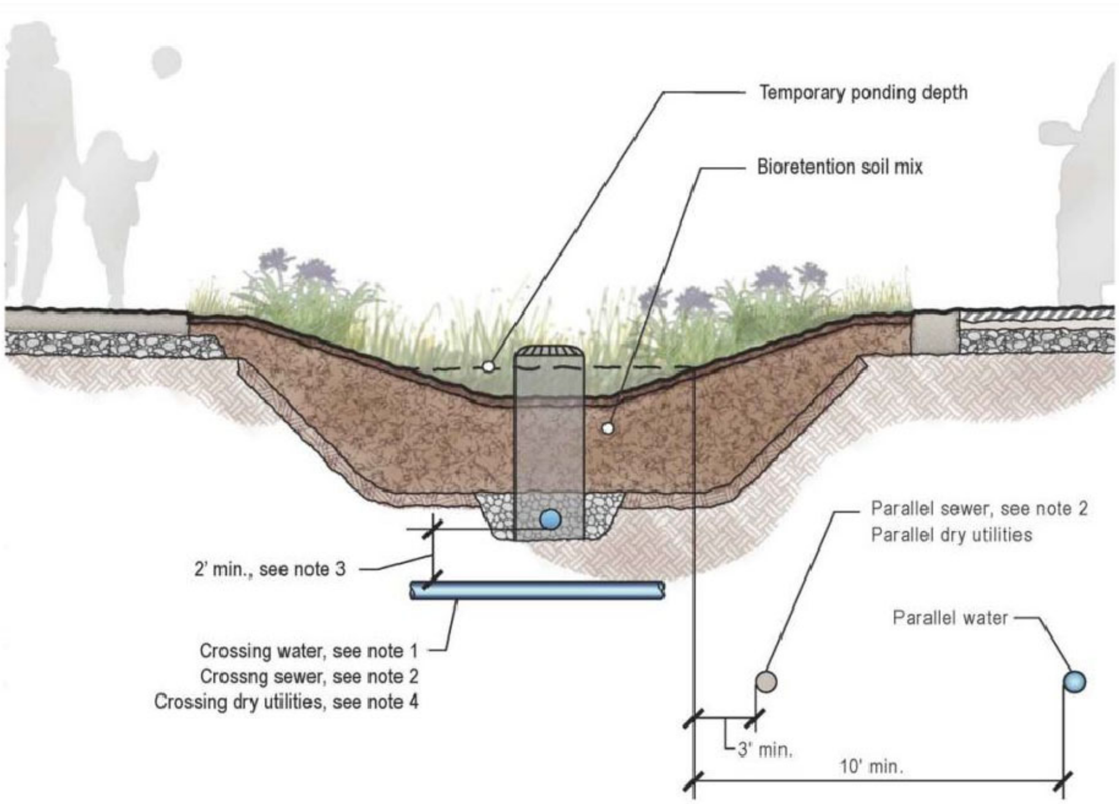
- Bioretention testing mesocosms were highly effective at treating PCBs from a low-level influent concentrations. The PCB concentrations were largely not detected in the effluent water and did not build up in the Default BSM in a two-year project (King County, 2020).
- Retrofit installations of three bioretention planter boxes along the Highway 99 corridor in Shoreline, WA found over 60% reduction in concentration of TSS and TPH, and over 80% reduction in concentrations of PAHs and PCBs. The bioretention planter box performance would likely have been greater with larger inlets to allow more runoff to be treated (King County, 2017).
- A two-year study evaluated several aspects of a regional detention facility, and in-particular two new large modified bioretention facilities in Federal Way, WA. They found broad reductions in concentrations of many parameters including TSS, fecal coliform, PAHs, PCBs and total metals (zinc, lead, copper and cadmium) (King County, 2019).

Design Criteria

General Design Criteria

- See local jurisdiction requirements for locally required methods and assumptions.
- **Utilities:** Consult local jurisdiction requirements for horizontal and vertical separations required for publicly owned utilities, such as water, sewer, and stormwater pipes. Consult the appropriate franchise utility owners for utility separation requirements, which may include communications and/or gas. See Figure 6.43: Recommended Utility Setbacks for Bioretention for an example design detail illustrating vertical and horizontal separation requirements for roadway bioretention. Extensive potholing (or excavation to daylight and document utilities) may be needed during project planning and design to develop a complete understanding of the type, location, and construction of all utilities that may be impacted by the project. When applicable separation requirements cannot be met, designs should include appropriate mitigation measures, such as impermeable liners over the utility, sleeving utilities, fixing known leaky joints or cracked conduits, and/or adding an underdrain to the bioretention areas to minimize the amount of infiltrated stormwater that could enter the utility.

Figure 6.43: Recommended Utility Setbacks for Bioretention



NOTES:

1. Line bioretention or sleeve water lines at crossing locations, if directed by engineer.
2. Line bioretention where side sewer is above the bioretention facility, or use sealed sewer pipe where sewer pipes may be vulnerable to infiltration, if directed by engineer.
3. Use polyethylene foam pad or other approved materials when utility crossing separation standards cannot be achieved per local jurisdiction standards.
4. Dry utilities, such as power, gas, and communications, may be backfilled with non-infiltrating materials, such as controlled density fill or fluidized thermal backfill. Include appropriate measures in designs to protect these utilities and account for their possible effect on infiltration performance.
5. Suffcient potholing or other investigation techniques should be conducted to determine the location and construction of all utilties in the project corrdor.
6. If infiltration into utility trenches is a concern, use trench dams or other means of preventing or limiting migration of infiltrated stormwater.

Source: Low Impact Development Technical Guidance Manual for Puget Sound (WSU-PSP, 2012)

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- **Transportation safety:** The design configuration and selected plant types should provide adequate sight distances, clear zones, and appropriate setbacks for roadway applications in accordance with the local jurisdiction requirements. Bioretention BMP designs that extend the curb line into the roadway (e.g. chicanes and neck-downs) can provide traffic-calming functions and improve vehicle and pedestrian safety.

- **Impacts of surrounding activities:** Human activity influences the location of the BMP in the development. For example, locate bioretention BMPs away from traveled areas on individual lots to prevent soil compaction and damage to vegetation, or provide elevated or bermed pathways in areas where foot traffic is inevitable. Provide barriers, such as wheel stops, to restrict vehicle access in roadside and/or parking lot applications.

- **Visual buffering:** Bioretention BMPs can be used to buffer structures from roads, enhance privacy among residences, and for an aesthetic site feature.

- **Project submission requirements:** Submit the results of infiltration (K_{sat}) testing and groundwater elevation testing (or other documentation and justification for the rates and hydraulic restriction layer clearances) with the Stormwater Site Plan as justification for the feasibility decision regarding bioretention and as justification for assumptions made in the sizing calculations.

- **Legal documentation to track bioretention obligations:** Where drainage plan submittals include assumptions with regard to size and location of bioretention BMPs, approval of the plat, short-plat, or building permit should identify the bioretention obligation of each lot; and the appropriate lots should have deed requirements for construction and maintenance of those BMPs.

- Much of the design criteria within this BMP originated from the *Low Impact Development Technical Guidance Manual for Puget Sound* (Hinman and Wulkan, 2012) and the *Eastern Washington Low Impact Development Guidance Manual* (Ecology, 2013c). Refer to those documents for additional explanations and background.

  Note that the references noted above are for additional information purposes only. You must follow the guidance within this manual if there are any discrepancies between this manual and reference documents.

- **Site topography:** Based on geotechnical concerns, infiltration on slopes greater than 10% should only be considered with caution. The site assessment should clearly define any landslide and erosion critical areas and coastal bluffs, and appropriate setbacks required by the local jurisdiction. Thorough geotechnical analysis should be included when considering infiltration within or near slope setbacks. Depending on adjacent infrastructure (e.g. basements and subsurface utilities) and subgrade geology, geotechnical analysis may also be necessary on relatively low gradients.

Determining the Native Soil Design Infiltration Rate

Determining infiltration rates of the site soils is necessary to determine feasibility of designs that intend to infiltrate stormwater on-site. It is also necessary to estimate flow reduction benefits of such designs.

The certified soils professional or engineer can exercise discretion concerning the need for and extent of infiltration rate (saturated hydraulic conductivity, K_{sat}) testing. The professional can consider a reduction in the extent of infiltration (K_{sat}) testing if, in their judgment:

- information exists confirming that the site is unconsolidated outwash material with high infiltration rates, and there is adequate separation from groundwater, or
- the site subsurface characterization, including soil borings across the development site, indicate consistent soil characteristics and depths to seasonal high groundwater conditions or a hydraulic restriction layer.

The following provides recommended tests for the soils underlying bioretention BMPs. The test should be run at the anticipated elevation of the top of the native soil beneath the bioretention BMP.

Refer to 6.5.4 Determining the Design Infiltration Rate of the Native Soils for further guidance on the methods to determine the design infiltration rate of the native soils.

- Small bioretention cells (bioretention BMPs made up of one or multiple cells that receive water from 1 or 2 individual lots or < 1/4 acre of pavement or other impervious surface) have the following options for determining the native soil infiltration rate:
    1. One small-scale pilot infiltration test (PIT) as described in 6.5.4 Determining the Design Infiltration Rate of the Native Soils.
    2. If the site is underlain with soils not consolidated by glacial advance (e.g. recessional outwash soils), then the designer may use the grain size analysis method described in 6.5.4 Determining the Design Infiltration Rate of the Native Soils based on the layer (s) identified in results of one soil test pit or boring.
- Large bioretention cells (bioretention BMPs made up of one or multiple cells that receive water from several lots or 1/4 acre or more of pavement or other impervious surface) have the following options for determining the native soil infiltration rate:
    1. Multiple small-scale or one large-scale PIT. If using the small-scale test, measurements should be taken at several locations within the area of interest.
    2. If the site is underlain with soils not consolidated by glacial advance (e.g. recessional outwash soils), then the designer may use the grain size analysis method described in 6.5.4 Determining the Design Infiltration Rate of the Native Soils. Use the grain size analysis method based on more than one soil test pit or boring. The more test pits/borings used, and the more evidence of consistency in the soils, the less of a correction factor may be used.
- Bioretention swales have the following options for determining the native soil infiltration rate:
    1. Approximately 1 small-scale PIT per 200 linear feet of swale, and within each length of road with significant differences in subsurface characteristics.
    2. If the site is underlain with soils not consolidated by glacial advance (e.g. recessional outwash soils), then the designer may use the grain size analysis method described

in 6.5.4 Determining the Design Infiltration Rate of the Native Soils. Approximately 1 soil test pit/boring per 200 feet of swale and within each length of road with significant differences in subsurface characteristics.

- On a single, smaller commercial property (i.e. properties with one or two small businesses), one bioretention BMP will likely be appropriate. In that case, a small-scale PIT – or an alternative small scale test specified by the local government - should be performed at the proposed bioretention location. Tests at more than one site could reveal the advantages of one location over another.
- On larger commercial sites, a small-scale PIT every 5,000 sq. ft. is advisable. If soil characteristics across the site are consistent, a geotechnical professional may recommend a reduction in the number of tests.
- On multi-lot residential developments, multiple bioretention BMPs, or a BMP stretching over multiple properties may be appropriate. In most cases, it is necessary to perform small-scale PITs, or other small-scale tests as allowed by the local jurisdiction. A test is advisable at each potential bioretention site. Long, narrow bioretention BMPs, such as one following the road right-of-way, should have a test location at least every 200 lineal feet, and within each length of road with significant differences in subsurface characteristics.

After concluding an infiltration test, infiltration test sites should be over-excavated 3 feet below the projected bioretention BMP's bottom elevation unless minimum clearances to seasonal high groundwater have or will be determined by another method. This overexcavation is to determine if there are restrictive layers or groundwater. Observe whether water is infiltrating vertically or only spreading horizontally because of groundwater or a restrictive soil layer. Observations through a wet season can identify a seasonal groundwater restriction.

If a single bioretention BMP serves a drainage area exceeding 1 acre, a groundwater mounding analysis may be necessary in accordance with 6.5.2 Infiltration BMP Design Steps.

Determining the Bioretention Soil Mix Design Infiltration Rate

1. Use an initial saturated hydraulic conductivity (K_{sat})for the Bioretention Soil Mix (BSM) of 12 in/hr.

   Note that this is a lower rate than the actual initial k_{sat} of the BSM. This is because the design is based on the end of life of the BMP, which is assumed to be when the k_{sat} of the BSM reaches 12 in/hr.

2. Determine the appropriate safety factor:

   - If the contributing area to the bioretention BMP is equal to or exceeds any of the following thresholds:
     - 5,000 square feet of pollution-generating impervious surface;
     - 10,000 square feet of impervious surface;
     - ¾ acre of lawn and landscape,

     use 4 as the K_{sat} safety factor.

- If the contributing area is less than all of the above areas, or if the design includes a pretreatment BMP for solids removal, use 2 as the K_{sat} safety factor. The pretreatment BMP must be an approved pretreatment BMP as identified in this manual (i.e. not just part of the presettling area of this BMP).

3. Divide the initial K_{sat}(12 in/hr) by the appropriate safety factor (4 or 2) to determine the design BSM infiltration rate.

   Enter the subgrade and BSM infiltration rates in a numerical model to determine the Runoff Treatment and/or Flow Control benefits of the bioretention areas.

Recommended Modifications to ASTM D 2434 When Measuring Hydraulic Conductivity for Bioretention Soil Mixes

Proctor method ASTM D1557 Method C (6-inch mold) shall be used to determine maximum dry density values for compaction of the bioretention soil sample. Sample preparation for the Proctor test shall be amended in the following ways:

1. Maximum grain size within the sample shall be no more than ½ inches in size.
2. Snip larger organic particles (if present) into1/2 inch long pieces.
3. When adding water to the sample during the Proctor test, allow the sample to pre-soak for at least 48 hours to allow the organics to fully saturate before compacting the sample. This pre-soak ensures the organics have been fully saturated at the time of the test.

ASTM D2434 shall be used and amended in the following ways:

1. Apparatus:
   a. 6-inch mold size shall be used for the test.
   b. If using porous stone disks for the testing, the permeability of the stone disk shall be measured before and after the soil tests to ensure clogging or decreased permeability has not occurred during testing.
   c. Use the confined testing method, with 5- to 10-pound force spring
   d. Use de-aired water.
2. Sample:
   a. Maximum grain size within the sample shall not be more than ½ inch in size.
   b. Snip larger organic particles (if present) into ½-inch long pieces.
   c. Pre-soak the sample for at least 48 hours prior to loading it into the mold. During the pre-soak, the moisture content shall be higher than optimum moisture but less than full saturation (i.e. there shall be no free water). This pre-soak ensures the organics have been fully saturated at the time of the test.
3. Preparation of Sample:

a. Place soil in cylinder via a scoop.

b. Place soil in 1-inch lifts and compact using a 2-inch-diameter round tamper. Pre-weigh how much soil is necessary to fill 1-inch lift at 85% of maximum dry density, then tamp to 1-inch thickness. Once mold is full, verify that density is at 85% of maximum dry density (+ or – 0.5%). Apply vacuum (20 inches Hg) for 15 minutes before inundation.

c. Inundate sample slowly under a vacuum of 20 inches Hg over a period of 60 to 75 minutes.

d. Slowly remove vacuum (> 15 seconds).

e. Sample shall be soaked in the mold for 24 to 72 hours before starting test.

4. Procedure:

   a. The permeability test shall be conducted over a range of hydraulic gradients between 0.1 and 2.

   b. Steady state flow rates shall be documented for four consecutive measurements before increasing the head.

   c. The permeability test shall be completed within one day (one-day test duration).

BSM Porosity

The typical range of BSM porosity is 35% to 45%.

Flow Entrance

Flow entrance design will depend on topography, flow velocities, and volume entering the pretreatment and bioretention area, adjacent land use, and site constraints. Flows entering a bioretention BMP should be less than 1.0 foot per second (ft/sec) to minimize erosion potential. Five primary types of flow entrances can be used for bioretention cells:

1. **Dispersed, low-velocity flow across a landscape area:** Landscape areas and vegetated buffer strips slow incoming flows and provide an initial settling of particulates and are the preferred method of delivering flows to bioretention. Dispersed flow may not be possible given space limitations or if the BMP is controlling roadway or parking lot flows where curbs are mandatory.

2. **Dispersed or sheet flow across pavement or gravel and past wheel stops for parking areas:** When curbs are not mandatory, design to disperse and sheet flow runoff as much as possible from pavement or gravel and past wheel stops for parking areas.

3. **Curb cuts for roadside, driveway or parking lot areas:** Curb cuts should include a rock pad, concrete, or other erosion protection material in the channel entrance to dissipate energy. Minimum curb cut width should be 12 inches; however, 18 inches is recommended. The designer should calculate the size and choose the style of curb cut that is appropriate for the site conditions and runoff expectations. Avoid the use of angular rock or quarry

spalls and instead use round (river) rock if needed. Removing sediment from angular rock is difficult. The flow entrance should slope steeply (at least 1:1) from the curb line to the bioretention, dropping at least 3" (see Figure 6.44: Typical Curb Extension Inlet and Figure 6.45: Typical Concrete Curb Inlet) and provide an area for settling and periodic removal of sediment and coarse material before flow dissipates to the remainder of the bioretention area (Prince George's County, 2007); (USACE, 2003).

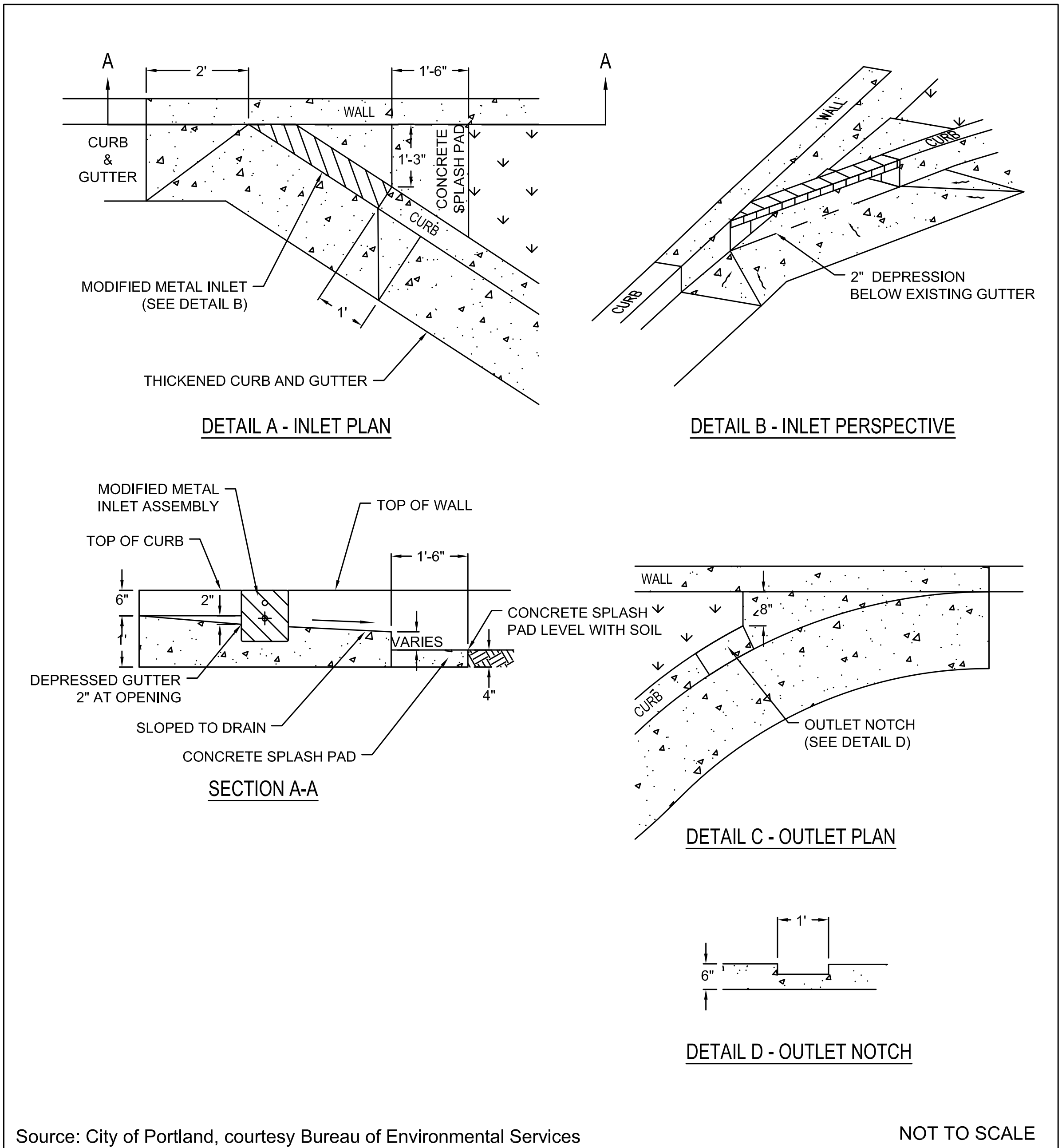
Curb cuts used for bioretention areas in high-use parking lots or roadways may require a higher level of maintenance due to increased accumulation of coarse particulates and trash in the flow entrance and associated bypass of flows. Recommended methods for areas where heavy trash and coarse particulates are anticipated are as follows:

- Make curb cut width a minimum of 18 inches.
- At a minimum, the flow entrance should drop 2 to 3 inches from the gutter line into the bioretention area and provide an area with a concrete bottom for settling and periodic removal of debris.
- Anticipate relatively more frequent inspection and maintenance for areas with large impervious areas, high traffic loads, and larger debris loads.
- Catch basins or forebays may be necessary at the flow entrance to adequately capture debris and sediment load from large contributing areas and high use areas. Piped flow entrance in this setting can easily clog, and catch basins with regular maintenance are necessary to capture coarse and fine debris and sediment.

4. **Piped flow entrance:** Piped entrances should include rock or other erosion protection material in the channel entrance to dissipate energy and disperse flow.
5. **Trench drains:** Trench drains can be used to cross sidewalks or driveways where a deeper pipe conveyance creates elevation problems. Trench drains tend to clog and may require additional maintenance (see Figure 6.46: Typical Trench Drain Inlet).

Woody plants can restrict or concentrate flows, can be damaged by erosion around the root ball, and should not be placed directly in the entrance flow path.

Figure 6.44: Typical Curb Extension Inlet



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Typical Curb Extension Inlet

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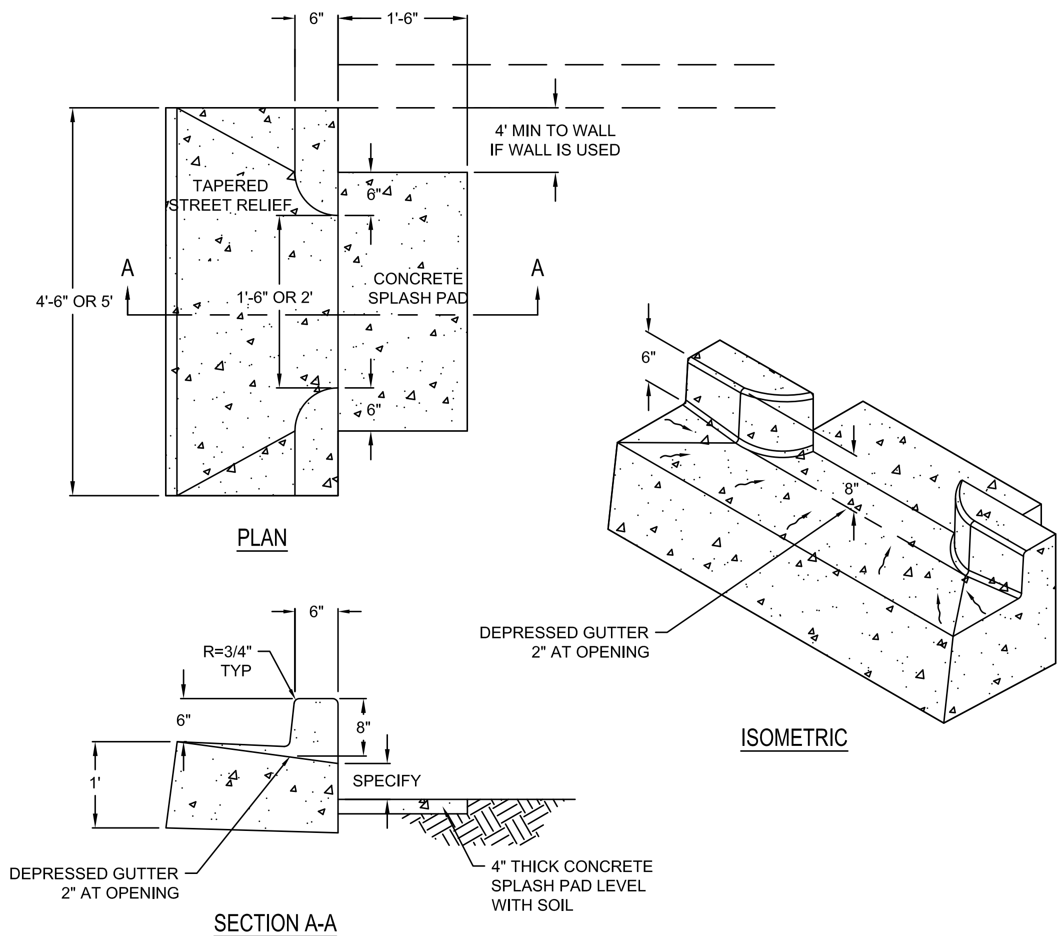
Figure 6.45: Typical Concrete Curb Inlet



CONSTRUCTION NOTES

1. Concrete splash pad elevation shall be level with soil inside planter.
2. Splash pad shall be six inches wider than inlet opening on both sides.

Source: City of Portland, courtesy Bureau of Environmental Services

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Typical Concrete Curb Inlet

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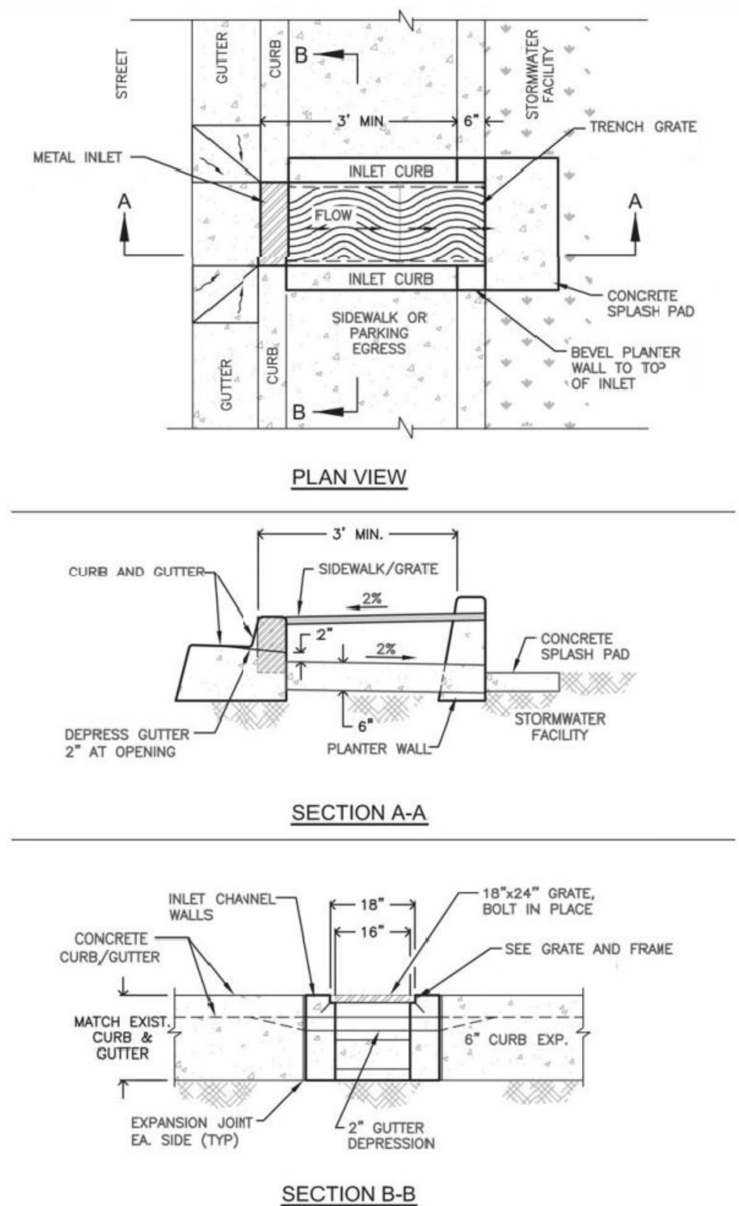
Figure 6.46: Typical Trench Drain Inlet



Source: City of Portland, courtesy Bureau of Environmental Services

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Typical Trench Drain Inlet

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Presettling

Forebays and presettling are recommended for concentrated flow entrances (curb cuts, trench drains, and pipes) to reduce accumulation of sediment and trash in the bioretention area and maintenance effort. Catch basins or open forebays can be used for presettling.

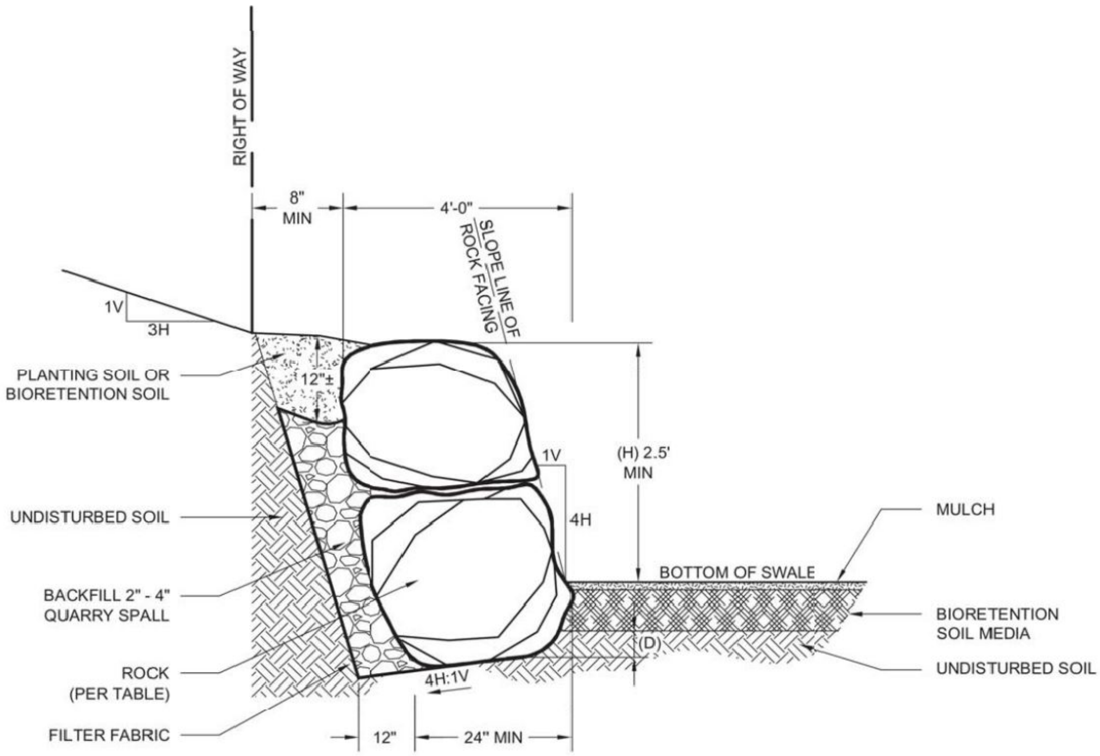
- **Catch basins:** In some locations where road sanding or higher than usual sediment inputs are anticipated, catch basins can be used to settle sediment and release water to the bioretention area through a grate for filtering coarse material.
- **Open forebays (presettling areas specifically designed to capture and hold flows that first enter the bioretention area):** The bottom of the presettling area should be large rock (4- to 8-inch streambed or round cobbles) or a concrete pad with a porous berm or weir that ponds the water to a maximum depth of 12 inches.

Bottom Area and Side Slopes

Bioretention areas are highly adaptable and can fit various settings such as rural and urban roadsides, ultraurban streetscapes, and parking lots by adjusting bottom area and side slope configuration. The recommended maximum and minimum dimensions are as follows:

- **Maximum planted side slope if total cell depth is greater than 3 feet:** 3H:1V. If steeper side slopes are necessary, rockeries, concrete walls, or soil wraps may be effective design options (see Figure 6.47: Bioretention Rockery Wall Detail). Local jurisdictions may require bike and/or pedestrian safety features, such as railings or curbs with curb cuts, when steep side slopes are adjacent to sidewalks, walkways, or bike lanes.
- **Minimum bottom width for bioretention swales:** 2 feet recommended, 1 foot minimum. Carefully consider flow depths and velocities, flow velocity control (check dams), and appropriate vegetation or rock mulch to prevent erosion and channelization if considering a bottom width less than 2 feet.
- Bioretention areas should have a minimum shoulder of 12 inches between the road edge and the beginning of the bioretention side slope where flush curbs are used. Compaction effort for the shoulder should be 90% standard Proctor.

Figure 6.47: Bioretention Rockery Wall Detail



MINIMUM ROCK SIZES

(H)	SIZE(BASE)	SIZE(TOP)	(D)
2.5'	2-MAN	1-MAN	3"
4'	3-MAN	2-MAN	6"
7'	4-MAN	2-MAN	9"

NOTE:

1. GRAPHIC ADAPTED FROM CITY OF SEATTLE, BROADWVIEW GREEN GRID PROJECT DETAIL.
2. WALLS GREATER THAN 4 FEET IN HEIGHT REQUIRE WALL DESIGN. SEE LOCAL BUILDING CODE REQUIREMENTS.

Source: Low Impact Development Technical Guidance Manual for Puget Sound (WSU-PSP, 2012)

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Bioretention Rockery Wall Detail

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Bottom Slope

- Maximum = 8% (recommended; can go steeper with weirs, per local jurisdiction requirements)
- Evaluate use of underdrain for slope < 2%

Ponding Area and Depth

Plant and soil health, Flow Control needs, Runoff Treatment performance, location in the development, and mosquito breeding cycles will determine drawdown timing. For example, front yards and entrances to residential or commercial developments may require more rapid surface dewatering than necessary for plant and soil health due to aesthetic needs.

Ponding depth criteria:

- The maximum recommended ponding depth is 12 inches. The local jurisdiction may allow a deeper ponding depth, so long as the surface pool drawdown time criteria are met.
- The maximum allowable surface pool drawdown time is 72 hours after cessation of flow to the BMP.

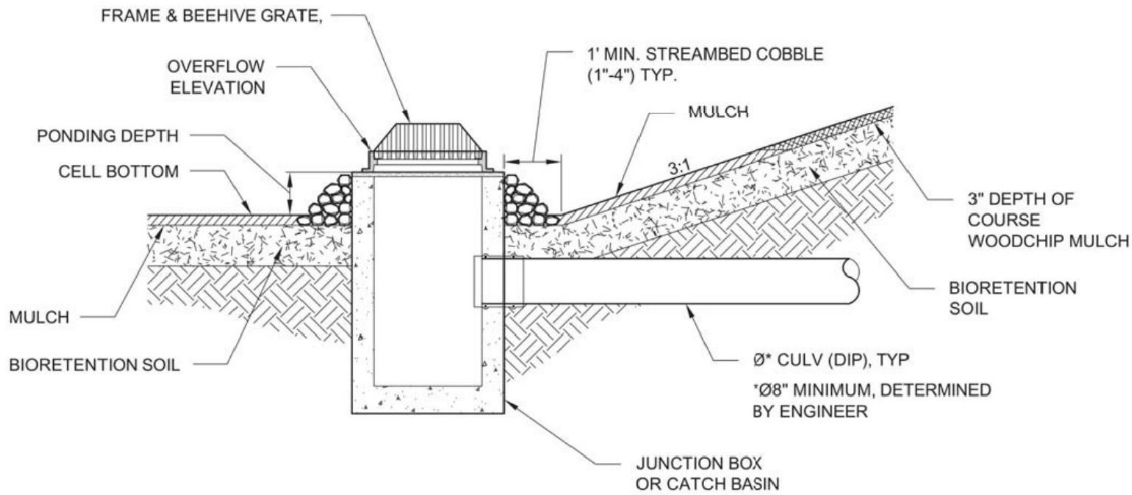
The ponding area provides surface storage for storm flows, particulate settling, and the first stages of pollutant treatment within the bioretention BMP. Pool depth and draw-down rate are recommended to provide surface storage, adequate infiltration capability, and soil moisture conditions that allow for a range of appropriate plant species. Soils must be allowed to dry out periodically in order to restore hydraulic capacity to receive flows from subsequent storms; maintain infiltration rates; maintain adequate soil oxygen levels for healthy soil biota and vegetation; and provide proper soil conditions for biodegradation and retention of pollutants.

Surface Overflow

Surface overflow can be provided by vertical stand pipes that are connected to underdrain systems, horizontal drainage pipes, or armored overflow channels installed at the designed maximum ponding elevations (see Figure 6.48: Typical Bioretention Outlet Structure). Overflow can also be provided by a curb cut at the downgradient end of the bioretention area to direct overflows back to the street. Overflow conveyance structures are necessary for all bioretention BMPs to safely convey flows that exceed the capacity of the BMP and to protect downstream natural resources and property.

The minimum freeboard from the invert of the overflow stand pipe, horizontal drainage pipe, or earthen channel should be 6 inches unless otherwise specified by the local jurisdiction's design standards.

Figure 6.48: Typical Bioretention Outlet Structure



Source: Low Impact Development Technical Guidance Manual for Puget Sound (WSU-PSP, 2012)

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Typical Bioretention Outlet Structure

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Soil Depth

The "Default" and "Custom" BSM depth must be 18 inches to provide Runoff Treatment and good growing conditions for selected plants. Ecology does not recommend "Default" or "Custom" BSM depths greater than 18 inches due to monitoring results indicating that phosphorus can leach from the BSM.

See the High Performance Bioretention Soil Mix Specifications (above) for the appropriate depth (s) of the HPBSM Layer(s).

Filter Fabrics

Do not use filter fabrics between the subgrade and the Bioretention Soil Mix. The gradation between existing soils and Bioretention Soil Mix is not great enough to allow significant migration of fines into the Bioretention Soil Mix. Additionally, filter fabrics may clog with downward migration of fines from the Bioretention Soil Mix.

Underdrains (optional)

Using Underdrains in Bioretention (General Underdrain Guidance)

The volume above an underdrain pipe in a bioretention BMP provides pollutant filtering and minor detention. However, only the void volume of the aggregate below the underdrain invert and above the bottom of the bioretention BMP (subgrade) can be used when calculating the amount of storage volume that provides a Flow Control benefit when infiltrating into the subgrade soils. Assume a 40% void volume for the Type 26 mineral aggregate specified below.

Bioretention should be installed with an underdrain only if any of the following is true:

- Located near sensitive infrastructure (e.g. unsealed basements) and potential for flooding is likely.
- Used for filtering storm flows from gas stations or other pollutant hotspots (requires impermeable liner).
- Located above native soils with infiltration rates that are not adequate to meet maximum pool and drawdown times, or are below a minimum rate allowed by the local government.
- Located in an area with contaminated groundwater and/or contaminated soils;
- Located in an area that does not provide the minimum depth to a hydraulic restriction layer;
- Located where longitudinal slopes are < 2%.

Underdrains should only be used in areas where the underdrain discharge would not be routed to a phosphorus-sensitive water body, unless using the HPBSM. (Ecology, 2016c)

The underdrain can be connected to a downstream open conveyance (such as a bioretention swale), to another bioretention cell as part of a connected treatment system, day-lighted to a dispersion area using an effective flow dispersion practice, or connected to a storm drain.

Underdrain Pipe

Underdrains shall be slotted, thick-walled plastic pipe. The slot opening should be smaller than the smallest aggregate gradation for the gravel filter bed (see Underdrain Aggregate Filter and Bedding Layer below) to prevent migration of the material into the drain. This configuration allows for pressurized water cleaning and root cutting if necessary.

The following are recommendations for underdrain pipes in bioretention BMPs:

- The minimum pipe diameter should be 4 inches (pipe diameter will depend on hydraulic capacity required; 4 to 8 inches is common).
- It should be slotted subsurface drain made of polyvinyl chloride (PVC) per ASTM D1785-12 SCH 40:
  - Slots should be cut perpendicular to the long axis of the pipe, measure 0.04 to 0.069 inches by 1 inch, and be spaced 0.25 inches apart (spaced longitudinally). Slots should be arranged in two rows spaced on 45-degree centers and cover one-half the circumference of the pipe.
  - Slots can be oriented on the top or the bottom of the pipe.
  - See Underdrain Aggregate Filter and Bedding Layer (below) for aggregate gradation appropriate for this slot size.
- Underdrains should be sloped at a minimum of 0.5% unless otherwise specified by a licensed professional.
- Perforated PVC or flexible slotted high-density polyethylene (HDPE) pipe cannot be cleaned with pressurized water or root cutting equipment, are less durable, and are not recommended.
- Wrapping the underdrain pipe in geotextile increases chances of clogging and is not recommended (Low Impact Development Center, 2012).
- A 6-inch-diameter rigid unperforated observation pipe or other maintenance access should be connected to the underdrain every 250 to 300 feet to provide a clean-out port as well as an observation well to monitor dewatering rates (Prince George's County, 2007).

Underdrain Aggregate Filter and Bedding Layer

Aggregate filter and bedding layers buffer the underdrain system from sediment input and clogging. When properly selected for the soil gradation, geosynthetic filter fabrics can provide adequate protection from the migration of fines. However, aggregate filter and bedding layers, with proper gradations, provide a larger surface area for protecting underdrains and are preferred.

Place the underdrain pipe on a bed of the Type 26 aggregate with a minimum thickness of 6 inches and cover with Type 26 aggregate to provide a 1-foot minimum depth around the top and sides of the slotted pipe. See the *Low Impact Development Technical Guidance Manual for Puget Sound* (Hinman and Wulkan, 2012).

Table 6.27: Mineral Aggregate Gradation for Underdrain Filter and Bedding Layer

Sieve size	Percent Passing
¾ inch	100
¼ inch	30-60
US No. 8	20-50
US No. 50	3-12
US No. 200	0-1
Note: The above gradation is a Type 26 mineral aggregate as detailed for gravel backfill for drains in the *City of Seattle Standard Specifications for Road, Bridge, and Municipal Construction* (Seattle Public Utilities, 2014).	

Underdrain Position and Orifice Controls

For bioretention areas with underdrains, elevating the drain to create a temporary saturated zone beneath the drain promotes denitrification (conversion of nitrate to nitrogen gas) and prolongs moist soil conditions for plant survival during dry periods.

Underdrains rapidly convey water out of the bioretention area and decrease detention time and flow retention. Properly designed and installed bioretention have shown very good flow control performance on soils with low infiltration rates (Hinman, 2009). Accordingly, when underdrains are used, orifices or other control structures are recommended to improve flow control. Access for adding or adjusting orifice configurations and other control structures is also recommended for adaptive management and optimum performance.

Orifice and Other Flow Control Structures

The minimum orifice diameter is an important consideration in cold climates, where ice formation could restrict flows if the underdrain is not maintained during freezing periods. Consult the local jurisdiction standards for minimum orifice diameter to be used in design and consider long-term maintenance when selecting any type of flow control structure.

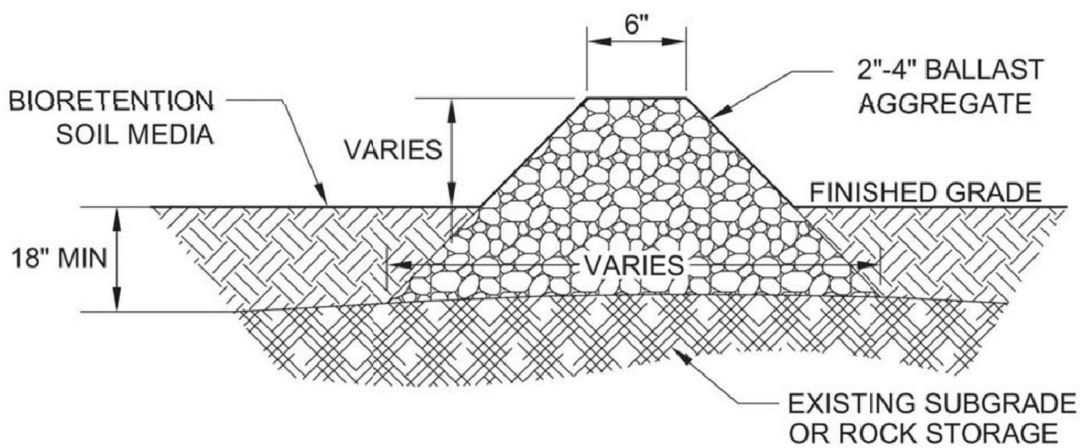
If prolonged periods of freezing temperatures at the depth of the underdrain is not a concern for the site, then the minimum orifice diameter should be 0.5 inches to minimize clogging and maintenance requirements.

Check Dams and Weirs

Check dams or weirs may be necessary for reducing flow velocity and potential erosion, as well as increasing detention time and infiltration capability on sloped sites. Typical materials include concrete, wood, rock, compacted dense soil covered with vegetation, and vegetated hedge rows. Design depends on flow control goals, local regulations for structures within road rights-of-way, and aesthetics. Optimum spacing is determined by flow control benefit (through modeling) in relation to cost considerations. Some typical check dam designs are included in Figure 6.49: Typical Bioretention Check Dam.

If check dams and/or weirs are used, only include the effective storage available behind the check dams and/or weirs in the modeled volume.

Figure 6.49: Typical Bioretention Check Dam



Source: Low Impact Development Technical Guidance Manual for Puget Sound (WSU-PSP, 2012)

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Typical Bioretention Check Dam

Revised June 2013

UIC Discharge

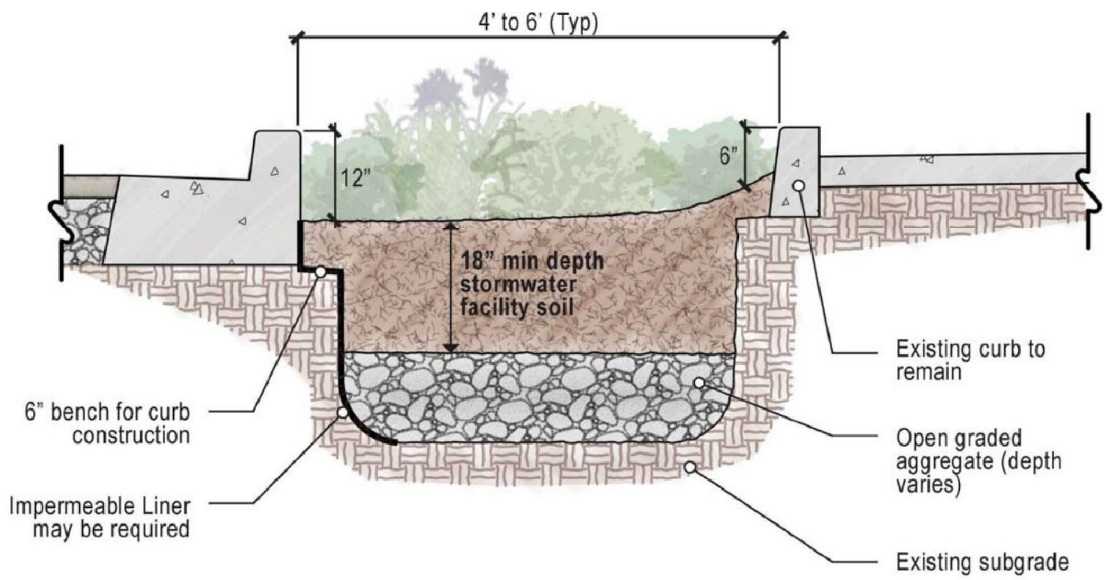
Stormwater that has passed through the Bioretention Soil Mix may also discharge to a gravel-filled dug or drilled drain. Underground Injection Control (UIC) regulations are applicable and must be followed (Chapter 173-218 WAC). See Chapter 5 - UIC Program Guidelines.

Hydraulic Restriction Layers

Adjacent roads, foundations, or other infrastructure may require that infiltration pathways are restricted to prevent excessive hydrologic loading. Two types of restricting layers can be incorporated into bioretention designs:

- Clay (bentonite) liners are low permeability liners. Where clay liners are used underdrain systems are necessary. See 6.1.9.3 Low Permeability Liners for guidelines.
- Geomembrane liners completely block infiltration to subgrade soils and are used for groundwater protection when bioretention BMPs are installed to filter storm flows from pollutant hotspots or on sidewalls of bioretention areas to restrict lateral flows to roadbeds or other sensitive infrastructure (see Figure 6.50: Typical Bioretention Planter Section With Liner). Where geomembrane liners are used to line the entire BMP, underdrain systems are necessary. See 6.1.9.3 Low Permeability Liners for guidelines.

Figure 6.50: Typical Bioretention Planter Section With Liner



Source: Low Impact Development Technical Guidance Manual for Puget Sound (WSU-PSP, 2012)

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Typical Bioretention Planter Section With Liner

Revised June 2016

Plant Materials

In general, the predominant plant material utilized in bioretention areas 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). Research on plant stress in bioretention indicates most water-loving plants are not successful unless well irrigated due to the well draining soil of the BSM mixtures (Taylor et al., 2020), (Marrinan et al., 2019), (Jayakaran et al., 2022). Drought-tolerant species are recommended for the perimeter of the facility or on mounded areas.

Appropriate plants should be selected for sun exposure, soil moisture, and adjacent plant communities. Native species or hardy cultivars are recommended and can flourish in the properly designed and placed BSM with no nutrient or pesticide inputs and 2 to 3 years irrigation for establishment. Manual control of invasive species may be necessary. Pesticides or herbicides should never be applied in bioretention areas.

In arid and semiarid environments, adapted, drought-tolerant species may be better suited to bioretention BMPs than native species. Plantings may also need to withstand added stresses associated with snow plowing and snow storage, where applicable. These conditions suggest a minimum plant establishment of 2 to 3 years.

The side slopes for the bioretention facility (vertical or sloped) can affect the plant selection and must be considered. Additionally, trees can be planted along the side slopes or bottom of bioretention cells that are unlined.

See Appendix 6-B: Planting Recommendations for planting recommendations.

The primary design considerations for plant selection are as follows:

- **Arid climates:** Plants should tolerate sustained drought (USEPA, 2013).
- **Cold climates:** In cold climates, bioretention can be used for snow storage. If used for this purpose, or if used to treat runoff from a surface where salt is used as a deicing chemical, the bioretention area should be planted with salt-tolerant, nonwoody plant species (USEPA, 2013). Other cold climate considerations include rooting depth and season of growth.
- **Soil moisture conditions:** Plants should be tolerant of summer drought, ponding fluctuations, and saturated soil conditions for the lengths of time anticipated by the BMP design.
- **Sun exposure:** Existing sun exposure and anticipated exposure when bioretention plants mature is a primary plant selection consideration.
- **Aboveground and belowground infrastructure in and near the BMP:** Plant size and wind firmness should be considered within the context of the surrounding infrastructure. Rooting depths should be selected to not damage underground utilities if present. Slotted or perforated pipe should be > 5 feet from tree locations (if space allows).
- **Expected pollutant loadings:** Plants should tolerate typical pollutants and loadings from the surrounding land uses.

- **Adjacent plant communities and potential invasive species control:** Consider planting hearty, fast growing species when adjacent to invasive species and anticipate maintenance needs to prevent loss of plants to encroachment of invasive species.
- **Habitat:** Native plants and hardy cultivars attract various insects and birds, and plant palettes can be selected to encourage specific species.
- **Site distances and setbacks for safety on roadway applications:** Provide site distances and setbacks for safety on roadway per local jurisdiction requirements.
- **Location of infrastructure:** Select plants and planting plan to allow visual inspection and easy location of BMP infrastructure (e.g. inlets, overflow structures and other utilities).
- **Expected use:** In higher density settings where foot traffic across bioretention areas is anticipated, elevated pathways with appropriate vegetation or other pervious material that can tolerate pedestrian use can be used. Pipes through elevated berms for pathways across bioretention areas can be used to allow flows from one cell to another.
- **Visual buffering:** Plants can be used to buffer structures from roads, enhance privacy among residences, and provide an aesthetic amenity for the site.
- **Aesthetics:** Visually pleasing plant designs add value to the property and encourage community and homeowner acceptance. Homeowner education and participation in plant selection and design for residential projects should be encouraged to promote greater involvement in long-term care.

Planting schemes will vary with the surrounding landscape and design objectives. For example, plant themes can reflect surrounding wooded or prairie areas. Monoculture planting designs are not recommended. As a general guideline, a minimum of three small trees, three shrubs, and three herbaceous ground cover species should be incorporated to protect against BMP failure due to disease and insect infestations of a single species (Prince George's County, 2007). See local jurisdiction requirements for plant spacing, if applicable.

Native and hardy cultivar plant species, placed appropriately, tolerate local climate and biological stresses and usually require no nutrient or pesticide application in properly designed soil mixes. Natives can be used as the exclusive material in bioretention or in combination with hardy cultivars that are not invasive and do not require chemical inputs. In native landscapes, plants are often found in associations that grow together well, given specific moisture, sun, soil, and plant chemical interactions. Native plant associations can, in part, help guide planting placement. To increase survival rates and ensure the quality of plant material, the following guidelines are suggested:

- Plants should conform to the standards of the latest version of *American Standard for Nursery Stock* as approved by the American Standards Institute, Inc. All plant grades should be those established in the latest version of *American Standards for Nursery Stock*.
- All plant materials shall have normal, well-developed branches and a vigorous root system. Plants should be healthy and free from physical defects, plant diseases, and insect pests. Shade and flowering trees should be symmetrically balanced. Major branches should not have V-shaped crotches capable of causing structural weakness. Trunks should be free of unhealed branch removal wounds > 1-inch diameter (Low Impact Development Center,

2012).

- **Plant size:** For installation, small plant material provides several advantages and is recommended. Specifically, small plant material requires less careful handling, less initial irrigation, experiences less transplant shock, is less expensive, adapts more quickly to a site, and transplants more successfully than larger material (Sound Native Plants, 2000). Typically, small herbaceous material and grasses are supplied as plugs or 4-inch pots, and small trees and shrubs are generally supplied in pots of 3 gallons or less.

- **Plant maturity and placement:** Bioretention areas provide excellent soil and growing conditions; accordingly, plants will likely reach maximum height and width. Planting plans should anticipate these dimensions for site distances, adjacent infrastructure, and planting densities. Shrubs should be located taking into account size at maturity to prevent excessive shading and ensure establishment and vigor of bioretention area bottom plants.

- All plants should be tagged for identification when delivered.

- Optimum planting time is during April or May; although fall planting between September 15 and October 31 is acceptable.

Mulch Layer

You can design bioretention areas with or without a mulch layer; however, it is recommended in a recent study (Jayakaran et al., 2022) to maintain a 2-3 inch mulch layer for improved soil moisture, weed suppression, plant survival and pollutant capture. Properly selected mulch material reduces weed establishment (particularly during plant establishment period), the need for herbicides, regulates soil temperatures and moisture, and adds organic matter to soil.

The material(s) used for the mulch layer shall not include biosolids or manures.

When used, mulch should be:

- Coarse compost in the bottom of the BMP and up to the ponding elevation (compost is less likely to float when the cell is inundated);

- Shredded or chipped hardwood or softwood on side slopes above ponding elevation and rim area. Arborist mulch is mostly woody trimmings from trees and shrubs and is a good source of mulch material. Wood chip operations are a good source for mulch material that has more control of size distribution and consistency. Do not use shredded construction wood debris or any shredded wood to which preservatives have been added.

- Free of weed seeds, soil, roots and other material that is not bole or branch wood and bark.

- A maximum of 2 to 3 inches thick to prevent the inhibition of proper oxygen and carbon dioxide cycling between the soil and atmosphere (Prince George's County, 2007).

Mulch shall **not** be:

- Grass clippings (decomposing grass clippings are a source of nitrogen and are not recommended for mulch in bioretention areas).

- Pure bark (bark is essentially sterile and inhibits plant establishment).

If planting bioretention areas is delayed (e.g. BSM is placed in summer and plants are not installed until fall), mulch should be placed immediately to prevent weed establishment.

Dense ground cover enhances soil structure from root activity, does not have the tendency to float during heavy rain events, inhibits weed establishment, provides additional aesthetic appeal, and is recommended when high heavy metal loading is not anticipated. Mulch is recommended in conjunction with the ground cover until ground cover is established.

Research indicates that most attenuation of heavy metals in bioretention cells occurs in the first 1 to 2 inches of the mulch layer. That layer can be removed or added to as part of a standard and periodic landscape maintenance procedure. No indications of special disposal needs are indicated at this time from older bioretention BMPs in the eastern United States (personal communication between C. Hinman and L. Coffman).

In bioretention areas where higher flow velocities are anticipated, an aggregate mulch may be used to dissipate flow energy and protect underlying Bioretention Soil Mix. Aggregate mulch varies in size and type, but 1 to 1 1/2 inch gravel (rounded) decorative rock is typical.

Construction Criteria

Prior to construction, meet with the contractor, subcontractors, construction management, and inspection staff to review critical design elements and confirm specification requirements, proper construction procedures, construction sequencing, and inspection timing. Runoff from construction activity should not be allowed into the bioretention areas unless there is no other option for conveying construction stormwater, there is adequate protection of the subgrade soil and BSM, and introduction of stormwater is approved by a licensed professional.

Excavation

Soil compaction can lead to bioretention BMP failure; accordingly, minimizing compaction of the base and sidewalls of the bioretention area is critical. Excavation should never be allowed during wet or saturated conditions (compaction can reach depths of 2-3 feet during wet conditions and mitigation is likely to not be possible). Excavation should be performed by machinery operating adjacent to the bioretention BMP, and no heavy equipment with narrow tracks, narrow tires, or large lugged, high pressure tires should be allowed on the bottom of the bioretention BMP. If machinery must operate in the bioretention area for excavation, use light weight, low ground-contact pressure equipment and rip the base at completion to refracture soil to a minimum of 12 inches. If machinery operates in the BMP footprint, subgrade infiltration rates must be field tested and compared to initial K_{sat} tests obtained during design. Failure to meet or exceed the initial K_{sat} tests will require revised engineering designs to verify achievement of Runoff Treatment and Flow Control benefits that were estimated in the Stormwater Site Plan.

Prior to placement of the Bioretention Soil Mix, the finished subgrade shall:

- Be scarified to a minimum depth of 3 inches.
- Have any sediment deposited from construction runoff removed. To remove all introduced sediment, subgrade soil should be removed to a depth of 3-6 inches and replaced with Bioretention Soil Mix.
- Be inspected by the responsible engineer to verify required subgrade condition.

Sidewalls of the BMP, beneath the surface of the Bioretention Soil Mix, can be vertical if soil stability is adequate. Exposed sidewalls of the completed bioretention area with Bioretention Soil Mix in place should be no steeper than 3H:1V. The bottom of the BMP should be flat for cells and planters, and sloped to match the design grade for swales.

Bioretention Soil Mix Placement

On-site soil mixing or placement shall not be performed if the Bioretention Soil Mix or subgrade soil is saturated. The Bioretention Soil Mix should be placed and graded by machinery operating adjacent to the bioretention BMP. If machinery must operate in the bioretention cell for soil placement, use light weight equipment with low ground-contact pressure. If machinery operates in the BMP footprint, subgrade infiltration rates must be field tested and compared to initial K_{sat} tests obtained during design. Failure to meet or exceed the initial K_{sat} tests will require revised engineering designs to verify achievement of Runoff Treatment and Flow Control benefits that were estimated in the Stormwater Site Plan.

The soil mixture shall be placed in horizontal layers not to exceed 6 inches per lift for the entire area of the bioretention BMP.

Compact the Bioretention Soil Mix to a relative compaction of 85 percent of modified maximum dry density (ASTM D 1557). Compaction can be achieved by boot packing (simply walking over all areas of each lift), and then apply 0.2 inches of water per 1 inch of Bioretention Soil Mix depth. Water for settling should be applied by spraying or sprinkling.

Temporary Erosion and Sediment Control (TESC)

Controlling erosion and sediment are most difficult during clearing, grading, and construction; accordingly, minimizing site disturbance to the greatest extent practicable is the most effective sediment management. During construction:

- Bioretention BMPs should not be used as sediment control BMPs, and all drainage should be directed away from bioretention BMPs after initial rough grading. Flow can be directed away from the BMP with temporary diversion swales or other approved protection. If introduction of construction runoff cannot be avoided see below for guidelines.
- Construction on bioretention BMPs should not begin until all contributing drainage areas are stabilized according to erosion and sediment control BMPs and to the satisfaction of the engineer.
- If the design includes curb and gutter, the curb cuts and inlets should be blocked until Bioretention Soil Mix and mulch have been placed and planting completed (when possible), and dispersion pads are in place.

Every effort should be made during design, construction sequencing, and construction to prevent sediment from entering bioretention BMPs. However, bioretention areas are often distributed throughout the project area and can present unique challenges during construction. Minimizing sedimentation, removing sediment from bioretention areas, and replacing any soil removed with new BSM when project is complete are necessary for a proper functioning system. Deep compaction in bioretention areas is very difficult to mitigate and must be prevented.

See the *Low Impact Development Technical Guidance Manual for Puget Sound* (Hinman and Wulkan, 2012) for guidelines if no other options exist and runoff during construction must be directed through the bioretention BMPs.

Erosion and sediment control practices must be inspected and maintained on a regular basis.

Verification

If using the default Bioretention Soil Mix, pre-placement laboratory analysis for saturated hydraulic conductivity of the Bioretention Soil Mix is not required. Verification of the mineral aggregate gradation, compliance with the compost specifications, and the mix ratio must be provided.

If using a custom Bioretention Soil Mix, verification of compliance with the minimum design criteria cited above for such custom mixes must be provided. This will require laboratory testing of the material that will be used in the installation. Testing shall be performed by a Seal of Testing Assurance, AASHTO, ASTM or other standards organization accredited laboratory with current and maintained certification. Samples for testing must be supplied from the Bioretention Soil Mix that will be placed in the bioretention areas.

If testing infiltration rates is necessary for post-construction verification, use the Pilot Infiltration Test (PIT) method or a double ring infiltrometer test (or other small-scale testing allowed by the local government with jurisdiction). If using the PIT method, do not excavate the Bioretention Soil Mix (conduct the test at the elevation of the finished Bioretention Soil Mix), use a maximum of 6 inch ponding depth and conduct the test before plants are installed.

Maintenance

Bioretention areas require periodic plant, soil, and mulch layer maintenance to ensure optimum infiltration, storage, and pollutant removal capabilities. Providing more frequent and well-timed maintenance (e.g., weeding prior to seed dispersal) during the first 3 years will ensure greater success and reduce future maintenance of bioretention areas. In general, bioretention maintenance recommendations are typical landscape care procedures and include the following:

- **Watering:** Plants should be selected to be drought tolerant and not require watering after establishment (2 to 3 years). Watering may be required during prolonged dry periods after plants are established.
- **Erosion control:** Inspect flow entrances, ponding area, and surface overflow areas periodically, and replace soil, plant material, and/or mulch layer in areas if erosion has occurred. Properly designed BMPs with appropriate flow velocities should not have erosion problems except perhaps in extreme events. If erosion problems occur, the following should be reevaluated and adjusted as needed:
    1. amount of contributing area draining to the BMP;
    2. flow velocities and gradients within the cell; and
    3. flow dissipation and erosion protection strategies in the pretreatment area and flow entrance.

If sediment is deposited in the bioretention area, immediately determine the source within the contributing area, stabilize, and remove excess surface deposits.

- **Sediment removal:** Follow the maintenance plan schedule for visual inspection and remove sediment if the volume of the ponding area has been compromised.
- **Plant material:** Depending on safety (pedestrian obstruction or site distances) and aesthetic requirements, occasional pruning and removing dead plant material may be necessary. Replace all dead plants, and if specific plants have a high mortality rate, assess the cause and replace with appropriate species. Periodic weeding is necessary until plants are established and adequately shade and capture the site from weed establishment.
- **Weeding:** Invasive or nuisance plants should be removed regularly and not allowed to accumulate and exclude planted species. At a minimum, schedule weeding with inspections to coincide with important horticultural cycles (e.g. prior to major weed varieties dispersing seeds). Weeding should be done manually and without herbicide applications. The weeding schedule should become less frequent if the appropriate plant species and planting density are used and the selected plants grow to capture the site and exclude undesirable weeds.
- **Nutrients and pesticides:** The soil mix and plants are selected for optimum fertility, plant establishment, and growth. Nutrient and pesticide inputs should not be required and may degrade the pollutant processing capability of the bioretention area, as well as contribute pollutant loads to receiving waters. By design, bioretention areas are located in areas where phosphorus and nitrogen levels may be elevated, and these should not be limiting nutrients. If in question, have the soil analyzed for fertility.
- **Mulch:** Replace mulch annually in bioretention BMPs where heavy metal deposition is high (e.g. contributing areas that include gas stations, ports and roads with high traffic loads). In residential settings or other areas where metals or other pollutant loads are not anticipated to be high, replace or add mulch as needed to maintain a 2 to 3 inch depth.
- **Soil:** Soil mixes for bioretention BMPs are designed to maintain long-term fertility and pollutant processing capability. Estimates from metal attenuation research suggest that metal accumulation should not present an environmental concern for at least 20 years in bioretention systems, but this will vary according to pollutant load. Replacing mulch media in bioretention BMPs where heavy metal deposition is likely provides an additional level of protection for prolonged performance. If in question, have soil analyzed for fertility and pollutant levels.

Refer to Appendix 6-A: BMP Maintenance Tables for additional maintenance guidelines.

BMP F6.24: Permeable Pavement

Purpose and Definition

Ecology accepts Permeable Pavement as having the potential to meet 2.4.5 CE5: Runoff Treatment and 2.4.6 CE6: Flow Control for the contributing drainage areas depending upon site conditions, configuration, and sizing.

Pavement for vehicle and pedestrian travel occupies roughly twice the space of buildings. While essential for the movement of people, goods, and services, pavement used by vehicles generates significant levels of heavy metals and most hydrocarbon pollutants in stormwater (Ferguson, 2005). The concentration of pollutants (specifically metals and hydrocarbons) in surface flow from pavement used by vehicles, in general, increases with traffic intensity (Ferguson, 2005), (Colandini et al., 1995).

Both pedestrian and vehicle (impervious) pavements also contribute to increased peak flow, flow durations, and associated physical habitat degradation of streams and wetlands. Effective management of stormwater quality and quantity from paved surfaces is, therefore, critical for improving conditions in receiving waters.

Permeable pavement can be designed to accommodate pedestrian, bicycle, and auto traffic while allowing infiltration, treatment, and storage of stormwater. The general categories of permeable pavement include the following:

- **Porous hot or warm-mix asphalt pavement:** A flexible pavement similar to standard asphalt that uses a bituminous binder to adhere aggregate together. However, the fine material (sand and finer) is reduced or eliminated and, as a result, voids form between the aggregate in the pavement surface and allow water to infiltrate. See Figure 6.51: Example of a Permeable Pavement (Concrete or Asphalt) Section and Figure 6.52: Typical Porous Asphalt Section.

- **Pervious Portland cement concrete:** A rigid pavement similar to conventional concrete that uses a cementitious material to bind aggregate together. However, the fine aggregate (sand) component is reduced or eliminated in the gradation and, as a result, voids form between the aggregate in the pavement surface and allow water to infiltrate. See Figure 6.51: Example of a Permeable Pavement (Concrete or Asphalt) Section.

- **Permeable interlocking concrete pavements (PICPs) and aggregate pavers:** PICPs are solid, precast, manufactured modular units. The solid pavers are impervious, high-strength Portland cement concrete manufactured with specialized production equipment. Pavements constructed with these units create joints that are filled with permeable aggregates and installed on an open-graded aggregate bedding course.

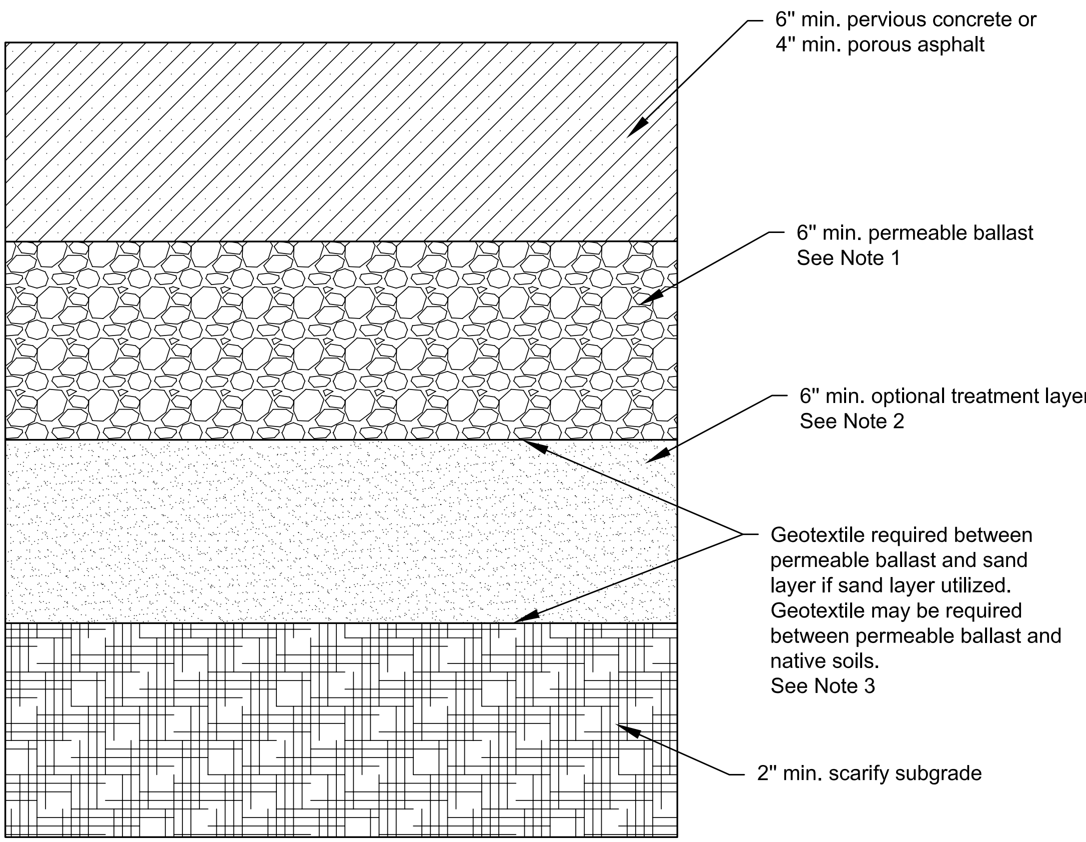
  Aggregate pavers (sometime called pervious pavers) are a different class of pavers from PICP. These include modular precast paving units made with similar-sized aggregates bound together with Portland cement concrete with high-strength epoxy or other adhesives. Like PICP, the joints or openings in the units are filled with open-graded aggregate and placed on an open-graded aggregate bedding course. Aggregate pavers are intended for pedestrian use only.

  See Figure 6.53: Example of a Permeable Paver Section.

- **Grid systems made of concrete or plastic:** Concrete units are precast in a manufacturing facility, packaged and shipped to the site for installation. Plastic grids typically are delivered to the site in rolls or sections. The openings in both grid types are filled with topsoil and grass or permeable aggregate. Plastic grid sections connect together and are pinned into a dense-graded base, or are eventually held in place by the grass root structure. Both systems can be installed on an open-graded aggregate base as well as a dense-graded aggregate base.

Nomenclature for permeable pavement varies among designers, installers, and geographic regions. For this manual, permeable pavement is used to describe the general category of pavements that are designed to allow infiltration through the pavement section. The following terms are used throughout this manual and represent the major categories of permeable pavements that carry vehicle as well as pedestrian traffic: pervious concrete, porous asphalt, permeable interlocking concrete pavements, and concrete and plastic grid pavements.

Figure 6.51: Example of a Permeable Pavement (Concrete or Asphalt) Section



Notes:

1. Thicker section of ballast may be required to establish sufficient reservoir capacity. Engineer to provide calculations.
2. 6" minimum treatment layer of sand or media if required.
3. Geotextile may be required between native soils and permeable pavement section, per soils professional recommendation. Geotextile will be required between permeable ballast and sand layer. Geotextile shall be geotextile for seperation per WSDOT 9.33.2(1), woven, Table 3, and installed per WSDOT 2-12.3(1).

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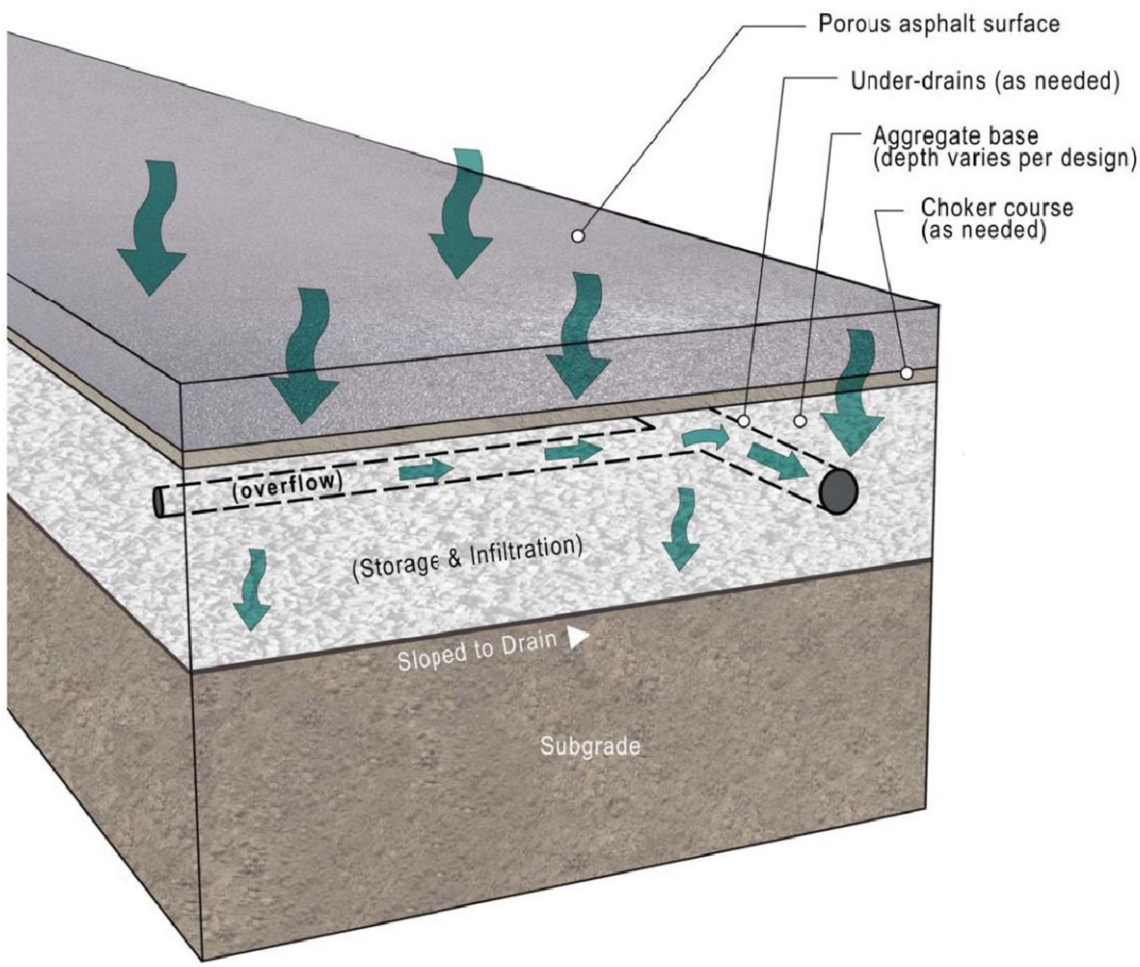
Example of a Permeable Pavement (Concrete or Asphalt) Section

Revised May 2019

Figure 6.52: Typical Porous Asphalt Section



Source: CleanWater Services and AHBL, Inc.

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Typical Porous Asphalt Section

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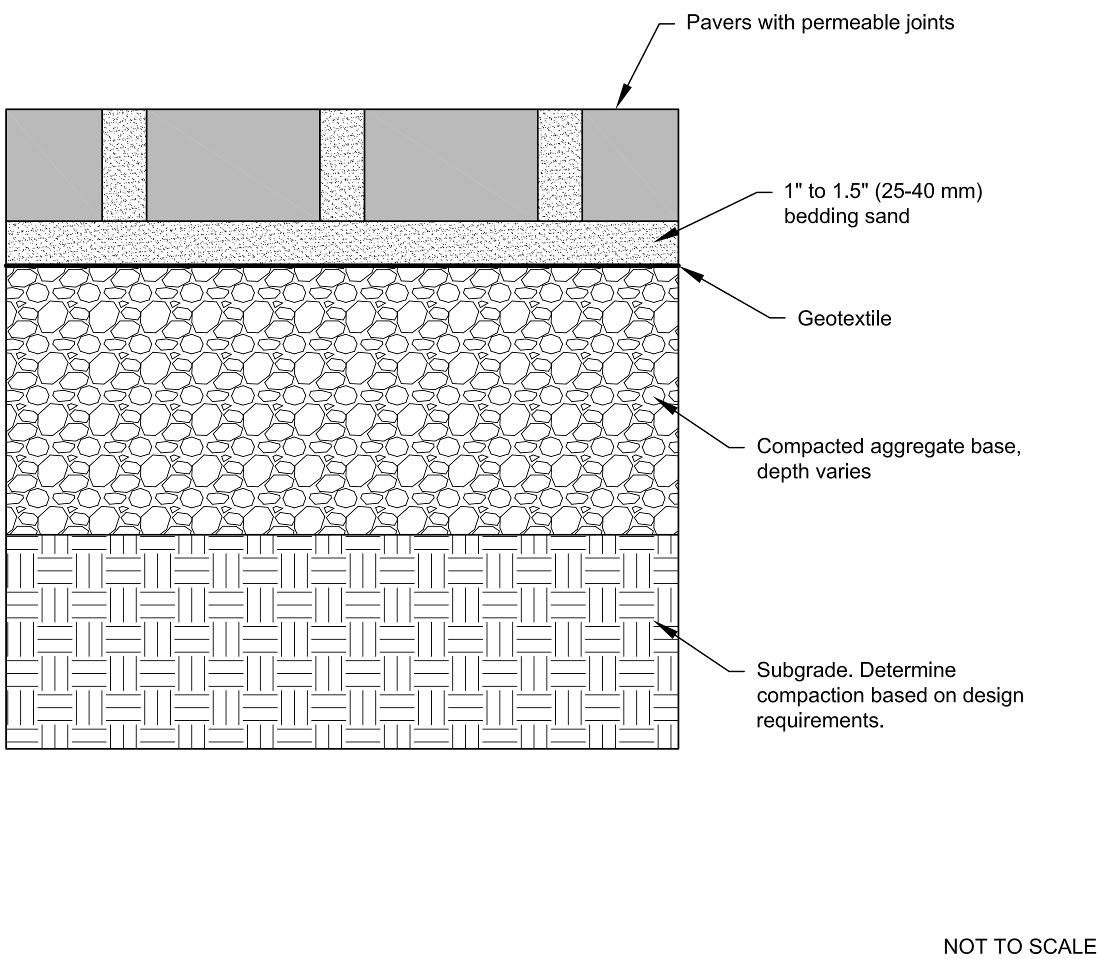
Figure 6.53: Example of a Permeable Paver Section



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Example of a Permeable Paver Section

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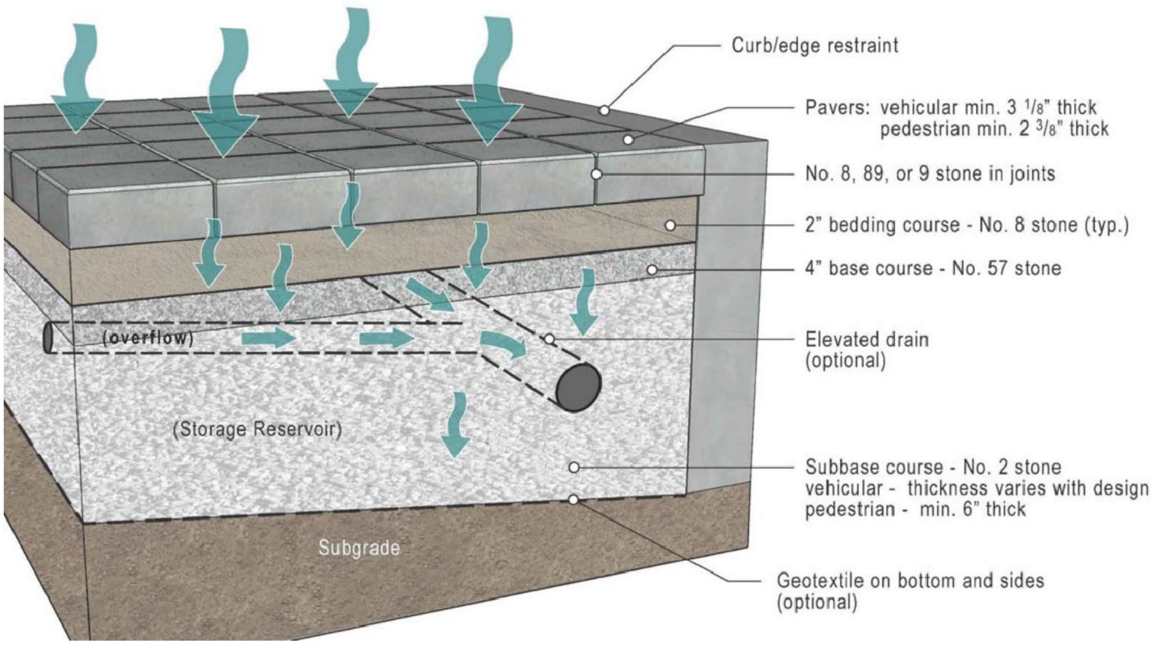
Figure 6.54: Typical Permeable Interlocking Concrete Paver Section



Source: CleanWater Services and AHBL, Inc.

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Typical Permeable Interlocking Concrete Paver Section

Revised June 2013

Applications and Limitations

Permeable pavements are an important integrated management practice within the LID approach and can be designed to accommodate pedestrian, bicycle and auto traffic while allowing Runoff Treatment and Flow Control of stormwater.

Permeable pavements are appropriate in many applications where traditionally impermeable pavements have been used. Typical applications for permeable pavements include parking lots, sidewalks, pedestrian and bike trails, driveways, residential access roads, and emergency and facility maintenance roads.

Grid pavers are not intended for streets but are often used for emergency access lanes and intermittently used (overflow) parking areas. All other types of permeable pavement can withstand loads from the number of trucks associated with local roads. Specialized engineering expertise is required for designs for heavy loads and cold weather considerations.

Thoroughfares, highways, and other roads that combine high vehicle loads and high-speed traffic are generally not considered appropriate for permeable pavements. However, porous asphalt has proven structurally sound and remained permeable in a few arterial and highway applications (Hossain et al., 1992) and pervious concrete and permeable interlocking concrete pavement have been successfully used in industrial settings with low speeds and high vehicle loads.

Limitations to permeable pavements include:

- No run-on from pervious surfaces is preferred. If runoff comes from minor or incidental pervious areas, those areas must be fully stabilized.
- Unless the pavement, base course, and subgrade have been designed to accept runoff from adjacent impervious surfaces, slope impervious runoff away from the permeable pavement to the maximum extent practicable. Sheet flow from up-gradient impervious areas is not recommended, but permissible if the permeable pavement area is greater than the impervious pavement area.

Climate and Freeze-Thaw Considerations

Properly designed, constructed, and maintained permeable pavement can be an effective design solution in cold weather climates. Permeable pavement use is geographically widespread throughout the United States and has been used in arid climates such as Tucson, Arizona, wet climates such as areas of western Washington and Florida, and areas with significant seasonal temperature variation such as Ohio and Minnesota.

Properly designed permeable pavement installations have performed well in the midwestern and northeastern United States, where freeze-thaw cycles are severe (Adams, 2003), (Wei, 1986). Cold weather design guidance from the University of New Hampshire is recognized in many areas (e.g. Michigan and Ohio) as the foremost guidance for the design of permeable pavements in cold weather climates (UNHSC, 2009).

It is recommended that the permeable pavement BMP is sized such that the aggregate storage bed layer extends at least 4 inches below the frost line.

Infeasibility Criteria

The following screening criteria describe conditions that make permeable pavement infeasible or inefficient. If a project triggers any of the below-listed screening criteria, yet the proponent wishes to use permeable pavement, they may propose a functional design that effectively mitigates these issues to the local jurisdiction.

These criteria also apply to impervious pavements that would employ stormwater collection from the surface of impervious pavement with redistribution below the pavement.

- Citation of any of the following infeasibility criteria must be based on an evaluation of site-specific conditions and a written recommendation from an appropriate licensed professional (e.g. engineer, geologist, hydrogeologist)
    - Where professional geotechnical evaluation recommends infiltration not be used due to reasonable concerns about erosion, slope failure, or down gradient flooding.
    - Within an area whose groundwater drains into an erosion hazard, or landslide hazard area.
    - Where infiltrating and ponded water below new permeable pavement area would compromise adjacent impervious pavements.
    - Where infiltrating water below a new permeable pavement area would threaten existing below grade basements.
    - Where infiltrating water would threaten shoreline structures such as bulkheads.
    - Down slope of steep, erosion prone areas that are likely to deliver sediment.
    - Where fill soils are used that can become unstable when saturated.
    - On excessively steep slopes where water within the aggregate base layer or at the sub-grade surface cannot be controlled by detention structures and may cause erosion and structural failure, or where surface runoff velocities may preclude adequate infiltration at the pavement surface.
    - Where permeable pavements can not provide sufficient strength to support heavy loads at industrial facilities such as ports.
    - Where installation of permeable pavement would threaten the safety or reliability of pre-existing underground utilities, pre-existing underground storage tanks, or pre-existing road sub-grades.
- The following infeasibility criteria are based on conditions such as topography and distances to predetermined boundaries. Citation of the following criteria do not need site-specific written recommendations from a licensed professional, although some may require professional services to determine:
    - Within an area designated as an erosion hazard, or landslide hazard.
    - Within 50 feet from the top of slopes that are greater than 20%.

- For properties with known soil or groundwater contamination (typically federal Superfund sites or state cleanup sites under the Model Toxics Control Act (MTCA)):
  - Within 100 feet of an area known to have deep soil contamination;
  - Where groundwater modeling indicates infiltration will likely increase or change the direction of the migration of pollutants in the groundwater;
  - Wherever surface soils have been found to be contaminated unless those soils are removed within 10 horizontal feet from the infiltration area;
  - Any area where permeable pavement BMPs are prohibited by an approved cleanup plan under the state Model Toxics Control Act (MTCA) or Federal Superfund Law, or an environmental covenant under Chapter 64.70 RCW.
- Within 100 feet of a closed or active landfill.
- Within 100 feet of a drinking water well, or a spring used for drinking water supply, if the permeable pavement is (or has run-on from) a pollution-generating surface.
- Within 10 feet of a small on-site sewage disposal drainfield, including reserve areas, and grey water reuse systems. For setbacks from a “large on-site sewage disposal system”, see Chapter 246-272B WAC.
- Within 10 feet of any underground storage tank and connecting underground pipes, regardless of tank size. As used in these criteria, an underground storage tank means any tank used to store petroleum products, chemicals, or liquid hazardous wastes of which 10% or more of the storage volume (including volume in the connecting piping system) is beneath the ground surface.
- At multi-level parking garages, and over culverts and bridges.
- Where the site design cannot avoid putting pavement in areas likely to have long-term excessive sediment deposition after construction (e.g. construction and landscaping material yards).
- Where the subgrade slope exceeds 6 percent after reasonable efforts to grade.
- Where the permeable pavement wearing course slope exceeds the maximum recommended design slope (see design criteria below) after reasonable efforts to design grade.
- Where, below a pollution-generating permeable pavement (e.g. a road or parking lot) the native soils do not meet the criteria for Runoff Treatment in 6.5.6 Site Suitability Criteria (SSC).

  Note: In these instances, the local jurisdiction has the option of requiring an engineered treatment layer (see Permeable Pavement as Runoff Treatment) to render the permeable pavement BMP as "feasible". The appropriate treatment layer depends on if the site must meet Runoff Treatment requirements per 2.4.5 CE5: Runoff Treatment.

- Where seasonal high groundwater or an underlying impermeable/low permeable layer would create saturated conditions within one foot of the bottom of the permeable pavement BMP. The bottom of the permeable pavement BMP is the bottom of the lowest layer that has been designed to be part of the BMP, such as the lowest gravel base course or a sand layer used for treatment below the permeable pavement.
- Where underlying soils are unsuitable for supporting traffic loads when saturated. Soils meeting a California Bearing Ratio of 5% are considered suitable for residential access roads.
- Where appropriate field testing indicates soils have a measured (a.k.a. initial) native soil saturated hydraulic conductivity (K_{sat}) less than 0.3 inches per hour. See 6.5.4 Determining the Design Infiltration Rate of the Native Soils.
- Roads that receive more than very low traffic volumes. Roads with a projected Average Daily Traffic (ADT) volume of 400 vehicles or less are very low volume roads (AASHTO, 2001), (USDOT, 2013).

  Note: This infeasibility criterion does not extend to sidewalks and other non-traffic bearing surfaces.
- Areas having more than very low truck traffic. Areas with very low truck traffic volumes are roads 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.
- Where replacing existing impervious surfaces, unless the existing surface is a non-pollution generating surface over an outwash soil with a measured (initial) saturated hydraulic conductivity (K_{sat}) of four inches per hour or greater.
- At sites where the land use requires oil control BMPs per 6.1.2 Choosing Your Runoff Treatment BMPs.
- In areas with “industrial activity” as identified in 40 CFR 122.26(b)(14).
- Where the risk of concentrated pollutant spills is more likely such as gas stations, truck stops, and industrial chemical storage sites.
- Where routine (such as weekly), heavy applications of sand occur in frequent snow zones to maintain traction during weeks of snow and ice accumulation.

- A local government may designate geographic areas within which permeable pavement, or certain types of permeable pavement, may be designated as infeasible due to year-round, seasonal or periodic high groundwater conditions, or due to inadequate infiltration rates. Designations must be based upon a preponderance of field data, collected within the area of concern, that indicate a high likelihood of failure to achieve the minimum groundwater clearance or infiltration rates identified in the above infeasibility criteria. The local government must develop a technical report, and make it available upon request to Ecology. The technical report must be authored by (a) professional(s) with appropriate expertise (e.g. registered engineer, geologist, hydrogeologist, or certified soil scientist), and document the location and pertinent values/observations of data that were used to recommend the designation and boundaries for the geographic area. The types of pertinent data include, but are not limited to:

    - Standing water heights or evidence of recent saturated conditions in observation wells, test pits, test holes, and well logs.
    - Observations of areal extent and time of surface ponding, including local government or professional observations of high water tables, frequent or long durations of standing water, springs, wetlands, and/or frequent flooding.
    - Results of infiltration tests

- In addition, a local government can map areas that meet a specific infeasibility criterion listed above provided they have an adequate data basis. Criteria that are most amenable to mapping are:
    - Where land for permeable pavement is within an area designated by the local government as an erosion hazard, or landslide hazard
    - Within 50 feet from the top of slopes that are greater than 20% and over 10 feet vertical relief
    - Within 100 feet of a closed or active landfill

Design Criteria

Design Considerations Based on Permeable Pavement Type

There are many design needs common to most permeable pavements and some unique aspects to each system. Industry associations and product manufacturers can assist with design and specification guidance. Proper design is essential for adequate infiltration, storage, and release of storm flows as well as structural integrity. Construction specifications should stipulate that contractors on the job site hold certificates from industry programs on installing their systems. The pervious concrete and permeable interlocking concrete paver industry associations offer such education programs for contractors. Specifications should also include contractor experience with projects of similar size and scope.

General Design Criteria

- Ecology has listed herein the critical design criteria you must consider when designing permeable pavement. Local governments can adopt alternative design criteria, as long as it does not conflict with the criteria listed herein.
- You can find additional guidance for permeable pavement design in the *Low Impact Development Technical Guidance Manual for Puget Sound* (Hinman and Wulkan, 2012).

Note that the *Low Impact Development Technical Guidance Manual for Puget Sound* (Hinman and Wulkan, 2012) is for additional informational purposes only. You must follow the guidance within this manual if there are any discrepancies between this manual and the *Low Impact Development Technical Guidance Manual for Puget Sound* (Hinman and Wulkan, 2012).

- Project submission requirements: Submit results of infiltration (K_{sat}) testing, groundwater elevation testing (or other documentation and justification for the rates and hydraulic restriction layer clearances) with the Stormwater Site Plan as justification for the feasibility decision regarding permeable pavement, and as justification for assumptions made in the runoff modeling. If necessary, also submit documentation of meeting the criteria for Runoff Treatment in 6.5.6 Site Suitability Criteria (SSC).
- Legal documentation to track permeable pavement obligations: Where drainage plan submittals include assumptions in regard to size and location of permeable pavement, approval of the plat or short-plat should identify the permeable pavement obligation of each lot; and the appropriate lots should have deed requirements for construction and maintenance of those BMPs.

Permeable Pavement Design Steps

The general design steps for designing permeable pavement are as follows:

1. Select a permeable pavement type based on site characteristics (slope) and preferred aesthetic.
2. Determine if Runoff Treatment is needed (e.g. to comply with 2.4.5 CE5: Runoff Treatment).
3. Determine the subgrade infiltration rate.
4. Determine if an underdrain is required.
5. Model the permeable pavement, including any contributing area providing runoff onto the permeable pavement.
6. Use the model results to determine the maximum water surface elevation, accounting for the void space in the storage bed.
7. Size the storage bed depth below the first overflow (or underdrain elevation, if used as determined in Step 4 above).
8. Consider increasing the storage depth if the elevation calculated in Step 6 is above the frost depth elevation.

Permeable Pavement as Runoff Treatment

Ecology does not offer a Runoff Treatment credit (i.e. basic, metals, phosphorus, or oil control) for stormwater passing through a standard permeable pavement wearing course or the aggregate base layer. Ecology does presume that the standard permeable pavement wearing course provides Pretreatment.

The following design approaches can be used to achieve Runoff Treatment as part of a permeable pavement BMP:

- The native soils below the permeable pavement meet the criteria for Runoff Treatment per 6.5.6 Site Suitability Criteria (SSC).

  This would meet the basic, metals, and phosphorus treatment performance goals.

- The permeable pavement design includes a 6" layer of sand that meets the size gradation (by weight) given in Table 6.30: Sand Medium Specification.

  This would meet the basic treatment performance goal.

- The permeable pavement design includes a 12" layer of sand that meets the size gradation (by weight) given in Table 6.30: Sand Medium Specification.

  This would meet the basic and metals treatment performance goals.

Note that any treatment layers (e.g. sand layers or native soil layers), as well as the aggregate base layer must be considered as part of the BMP when determining the separation from the bottom of the BMP to the seasonal high groundwater or other restrictive layer.

Slope Considerations

- Minimum slope = 1% to 2% to allow for surface overflow in extreme rainfall
- Consider detention structures (e.g. subsurface check dams) on slopes > 3%
- General recommendations for maximum slopes for permeable pavement types are as follows:
  - Porous asphalt: 5%
  - Pervious concrete: 12%
  - Permeable interlocking concrete pavers: 12%
  - Concrete and plastic grid systems: maximum slope recommendations vary by manufacturer and generally range from 6% to 12% (primarily a traction rather than infiltration or structural limitation). Contact the manufacturer or local supplier for specific product recommendations.

Subgrade

- In general, the requirement for subgrade strength beneath rigid pavement (pervious concrete) is less than for flexible pavements (porous asphalt). The structural performance of flexible permeable pavement systems relies on the proper design and construction of the aggregate base to provide structural support on subgrades with less compaction and increased soil moisture.
- Compact the subgrade to the minimum compaction necessary for structural stability. Two guidelines currently used to specify subgrade compaction are “firm and unyielding”

(qualitative), and 90- 92% Standard Proctor (quantitative). Subgrade should not be subject to compaction beyond the qualitative and quantitative levels identified herein. Do not allow construction traffic and equipment onto the subgrade except when construction access on subgrade is required for the pavement section installation.

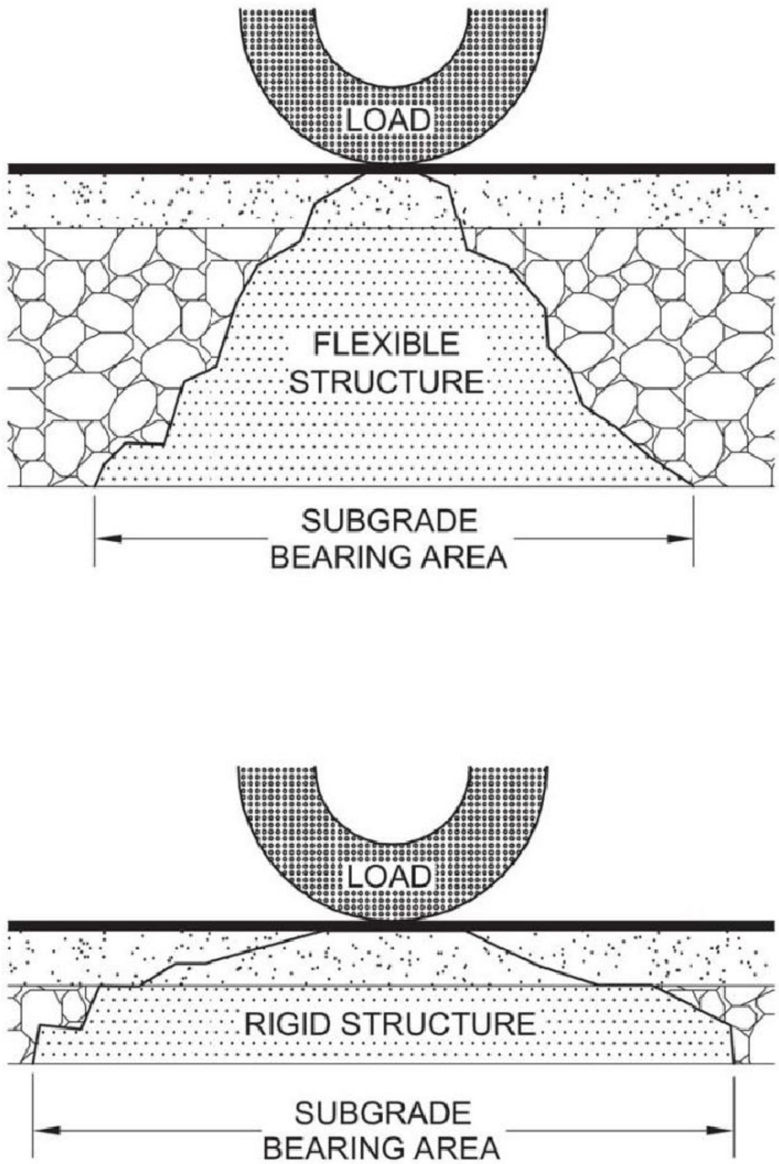
- See Installation Guidelines (for All Permeable Pavement Types) for construction techniques to reduce compaction of the subgrade soils.

Infiltration and Subgrade Structural Support

Water, and particularly prolonged saturated conditions, can weaken most subgrade soils (Ferguson, 2005). For flexible permeable pavements, reduced compaction of the subgrade and the introduction of water to the subgrade can be compensated for by proper structural and hydrologic design, by selecting proper aggregate base materials, and increasing the aggregate base depth. A properly designed aggregate base distributes vehicle load and subgrade bearing area (see Figure 6.55: Conceptual Diagram of the Load Distribution Provided by Rigid (Pervious Concrete) and Flexible Permeable Pavements and the Aggregate Base). The primary method for strengthening rigid pervious concrete is to increase the thickness of the pavement.

Increasing the aggregate base depth in permeable pavement systems provides the added benefit of increasing stormwater storage capacity, which can be particularly beneficial on subgrades with low permeability. Additionally, open graded rock may remain more stable in saturated conditions than densely graded road bases because the clean rock has less aggregate fines and, as a result, reduced pore pressures during saturated conditions (Smith, 2011). However, the same author also references several sources that indicate reduced structural capacity of open-graded bases compared to dense-graded bases under stresses from vehicle loads. Industry association literature should be referenced for determining base thicknesses for structural support.

Figure 6.55: Conceptual Diagram of the Load Distribution Provided by Rigid (Pervious Concrete) and Flexible Permeable Pavements and the Aggregate Base



Source: Low Impact Development Technical Guidance Manual for Puget Sound (WSU-PSP, 2012)

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Conceptual Diagram of the Load Distribution Provided by Rigid (Pervious Concrete) and Flexible Permeable Pavements and the Aggregate Base

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Separation or Bottom Filter Layer (recommended but optional)

A layer of sand or crushed stone (0.5 inch or smaller) graded flat is recommended to promote infiltration across the surface, stabilize the base layer, protect underlying soil from compaction, and serve as a transition between the base course and the underlying geotextile material.

Geotextile and Geogrids (Optional)

Geotextiles between the subgrade and aggregate base are not required or necessary for many soil types. However, for all permeable pavements, geotextile is recommended on the side slopes of the open graded base perimeter next to the soil subgrade if concrete curbs or impermeable liners are not provided that extend the full depth of the base/subbase. AASHTO M-288 (AASHTO, 2011) provides guidance for selection of geotextiles specifically for separation and drainage applications.

Geotextiles and geogrids are generally recommended for the following uses:

- As a filter layer to prevent clogging of infiltration surfaces
- For soil types with poor structural stability to prevent downward movement of the aggregate base into the subgrade (geotextiles or geogrids)

Clogging of the subgrade soil under permeable pavement systems could occur by fines from surface stormwater flow moving downward through the pavement section or from fines associated with the base aggregate washing off the rock and moving downward to the subgrade surface. Clogging of the base aggregate by the upward migration of fines into the aggregate has also been observed. The probability of clogging due to surface flow should be extremely low, given the current research that shows accumulation of fines predominantly in the upper few centimeters of permeable pavement sections. Movement of fines from the aggregate base rock is likely if the aggregate base specification for the pavement system allows for excessive fines. The third process (upward movement of fines into the base aggregate) requires capillary tension for water (and sediment) to move upward into the base material. Base aggregate for permeable pavement systems are open graded (20% to 40% voids are common) which minimizes the capillary tension necessary for upward movement of materials (WSU and PSP, 2012).

Currently, the rate and subsequent risk of soil subgrade clogging from fines is not well understood. While permeable pavement surfaces trap sediment prior to entering the base and soil subgrade, there is no research or forensic exploration of existing permeable pavement projects demonstrating the extent of fines accumulating on soil subgrades (WSU and PSP, 2012).

For applications on fine-grained weak soil types, geotextile or geogrid may be necessary to minimize downward movement of base aggregate. Geotextiles provide tensile strength as the subgrade attempts to deform under load and the fabric is placed in tension, thereby improving load bearing of the pavement section (Ferguson, 2005).

Sidewall Membrane Liners and Barriers

Membrane liners on sidewalls of permeable pavement installations are recommended to:

- Reduce sidewall soil movement and degradation of subgrade infiltration capability; and
- Protect adjacent densely graded subgrade material from migrating into the more open graded aggregate base of the permeable pavement.

Polyvinyl chloride (PVC) membranes that are 30 millimeters are typical and should be placed vertically in the soils, extending from the top of the aggregate base to the bottom of the subgrade.

Aggregate Base / Storage Layer

The open-graded aggregate base provides the following:

1. A stable base that distributes vehicle loads from the pavement to the subgrade
2. A highly permeable layer to disperse water downward and laterally to the underlying soil
3. A temporary reservoir that stores water prior to infiltration into the underlying soil or collection in underdrains for conveyance (WSDOT, 2003)

Aggregate base material is often composed of larger aggregate (1.5 to 2.5 inches). Smaller rock (leveling or choker course) may be used between the larger rock and the pavement depending on pavement type, working surface required to place the pavement, and base aggregate size (see sections below on specific pavement type and leveling or choker course guidelines). Typical void space in base layers range from 20% to 40% (WSDOT, 2003), (Cahill et al., 2003). Depending on the target flow control standard, groundwater and underlying soil type, retention or detention requirements can be partially or entirely met in the aggregate base. Aggregate base depths of 6 to 36 inches are common depending on pavement type, structural design, storage needs, and environmental factors such as cold weather.

Flexible pavements (e.g. porous asphalt and permeable pavers) require properly designed aggregate base material for structural stability. Rigid pavements (pervious concrete) do not require an aggregate base for structural stability; however, a minimum depth of 6 inches is recommended for stormwater storage and providing a uniform surface for applying pervious concrete.

Increasing aggregate base depth for stormwater storage provides the additional benefit of increasing the strength of the overall pavement section by isolating underlying soil movement and imperfections that may otherwise be transmitted to the wearing course (Cahill et al., 2003).

Local governments should adopt their own minimum base material requirements as they see necessary for support of flexible pavements. Many design combinations are possible. The material must be free draining. The municipality should determine and publish estimates of the void space for each standard base material allowed in their jurisdiction.

Aggregate Base / Storage Layer Guidance Specific to Permeable Pavement Types

- **Porous Hot-Mix Asphalt Aggregate Base / Storage Layer Guidance**
    - Minimum base depth for structural support should be based on hydrologic modeling to determine storage capacity needed and structural pavement design consideration.

- Maximum depth is determined by the extent to which the designer intends to achieve a flow control standard with the use of a below-grade storage bed. Aggregate base depths of 12 to 24 inches are common depending on storage needs.
- Several aggregate gradations can be used for a porous asphalt base. For a successful installation, the aggregate should:
  - Have adequate voids for water storage (20% to 40% voids is typical);
  - Be clean and have minimal fines (0% to 2% passing the No. 200 sieve maximum); and
  - Be angular and have adequate fractured face to lock together and provide structural support (70% minimum and 90% preferred for fractured face).
- Two example aggregate guidelines are as follows:
  - WSDOT Permeable Ballast (9-03.9(2) 0.75 to 2.5 inches) with a 1- to 2-inch-deep choker course consisting of the same aggregate gradation that is used for the pavement wearing course (see Aggregate Gradation (for Porous Hot-Mix Asphalt)).
  - A 0.75- to 1.5-inch clean, coarse crushed rock aggregate with 0% to 2% passing the No. 200 sieve. This gradation provides a uniform working surface and does not require a choker course. However, additional attention during installation of the pavement is required (see Construction Criteria and Installation Guidelines (for All Permeable Pavement Types)).

- **Portland Cement Pervious Concrete Aggregate Base / Storage Layer Guidance**
  - The minimum base depth should be based on structural design consideration.
  - Maximum depth is determined by the extent to which the designer intends to achieve a flow control standard with the use of a below-grade storage bed. Aggregate base depths of 6 to 18 inches are common when designing for retention or detention.
  - The coarse aggregate layer varies depending on structural and stormwater management needs. Typical placements are crushed washed aggregate and include WSDOT Permeable Ballast (0.75 to 2.5 inches). Do not use round rock where the perimeter of the base aggregate is not confined (e.g. sidewalk placed above grade). Round rock will easily move or roll from the perimeter of the aggregate base, creating weak voids with no structural support for the pavement.
  - The concrete can be placed directly over the coarse aggregate or an open graded leveling course (e.g. ½-inch to U.S. sieve size No. 8 or AASHTO No. 57 crushed washed rock), which may be placed over the larger rock for final grading to provide a more stable, uniform working surface and reduce variation in thickness.
- **Permeable Interlocking Concrete Pavers Aggregate Base / Storage Layer Guidance**
  - Minimum subbase thickness depends on vehicle loads, soil type, stormwater storage requirements, and freeze-thaw conditions. Typical subbase depths range from 6 to

24 inches. ICPI recommends base/subbase thicknesses for pavements up to a lifetime of 1 million equivalent single-axle loads (ESALs) that are 18,000 pounds each. For example, at lifetime ESALs of 500,000 with a CBR of 5%, the subbase (ASTM No. 2 rock) should be 18 inches, and the base (ASTM No. 57 rock) thickness should be 4 inches. Increased aggregate subbase thicknesses can be applied for increased stormwater volume storage. See ICPI guidelines for details on base thickness and design (Smith, 2011).

  - Minimum subbase depth for pedestrian applications should be 6 inches (Smith, 2011).
  - See Figure 6.54: Typical Permeable Interlocking Concrete Paver Section for aggregate subbase, base, bedding course, and paver materials.
  - The subbase and base aggregate should be hard, durable, crushed rock with 90% fractured faces, a Los Angeles (LA) Abrasion of < 40 (ASTM C131-06 and C535-12) and a design CBR of 80% (Smith, 2011).

- **Plastic or Concrete Grid Systems Aggregate Base / Storage Layer Guidance**
  - Minimum base thickness depends on vehicle loads, soil type, and stormwater storage requirements. Typical minimum depth is 4 to 6 inches for driveways, alleys, and parking lots (less base course depth is required for trails) (personal communication between C. Hinman and A. Gersen, 2004). Increased depths can be applied for additional storage capacity if needed to meet flow control goals.
  - Typical base aggregate is a sandy gravel material typical for road base construction.
  - Example aggregate grading:

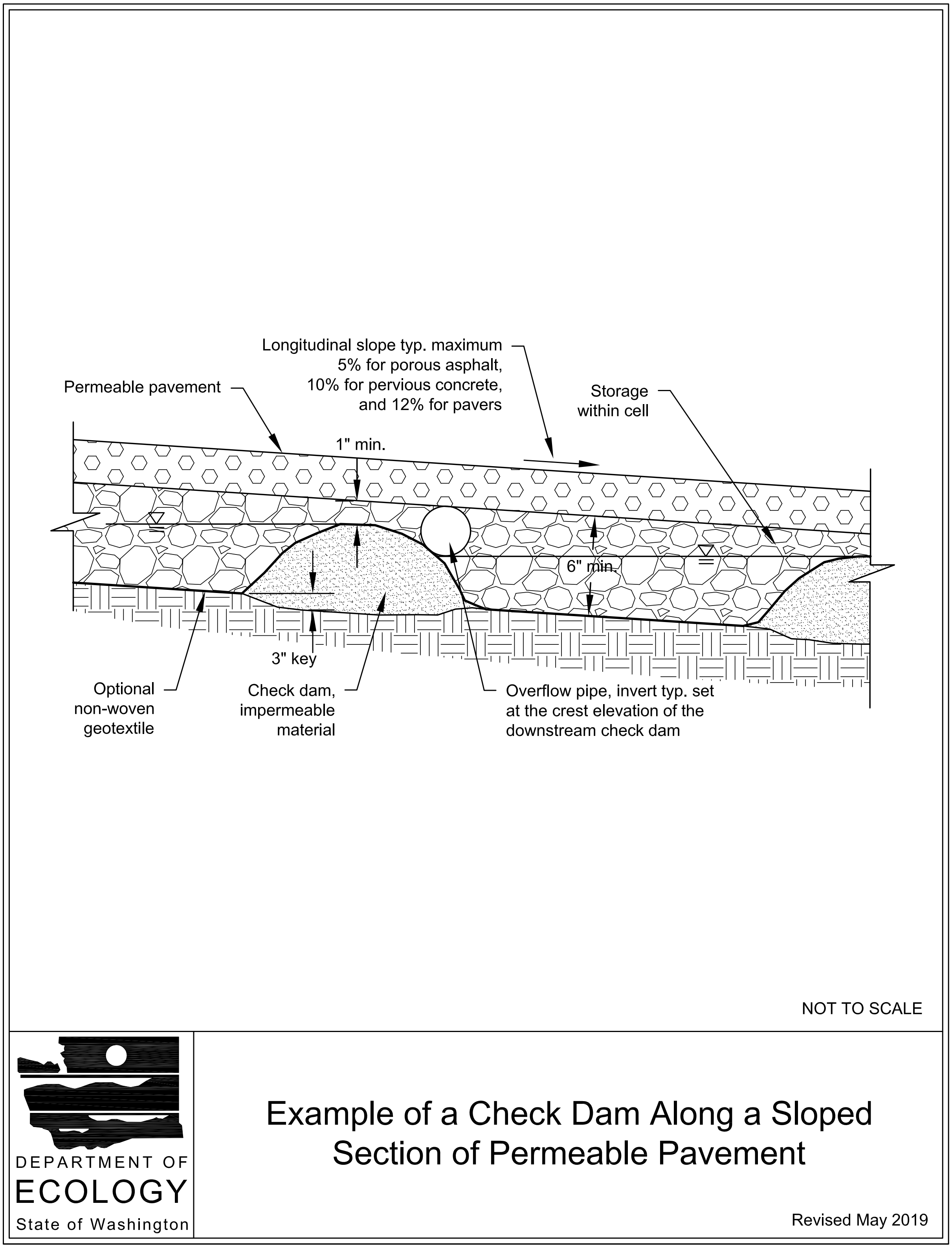
U.S. Standard Sieve	Percent Passing
1 inch	100
3⁄4 inch	90 to 100
3⁄8 inch	70 to 80
No. 4	55 to 70
No. 10	45 to 55
No. 40	25 to 35
No. 200	3 to 8

Subsurface Check Dams and Gravel Trenches

As permeable pavement subgrade slopes increase, storage and infiltration capacity decrease and flow velocities increase. To increase infiltration, improve flow attenuation, and reduce structural problems associated with subgrade erosion on slopes, use one of the following detention structures placed on the subgrade and below the pavement surface:

- Periodic impermeable check dams with an overflow drain invert placed at the maximum ponding depth. The distance between check dams will vary depending on slope, flow control goals, and cost (see Figure 6.56: Example of a Check Dam Along a Sloped Section of Permeable Pavement).
- Gravel trenches with an overflow drain invert placed at the maximum ponding depth. The distance between trenches will vary depending on slope, flow control goals, and cost.

Figure 6.56: Example of a Check Dam Along a Sloped Section of Permeable Pavement



Wearing Course / Surface Layer

The wearing course provides support (in conjunction with the aggregate base) for the designed traffic loads while maintaining adequate porosity for storm flow infiltration. In general, permeable top courses have very high initial infiltration rates with various asphalt and concrete research reporting 28 to 1,750 in/hr when new. Various rates of clogging have been observed in wearing courses and should be anticipated and planned for in the system design. Permeable pavement systems allow infiltration of storm flows; however, to prevent freeze-thaw damage and retain infilt-ration capability, the wearing course should not become saturated from excessive water volume stored in the aggregate base layer.

For all surface layer types, a minimum initial infiltration rate of 20 inches per hour is necessary. To improve the probability of long-term performance, significantly higher initial infiltration rates are desirable.

- ***Porous Asphalt:*** Products must have adequate void spaces through which water can infiltrate. A void space within the range of 16 – 25% is typical.
- ***Pervious Concrete:*** Products must have adequate void spaces through which water can infiltrate. A void space within the range of 15 – 35% is typical..
- ***Grid/lattice systems filled with gravel, sand, or a soil of finer particles with or without grass:*** The fill material must be at least a minimum of 2 inches of sand, gravel, or soil.
- ***Permeable Interlocking Concrete Pavement and Aggregate Pavers:*** Pavement joints should be filled with No. 8, 89 or 9 stone. Consult with paver manufacturer specifications to determine the appropriate material type and size.

Wearing Course / Surface Layer Guidance Specific to Permeable Pavement Types

- **Porous Hot-Mix Asphalt Wearing Course / Surface Layer Guidance**
  - *Pavement or Wearing Course Materials (for Porous Hot-Mix Asphalt)*

    Material availability may vary regionally, and mix design may vary for the materials. The following are references for mix design that may be appropriate for the site:

    - Porous Asphalt Pavements for Stormwater Management (NAPA, 2008)
    - Latest version of the WSDOT General Special Provisions (GSPs) for Porous Hot Mix Asphalt (PHMA), Porous Warm Mix Asphalt (PWMA)
  - *Thickness (for Porous Hot-Mix Asphalt)*
    - Porous asphalt has a slightly lower structural contribution than conventional asphalt. Follow (NAPA, 2008) for the structural contribution and recommended asphalt pavement thicknesses.
    - Parking lots: 2 to 4 inches typical, 3 inches minimum recommended.
    - Residential access roads and arterials: 4 to 6 inches typical.

- *Aggregate Gradation (for Porous Hot-Mix Asphalt)*

U.S. Standard Sieve	Percent Passing
3/4 inch	100
1/2 inch	90 to 100
3⁄8 inch	70 to 90
No. 4	20 to 40
No. 8	10 to 20
No. 40	7 to 13
No. 200	0 to 3

  A small percentage of fine aggregate is necessary to stabilize the larger porous aggregate fraction. The finer fraction also increases the viscosity of the asphalt cement and controls asphalt drainage characteristics.

- *Bituminous Asphalt Cement (for Porous Hot-Mix Asphalt)*
  - **Content:** 6.0% to 6.5% by weight of total (dry aggregate) mix. Performance Grade (PG) 70-22. Do not use an asphalt cement performance grade less than PG 70-22 for open graded, porous asphalt mixes.

    Note: Supplies of PG 70-22 may be limited in the winter season.
  - **Drain-down:** 0.3% maximum according to ASTM D6390-11.
  - An elastomeric polymer can be added to the bituminous asphalt cement to reduce drain-down.

    Note: PG 70-22 and stiffer PG grades usually contain and elastomeric polymer.
  - Fibers can be added and may prevent drain-down.
  - **Antistripping agent:** As water moves through the porous asphalt pavement, the asphalt emulsion contact with water increases compared to conventional impervious asphalt. An antistripping agent reduces the erosion of asphalt binder from the mineral aggregate and is, therefore, recommended for porous asphalt. A qualified products list of antistripping additives is available in the latest version of the WSDOT Standard Specifications. Use an approved test for antistrip such as AASHTO T 283-07, Standard Method of Test for Resistance of Compacted Asphalt Mixtures to Moisture-Induced Damage or the Hamburg test.
  - Total void space should be approximately 16% to 25% per ASTM D3203/D3203M-11 (conventional asphalt is 2% to 3%).

- **Portland Cement Pervious Concrete Wearing Course / Surface Layer Guidance**
  - *Pavement Materials (for Portland Cement Pervious Concrete)*

    The following guidelines provide typical ranges of materials for pervious concrete. Proper mix design and the resulting performance of the finished product depends on the specific aggregate used and proper cement content and water-cement ratios determined by that aggregate. Consult the qualified concrete supplier, local jurisdiction specifications, and ACI 522.1-08 for developing final mix design.
  - *Pavement Thickness (for Portland Cement Pervious Concrete)*
    - Parking lots: 5 to 9 inches typical
    - Roads: 6 to 12 inches typical
  - *Unit Weights (for Portland Cement Pervious Concrete)*

    Typical unit weight is 120 to 135 pounds per cubic foot (cf) ± 5%. Pervious concrete is approximately 70% to 80% of the unit weight of conventional concrete) (FCPA, n.d.).
  - *Void Content (for Portland Cement Pervious Concrete)*

    Per ASTM C138/C13813-M, 18 to 20% ± 3% to 5% are typical (interconnectivity of voids and, therefore, infiltration rates are inadequate < 15%) (ACI 522.1-08). Void content is measured indirectly by determining fresh (wet) concrete density using ASTM C138/C13813-M or ASTM C1688/CC168813-M and is a secondary measure reflecting strength and permeability of the hardened concrete. Acceptable permeability, strength, and appearance are primarily determined by the test panel (see Quality Control, Testing and Verification), which in part includes comparing unit weights of the accepted test panel cores and finished work cores.
  - *Water-to-Cement Ratio (for Portland Cement Pervious Concrete)*
    - Water-to-cement ratio of 0.26 to 0.45 provides the optimum aggregate coating and paste stability.
    - Water content is a critical design element of pervious concrete.
      - If too dry, cohesiveness and cement hydration efficiency may be reduced.
      - If too wet, the cement paste may drain down and result in a weak upper structure and clog the lower portion of the pavement (ACI 522.1-08).
  - *Total Cementitious Material Content (for Portland Cement Pervious Concrete)*

    Total cementitious content will range from 470 to 564 pounds per cubic yard.
    - Content should be determined by the supplier and identified in the mix design submittal.
    - The optimum content is entirely dependent on aggregate size, void content, and gradation (ACI 522.1-08).

- *Aggregate (for Portland Cement Pervious Concrete)*
  - Gradations are typically either single-sized coarse aggregate or gradations between 3/4- and 3/8-inch.
  - In general, the 1/4-inch crushed or round produces a slightly smoother surface than coarser aggregate.
  - Aggregate should meet requirements of ASTM D448-12 and C33/C33M-12.
  - Aggregate moisture at mixing is important to produce adequate workability and prevents draining of paste (ACI 522.1-08).
- *Portland Cement (for Portland Cement Pervious Concrete)*
  - Type I or II conforming to ASTM C150/C150M-12, C595/C595M-13 or C1157/C1157M-11.
  - Supplementary cementitious materials such as fly ash, ground blast furnace slag, and silica fume can be added to Portland cement.
  - Testing material compatibility is strongly recommended (ACI 522.1-08).
- *Admixtures (for Portland Cement Pervious Concrete)*
  - Water reducing/retarding, viscosity modifiers and hydration stabilizers can be used to increase working time and improve the workability of the pervious concrete mix.
  - Use potable water.
  - Fibers may add strength and permeability to the placed concrete, are recommended, and can be used as an integral component of the concrete mix.

- **Plastic or Concrete Grid Systems Wearing Course / Surface Layer Guidance**
  - *Aggregate Fill (for Plastic or Concrete Grid Systems)*
    - For aggregate systems:
      - Aggregate should be clean, washed, and hard angular rock typically 3⁄16- to 1/2-inch.
    - For grass systems:
      - For plastic grids, sand (usually with a soil polymer or conditioner), sandy loam or loamy sand are typical fill materials.
      - For concrete grids, fill the openings with topsoil.

Drainage Conveyance

The designer should be aware of where runoff will be conveyed, should the permeable pavement fail. Depending on the severity of the impacts that would result from failed permeable pavement, the designer may want to consider designing the project with adequate drainage conveyance facilities as if the road surface was impermeable. Roads with base courses that extend below the surrounding grade should have a designed drainage flow path to safely move water away from the road prism and into the roadside drainage facilities. Use of perforated storm drains to collect and transport infiltrated water from under the road surface will result in less effective designs and less Flow Control benefit.

Underdrains (Optional)

One or more underdrains may be installed at the bottom of a permeable pavement system if the infiltration capacity of the subgrade soil is not adequate to protect the following:

- The pavement and subgrade from freeze-thaw cycles
- The pavement wearing course from prolonged saturation that reduce infiltration capability
- Specific subgrade soil types from excessive periods of saturation that may lead to structural weakness

Underdrains without orifice or control structures will reduce infiltration to the subgrade and flow reduction which should be accounted for in hydrologic modeling for sizing purposes (see Permeable Pavement Design Steps).

Consider including an orifice on underdrains. With an orifice, the permeable pavement installation will operate as an underground detention system. Recommendations for permeable pavement underdrains include the following:

- Underdrain flows should be conveyed to an approved discharge point.
- At a minimum, slotted or perforated, thick-walled plastic pipe with a minimum diameter of 6 inches should be used. Slots or perforations can be oriented up or down for installation.
- An appropriate cover depth and pipe material should be used that considers vehicle loads.
- To reduce clogging, the minimum orifice diameter should be 0.5 inches and maintenance activities should include regular inspection. Review local jurisdiction requirements for local minimum orifice diameter for belowground structures. In cold climates, consider using a larger minimum orifice diameter to reduce clogging due to ice formation.
- Minimum slope = 0.5%
- Invert elevation per design

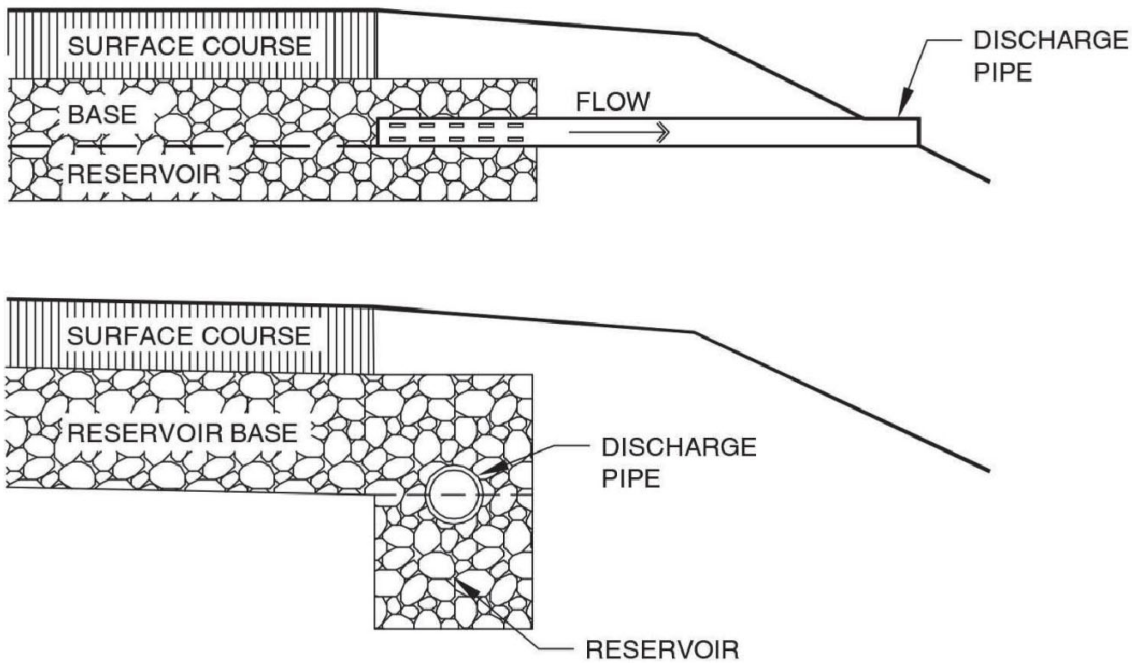
Elevated Drains (Optional Overflow)

An overflow or elevated drain may be installed in the aggregate base of a permeable pavement system if the infiltration capacity of the subgrade soil is not adequate to protect the pavement wearing course from saturation. An elevated drain can also be used to create retention beneath the elevated drain invert if the subgrade analysis determines that the subgrade can provide adequate structural support, given the duration of saturated conditions. BMP overflow can be provided by subsurface slotted drain pipe(s) or by lateral flow through the storage reservoir to a surface or subsurface conveyance. Flows must be routed to an approved discharge point (see Figure 6.57: Elevated Drain Designs for Permeable Pavement Aggregate Base/Reservoir).

Recommendations for elevated drain design include the following:

- The maximum elevation of the overflow invert from the subgrade should drain water in the base aggregate before reaching the bottom of the permeable pavement wearing course and prevent saturation of the pavement.
- If site constraints necessitate an overflow pipe in an area subject to traffic or other loading, cover depth and pipe material should be designed to accommodate those loads.
- The pipe diameter and spacing for slotted overflow pipes will depend on the hydraulic capacity required. For a sloped subgrade, at least one overflow pipe should be installed at the downslope end of the BMP.
- Observation and clean-out ports should be used to determine whether the overflow is dewatering properly and allows access for back flushing.
- Overflows shall be designed to convey excess flow to an approved discharge point.

Figure 6.57: Elevated Drain Designs for Permeable Pavement Aggregate Base/Reservoir



Source: Low Impact Development Technical Guidance Manual for Puget Sound (WSU-PSP, 2012)

NOT TO SCALE

DEPARTMENT OF ECOLOGY State of Washington

Elevated Drain Designs for Permeable Pavement Aggregate Base/Reservoir

Revised June 2013

Backup Infiltration

Backup infiltration can be designed into any permeable pavement system. Typical backup systems include aggregate areas along roads; parking lot medians and perimeters; and surface drains that are connected to the aggregate reservoir/base layer under the permeable pavement. The permeable pavement surface is then sloped gradually to the overflow or backup infiltration area (1% to 2% maximum slope recommended).

Flow Entrance

When designed to take runoff from other catchment areas, permeable pavement areas must be protected from sedimentation, which can cause clogging and degraded BMP performance. Acceptable flow entrance methods include sheet flow to the permeable pavement surface or subsurface delivery to the storage reservoir via pipes (e.g. for roof drainage). Accepted pretreatment for sediment removal (e.g. filter strip for surface flow and catch basin for subsurface delivery) should be included for any runoff to permeable pavement systems.

Edge Restraints (Used for Permeable Interlocking Concrete Pavers)

The type of edge restraint depends on whether the application is for pedestrian, residential driveways or vehicle use. For installations intended for vehicles, use a cast-in-place curb (typically 9 inches deep) that rests on the top of the subbase, or one that extends the full depth of the base and subbase. If the paver installation is adjacent to existing impervious pavement, the curb should extend to the full depth of pavement and aggregate base to protect the impervious installation base from excessive moisture and weakening. If the concrete curb does not extend the full depth an impermeable liner can be used to separate the two base materials (Smith, 2011).

Cast-in-place concrete curbs or dense-graded berms to provide a base to secure spiked metal or plastic edge restraints can be used for pedestrian and residential driveway applications. An additional option for pedestrian and light parking application is a subsurface concrete grade beam with pavers cemented to the concrete beam to create a rigid paver border.

Infiltration Test for Permeable Pavement Surface

- Permeable pavement driveways can be tested by simply throwing a bucket of water on the surface. If anything other than a scant amount puddles or runs off the surface, additional testing is necessary prior to accepting the construction.
- Permeable pavement roads may be initially tested with the bucket test described above. In addition, test the initial infiltration with a 6-inch ring, sealed at the base to the road surface, or with a sprinkler infiltrometer. Wet the road surface continuously for 10 minutes. Begin test to determine compliance with 20 inches per hour minimum rate. Use of ASTM C1701 or ASTM C1781, as appropriate, is also recommended.

Determining the Native Soil Infiltration Rates

Determining infiltration rates of the site soils is necessary to determine feasibility of designs that intend to infiltrate stormwater on-site. It is also necessary to estimate flow reduction benefits of such designs through modeling.

Refer to 6.5.4 Determining the Design Infiltration Rate of the Native Soils for further guidance on the methods to determine the design infiltration rate of the native soils and consider the following additional guidance for permeable pavement BMPs.

The certified soils professional or engineer can exercise discretion concerning the need for and extent of infiltration rate (saturated hydraulic conductivity, K_{sat}) testing. The professional can consider a reduction in the extent of infiltration (K_{sat}) testing if, in their judgment, information exists confirming that the site is unconsolidated outwash material with high infiltration rates, and there is adequate separation from groundwater.

On non-residential developments, one small-scale pilot infiltration test (PIT) (see 6.5.4 Determining the Design Infiltration Rate of the Native Soils) should be performed for every 5,000 square feet (sf) of permeable pavement, but not less than one test per site.

On residential developments, small-scale PITs should be performed at every proposed lot, at least every 200 feet of roadway, and within each length of road with significant differences in subsurface characteristics.

Tests at more than one site could reveal the advantages of one location over another. However, if the site subsurface, including soil borings across the development site, has consistent characteristics and depths to seasonal high groundwater, the number of test locations may be reduced to a frequency recommended by a licensed engineer in the state of Washington with geotechnical expertise.

Because permeable pavement infiltrates over a large area, a groundwater mounding analysis may not be critical to the infiltration BMP design, so long as the permeable pavement does not receive run-on from adjacent surfaces. See 6.5.2 Infiltration BMP Design Steps for general guidance for when Ecology recommends a groundwater mounding analysis as part of infiltration BMP design. For permeable pavements, Ecology recommends the designer follow this guidance, unless the permeable pavement does not receive run-on from adjacent surfaces, in which case the design professional may determine that a groundwater mounding analysis is not necessary.

Unless seasonal high groundwater elevations across the site have already been determined, upon conclusion of the infiltration testing, infiltration sites should be over-excavated 1 foot to see any restrictive layers or groundwater. Observations through a wet season can identify a seasonal groundwater restriction.

Perform infiltration testing in the soil profile at the estimated bottom elevation of base materials for the permeable pavement. If no base materials, (e.g. a pervious concrete sidewalk), perform the testing at the estimated bottom elevation of the pavement.

Accessibility

The permeable pavement systems examined in this section can be designed to meet Americans with Disabilities Act (ADA) requirements. Local, state and federal accessibility requirements can vary and designers should check with the permitting jurisdiction for accessibility related requirements.

The federal ADA design guidelines state that surfaces on accessible paths and travel routes should meet the following criteria:

- Firm, stable, and slip resistant
- Maximum openings that do not allow insertion of a 0.5-inch sphere

The International Building Code states that abrupt changes in height > 0.25 inches in accessible routes of travel shall be beveled to 1 vertical in 2 horizontal (ICC, 2003). Changes in level > 0.5 inches shall be accomplished with an approved ramp. Porous asphalt and pervious concrete, while rougher than conventional paving, do not have abrupt changes in level when properly installed. Concrete pavers have small openings or joints when properly installed and most concrete paver surfaces create smooth surfaces that meet ADA design guidelines. Consult with the paver supplier to confirm its product meets ADA requirements. Plastic and concrete grid systems use a specific aggregate with a reinforcing grid that creates a firm and relatively smooth surface.

Two qualifications for use of permeable pavement and designing for ADA should be noted. Sidewalk designs incorporate scoring, or more recently truncated domes, near the curb ramp to indicate an approaching traffic area for the blind. The rougher surfaces of permeable pavement may obscure this transition; accordingly, standard concrete with scoring or truncated domes should be used for curb ramps (FCPA, n.d.). Also, the aggregate within the cells of permeable pavers (such as Eco-Stone) can settle or be displaced from vehicle use. As a result, paver installations for ADA parking spaces and walkways may need to include pavers with smaller permeable joints or pavers constructed with permeable material and tight joints. Individual project designs should be assessed by site characteristics and regulatory requirements of the jurisdiction.

Construction Criteria

Installation procedures for permeable pavement systems are different from conventional pavement. For successful application of any permeable pavement system, the following guidelines should be followed:

Qualified Manufacturers, Installation Contractors, and Suppliers

Material manufacturers must have experience with producing proper mix designs for pervious concrete or porous asphalt and make materials that comply to national standards. Permeable interlocking concrete pavement and other factory produced materials should conform to national product standards. Installation contractors must be adequately trained, have substantial and successful experience with the pavement product, and adhere to material specifications for proprietary systems. Installation contractors should provide information showing successful application of permeable pavements for past projects and recommended certification, if available, for the specific type of permeable pavement. Suppliers must have experience with producing proper mix designs for pervious Portland cement concrete or porous hot-mix asphalt. Substituting inappropriate materials or installation techniques will likely result in structural or hydrologic performance problems or failures.

Sediment and Erosion Control During Construction and Long-Term

Erosion and introduction of sediment from surrounding land uses should be strictly controlled during and after construction to reduce clogging of the void spaces in the subgrade, base material, and permeable surface. Muddy construction equipment should not be allowed on the base material or pavement, sediment laden runoff should be directed to temporary Construction Runoff Treatment BMPs (e.g. settling ponds and swales), and exposed soil should be mulched, planted, and otherwise stabilized as soon as possible. Construction sequencing for proper installation and minimizing erosion and sediment inputs is critical for project success. Long-term O&M manuals that consider the physical setting, timing, and equipment needs should be developed during the design phase.

Poor quality installations are most often attributed to not following guidelines, structural or flow management problems, or failures are likely without qualified contractors and correct application of specifications.

Installation Guidelines (for All Permeable Pavement Types)

This section provides general installation guidelines for the subgrade, storage reservoir/aggregate base, and geotextiles (optional) for all types of permeable pavements. Following the general guidance, specific installation guidelines for porous asphalt, pervious concrete, PICP, and grid systems are provided.

Soils must not be tracked onto the wear layer or the base course during construction.

Subgrade

Careful attention to subgrade preparation during installation is required to balance the needs for structural support while maintaining infiltration capacity. For all permeable pavements, relative uniformity of subgrade conditions is necessary to prevent differential settling or other stress across the system.

On sites where the topsoil is removed and native subsoil exposed, no compaction may be required for adequate structural support while protection of the subgrade from compaction is necessary to retain infiltration capacity. For applications with heavy truck traffic, some soil subgrade compaction may be necessary for structural support. The effect of compaction on subgrade permeability will vary significantly depending on soil type. For example, the permeability of a coarser textured sand may be affected minimally while the permeability of finer textured soils will likely be significantly degraded for a given compaction effort. Effects of compaction on soil permeability can be assessed by conducting laboratory Proctor density tests on subgrade soils from the proposed permeable pavement site. Soils in test areas can be compacted to various density levels through field measurements and the resulting permeability measured using ASTM test methods.

For more information: See 6.5.4 Determining the Design Infiltration Rate of the Native Soils for more detail on test procedures.

To properly prepare and maintain infiltration capacity and structural support on permeable pavement subgrades, use the following procedures:

- During and after grading, excessive construction equipment or material stockpiling should not be compacted more than the recommended compaction value. The following guidelines should be used to prevent excessive compaction and maintain infiltration capacity of the subgrade:
    - Final grading should be completed by machinery operating on a preliminary subgrade that is ≥ 12 inches higher than final grade or structures to distribute equipment load (e.g. steel plates or aggregate base material). Final excavation then proceeds as machinery is pulling back and traveling on preliminary grade as final grade is excavated.
    - To prevent compaction when installing the aggregate base, the following steps (back-dumping) should be followed:
        1. The aggregate base is dumped onto the subgrade from the edge of the installation and aggregate is then pushed out onto the subgrade.
        2. Trucks dump subsequent loads from on top of the aggregate base as the installation progresses.
    - Avoid subgrade preparation during wet periods (soil compaction increases significantly if soil is wet).
    - If machinery must access the final grade, limit the access to a specific travel way that can be tilled before application of the base aggregate or place heavy steel plates on subgrade and limit traffic to the protective cover.

      Note: Allowing heavy machinery on permeable pavement subgrades during wet or saturated conditions will result in deep compaction (often 3 feet) and cannot be compensated for by shallow tilling or ripping soil (Balousek, 2003).
- If using the pavement system for retention in parking areas, excavate the subgrade level to allow even distribution of water through the aggregate base and maximize infiltration across the entire parking area (Cahill et al., 2003).
- Immediately before placing base aggregate and pavement, remove any accumulation of fine material (if present) with light equipment and scarify soil to a minimum depth of 6 inches to prevent sealing of the subgrade surface.
- Excavate the subgrade with level steps. The step length will vary depending on slope, flow control goals, and cost. Excavating level steps is most applicable for parking lots where the pavement surface is also stepped. While the subgrade is excavated level, the pavement surface should maintain a minimal slope of 1% to 2%.

Storage Reservoir/Aggregate Base

The open-graded aggregate base provides the following:

1. A stable base that distributes vehicle loads from the pavement to the subgrade
2. A highly permeable layer to disperse water downward and laterally to the underlying soil

3. A temporary reservoir that stores water prior to infiltration into the underlying soil or collection in underdrains for conveyance (WSDOT, 2003)

Aggregate base material is often composed of larger aggregate (1.5 to 2.5 inches). Smaller rock (leveling or choker course) may be used between the larger rock and the pavement depending on pavement type, working surface required to place the pavement, and base aggregate size (see sections below on specific pavement type and leveling or choker course guidelines). Typical void space in base layers range from 20% to 40% (WSDOT, 2003), (Cahill et al., 2003). Depending on the target flow control standard, groundwater and underlying soil type, retention or detention requirements can be partially or entirely met in the aggregate base. Aggregate base depths of 6 to 36 inches are common depending on pavement type, structural design, storage needs, and environmental factors such as cold weather (WSU and PSP, 2012).

Flexible pavements (e.g. porous asphalt and permeable pavers) require proper aggregate base material for structural stability. Rigid pavements (pervious concrete) do not require an aggregate base for structural stability; however, a minimum depth of 6 inches is recommended for stormwater storage and providing a uniform surface for applying pervious concrete (WSU and PSP, 2012).

Increasing aggregate base depth for stormwater storage provides the additional benefit of increasing the strength of the overall pavement section by isolating underlying soil movement and imperfections that may otherwise be transmitted to the wearing course (Cahill et al., 2003). For more information on aggregate base material and structural support, see Aggregate Base / Storage Layer Guidance Specific to Permeable Pavement Types.

Geotextile and Geogrids (Optional)

If geotextile is used between the subgrade and base aggregate, take the following actions:

- Use geotextile recommended by the manufacturer's specifications and recommendations of a licensed engineer in the state of Washington with geotechnical expertise for the given subgrade soil type and base aggregate.
- Extend the fabric up the sides of the excavation in all cases. This is especially important if the base is adjacent to conventional paving surfaces. The fabric can help 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/subbase.
- Overlap adjacent strips of fabric ≥ 24 inches. Leave enough fabric to completely wrap over small installations (e.g. sidewalks) or the edge of larger installations adequately to prevent sediment inputs from adjacent disturbed areas. Secure fabric outside of storage bed.
- After placement of base aggregate and again after placement of the pavement, fold the geotextile (if used) over the placements and secure it to protect the installation from sediment inputs. Excess geotextile should not be trimmed until the site is fully stabilized (USACE, 2003).

Installation Guidelines (Specific to Porous Hot-Mix Asphalt)

Aggregate Base/Storage Bed Installation

- Stabilize area and install erosion control to prevent runoff and sediment from entering storage bed.
- Install base aggregate in maximum of 8-inch lifts and lightly compact each lift. Compact complete aggregate base with a minimum 10-ton vibratory roller. Use a 13,500 pound force (lbf) plate compactor with a compaction indicator in places that can't be reached by roller compactor. Make two passes with the roller in vibratory mode and two passes in static mode until there is no visible movement of the aggregate. Moist aggregate will compact more thoroughly than dry aggregate. Do not crush the aggregate during compaction. Compacted aggregate subbase and base should not rut under aggregate delivery trucks or other construction equipment.
- If used, install choker course evenly over surface of coarse aggregate base and compact.
- Behind asphalt delivery trucks and in front of asphalt installation, rake out ruts caused by delivery trucks to provide a uniform surface and pavement depth.

Pavement or Wearing Course Installation

The porous asphalt pavement installations use the same equipment and similar procedures as conventional asphalt with three notable differences:

1. Mixing temperature should be 260°F to 280°F and 240°F to 260°F for lay down. Air temperature should be no lower than 45°F and rising.
2. The stiffer performance grade for the bituminous asphalt cement adheres more to delivery trucks and installation machinery; accordingly, additional time is necessary to clean equipment.
3. Porous asphalt aggregate base and choker courses are relatively uniform gradations and low in fine material. As a result, equipment operating on the aggregate base will cause more rutting than on more densely graded base material for conventional pavement and will require more hand labor to smooth ruts and prevent areas where the pavement is either too thin or too thick.

General Installation

- Install porous asphalt system toward the end of construction activities to minimize sedimentation. The subgrade can be excavated to within 6 to 12 inches of final subgrade elevation and grading completed in later stages of the project (Cahill et al., 2003).
- Erosion and introduction of sediment from surrounding land uses should be closely controlled during and after construction. Erosion and sediment controls should remain in place until area is completely stabilized with soil amendments and landscaping.
- Insulated covers over loads during hauling can reduce heat loss during transport and increase working time (Diniz, 1980). Temperatures at delivery that are too low can result in shorter working times, increased labor for hand work, and increased cleanup from asphalt adhering to machinery.
- Rising water in the underlying aggregate base should not be allowed to saturate the pavement (Cahill et al., 2003). A positive overflow (elevated drain) can be installed to

ensure that the asphalt top course is not saturated from excessively high water levels in the aggregate base.

Minimum Infiltration Rate for the Porous Hot Mix Asphalt

The minimum infiltration rate for newly placed porous asphalt should be 200 in/hr. Use ASTM C1701/C1701M-09 to test infiltration rates at locations representative of the pavement finished product at a maximum rate of 5,000 square feet (sf) per test.

Installation Guidelines (Specific to Portland Cement Pervious Concrete)

ACI 522.1-08 is the current national standard for specification of pervious concrete pavement. This manual defers to the current version of ACI 522.1-08 for developing pervious concrete pavement specifications. Included below are specific sections of ACI 522.1-08 relevant to infiltration rates, subgrade preparation, and aggregate base placement relevant to the region and developed from national experience.

Aggregate Base/Storage Bed Installation

- Stabilize area and install erosion control to prevent runoff and sediment from entering storage bed.
- Install coarse aggregate in maximum of 8-inch lifts and compact each lift (USACE, 2003). Use back dumping method described previously in this section to protect the subgrade from compaction.
- If utilized, install a 1- to 2-inch leveling course (typically No. 57 AASHTO crushed, washed rock) evenly over surface of coarse aggregate base and lightly compact to stabilize to provide a more stable, uniform working surface and reduce variation in thickness.

Pavement installation

- See Quality Control, Testing and Verification for confirming correct mixture and proper installation.
- With the correct water content, the delivered mix should contain a cement paste that smoothly covers all the aggregate particles that does not slide off or drain from the particles. The paste should cause the aggregate particles to adhere to each other.
- Pervious concrete mix should be placed within 60 minutes of water being introduced to the mix, and within 90 minutes of using an extended set control admixture (ACI 522.1-08) or an admixture recommended by the manufacturer.
- Adding water in the truck at the point of discharge of the concrete should be allowed to attain optimum mix consistency, workability, placement, and finish (ACI 522.1-08).
- Base aggregate should be wetted to reduce moisture loss and improve the curing process of pervious concrete.
- Concrete should be deposited as close to its final position as possible directly from the truck, using a conveyor belt or hand or powered carts (pervious concrete mixes are stiff and cannot be pumped).

- Several screed and compaction methods can be used, including low-frequency vibrating truss screeds, laser screeds, and a hand screed that levels the concrete at the top of the form (typically 3/8 to 3/4 inches). The surface is then covered with 6-millimeter plastic, and a static drum roller is used for final compaction (roller should provide approximately 10 pounds per square inch (psi) vertical force). A method that is becoming more prevalent and has advantages for quality of finish and speed uses rotating Bunyan screeds or hydraulically powered screeding drums that provide proper compaction at the finished elevation and a nearly finished surface in one operation. Hydraulically operated screeding drums come in various lengths and diameters.
- Placement widths should not exceed 15 feet unless contractor can demonstrate competence with test panels or previous installations to install greater widths.
- High frequency vibrators can seal the surface of the concrete and should not be used.
- Jointing: Shrinkage associated with drying is significantly less for pervious than conventional concrete. Accordingly, control joints are optional. If used, spacing of joints should follow the rules for conventional concrete and should typically be spaced at maximum 15- to 20-foot intervals. Joint depth should be one-quarter to one-third the depth of the pavement thickness. Control joints can also facilitate a cleaner break point if sections become damaged or are removed for utility work.

Curing

Due to its porous, open structure, pervious concrete dries rapidly. If curing is not controlled, the bond between the aggregate becomes weak and structural integrity will be seriously compromised. Curing is, therefore, a critical step in pervious concrete installation and the following steps should be carefully planned and implemented (ACI 522.1-08):

- Completely cover surface and edges with 6-millimeter plastic within 20 minutes of concrete discharge. The surface and edges should remain entirely covered for the entire curing time.
- Curing time: 7 days for pervious concrete with no additives and 10 days for mixtures that incorporate supplementary cementitious materials, such as fly ash and slag (ACI 522.1-08).
- Secure all edges adequately so that the plastic cannot be dislodged during cure time. Lumber, reinforcing bars, and concrete blocks can be used to secure the plastic continuously along the perimeter. If wooden forms are used, riser strips can be nailed back in place to secure plastic. Do not use dirt, sand or other granular material on the plastic because the sediment may wash or spill into the pores of the concrete during rainfall or removal of plastic (ACI 522.1-08).

Note: Admixtures are now becoming available that reduce or eliminate the need to cover the pavement installation with plastic. Consult ACI 522.1-08, industry representatives, and suppliers for recommendations.

Quality Control, Testing and Verification

The following provides a summary of quality control in ACI 522.1-08. Quality control and testing procedures to verify proper placement include test panels, fresh and hardened density, and average compacted thickness of the installation. It is critically important to require adequate

National Ready Mix Concrete Association (NRMCA)-certified placement personnel and contractor experience for the installation (see ACI 522.1-08 for more details). There are currently no generally accepted standardized methods to test compression or flexural strength of pervious concrete, and tests used for conventional concrete are not applicable due to the high variability in strength within the porous structure of pervious concrete and should not be used for verification (ACI 522.1-08).

The contractor should place test panels using mix proportions, materials, personnel, and equipment proposed for the project. Test the fresh and hardened density and thickness of the test panel(s). See the current version of ACI 522.1-08 for test procedures and tolerances. If the test panel is outside acceptable limits for one or more of the verification tests, the panel should be removed and replaced at the contractor's expense. If the test panel is accepted it may be incorporated into the completed installation.

Obtain a minimum 1 cf sample for fresh density testing for each day of placement (see ACI 522.1-08 for test procedures and tolerances).

Remove three cores per 5,000 sf not less than 7 days after placement to verify placement hardened density and thickness. See ACI 522.1-08 for test procedures and tolerances. If the tested portion of the installation is outside acceptable limits for 1 or more of the verification tests, the installation is subject to rejection and should be removed and replaced at the contractor's expense unless accepted by the owner (WSU and PSP, 2012).

Minimum Infiltration Rate for Pervious Concrete

The minimum infiltration rate for newly placed pervious concrete should be 200 in/hr. Use ASTM C1701/C1701M-09 to test infiltration rates of the test panel and at locations representative of the pavement finished product at a maximum rate of 5,000 sf per test.

Verifying Subgrade Infiltration Rates

Infiltration tests can also be used once subgrade preparation is complete to verify that infiltration rates used for design have not been significantly reduced from compaction. Pilot infiltration tests, and associated excavation beneath the pilot infiltration test (PIT) elevation, are not recommended at this stage in order to maintain the structural integrity of the subgrade. Rather, large-scale ring infiltrometer tests are recommended for accuracy and minimal subgrade disturbance.

For more information: See 6.5.4 Determining the Design Infiltration Rate of the Native Soils for the single-ring infiltrometer test method.

Utility excavations under or beside the road section can provide pits for soil classification, textural analysis, stratigraphy analysis, and/or infiltration tests and minimize time and expense for permeable pavement infiltration tests.

Installation Guidelines (Specific to Permeable Interlocking Concrete Pavers)

The ICPI provides technical information on best practices for PICP design, specification, construction, and maintenance. Manufacturers or suppliers of particular pavers should be consulted for materials and guidelines specific to that product. Experienced contractors with a certificate in the ICPI PICP Installer Program should perform installations. The following provides construction guidelines that apply broadly to permeable interlocking concrete pavers.

Aggregate Base/Storage Bed Installation

Stabilize area and install erosion control or diversion to prevent runoff and sediment from entering aggregate subbase, base, and pavers. Prevent sediment from contaminating aggregate base material if stored on-site.

If using the base course for retention in parking areas, excavate subgrade level to allow even distribution of water and maximize infiltration across entire parking area.

Install No. 2 rock in 6-inch lifts. Use back dumping method described previously in this section to protect subgrade from compaction. Compact with ≥ 4 passes of a 10-ton steel drum vibratory roller or a 13,500 lbf plate compactor. The first two passes should be with vibration, and the final two passes should be static. Consolidation of the subbase is improved if the aggregate is wet. Compaction is complete when there is no visible movement in the subbase as the roller moves across the surface (Smith, 2011).

The No. 57 rock base can be spread as one 4-inch lift. Compact with ≥ 4 passes of a 10-ton steel drum vibratory roller or a 13,500 lbf plate compactor. The first two passes should be with vibration and the final two passes should be static. The No. 57 rock should be installed moist to facilitate proper compaction.

Adequate density and stability are developed when no visible movement is observed in the base as the roller moves across the surface. If field testing is required, a nuclear density gauge can be used on the No. 57 base in backscatter mode; however, this type of test is not effective/appropriate for the larger No. 2 subbase rock. A nonnuclear stiffness gauge can be used to assess aggregate base density as well (Smith, 2011).

Asphalt stabilizer can be used with the No. 57 and/or the No. 2 rock if additional bearing support is needed, but should not be applied to the No. 8 aggregate. To maintain adequate void space, use a minimum of asphalt for stabilization (approximately 2 to 2.5% by weight of aggregate). An asphalt grade of AC20 or higher is recommended. The addition of stabilizer will reduce storage capacity of base aggregate and should be considered in the design (Smith, 2000).

Geotextile Fabric (optional)

- Geotextiles are recommended on the sides of excavations where a full-depth concrete curb is not used to prevent erosion of adjacent soil into the aggregate base. The fabric should extend ≥ 1 foot onto the subgrade bottom. A minimum overlap of 1 foot is recommended for well-drained soils and 2 feet for poorly draining soils (Smith, 2011).
- The use of geotextiles on the bottom of the subgrade excavation is optional.

Bedding Layer Installation

Install 2 inches of moist No. 8 rock for the leveling or choker course over compacted base. Screed and level No. 8 rock to within ± 3/8 inches over 10 feet surface variation. The No. 8 aggregate should be moist to facilitate movement into the No. 57 rock. Keep construction equipment and foot traffic off screed bedding layer to maintain uniform surface for pavers.

Paver Installation

- Pavers should be installed immediately after base preparation to minimize introduction of sediment and to reduce the displacement of bedding and base material from ongoing activity (Smith, 2000).
- Place pavers by hand or with mechanical installer. Paver joints are filled with No. 8, No. 89, or No. 9 rock. Spread and sweep with shovels and brooms (for small jobs) or small track loaders and power brooms or sweepers (for larger installations). Fill joints to within 0.25 inches and sweep surface clean for final compaction to avoid marring pavers with loose rocks on the surface.
- To maximize efficiency and reduce cost of mechanical installation, consult with the supplier to deliver pavers in layers that will be picked up by the installation machine in the final installed pattern.
- For installations > 50,000 square feet that are installed with mechanical equipment, consult with the paver manufacturer to monitor paver dimension and consistency of paver layers so that layers continue to fit together appropriately throughout installation.
- Cut pavers along borders should be no smaller than one-third of a whole paver if subjected to vehicle loading.

  Note: Do not use sand to fill paver openings or joints unless specified by the manufacturer. Sand in paver openings and joints can clog easily and will significantly reduce surface infiltration and system performance if system is not specifically designed for sand.
- Compact pavers with a 5,000 lbf, 75- to 90-hertz (Hz) plate compactor. Use a minimum of two passes with each subsequent pass perpendicular to the prior pass.
- If aggregate settles to > 0.25 inches from the top of the pavers, add rock, sweep clean, and compact again. The small amount of finer aggregate in the No. 8 rock will likely be adequate to fill narrow joints between pavers in pedestrian and vehicle applications. Sweep in additional material as required. ASTM No. 89 or No 9 rock can be used to fill spaces between pavers with narrow joints. In all cases, however, the bedding material should be ASTM No. 8 rock (Smith, 2011).
- For installations intended for vehicles, proof roll with ≥ two passes of a 10-ton rubber-tired roller.
- Do not compact pavers within 6 feet of unrestrained edges (Smith, 2011).
- The PICP installation contractor should return to the site after 6 months from completion of the work and provide the following if necessary: fill paver joints with rocks, replace broken or cracked pavers, and relevel settled pavers to specified elevations. Any rectification work should be considered part of original bid price with no additional compensation.

For more information: For detailed design guidelines and a construction specification, see *Permeable Interlocking Concrete Pavements: Design, Specifications, Construction, Maintenance* (Smith, 2011).

Installation Guidelines (Specific to Plastic or Concrete Grid Systems)

Aggregate Base/Storage Bed Installation

- Stabilize area and install erosion control to prevent runoff and sediment from entering storage bed.
- If using the base course for retention in parking areas, excavate storage bed level (if possible) to allow even distribution of water and maximize infiltration across entire parking area (terrace parking area if sloped).
- Install aggregate in 6-inch lifts maximum. Use back dumping method described previously in this to protect subgrade from compaction.
- Compact each lift of dense-graded aggregate base to 95% standard Proctor.

  Note: For dense-graded bases in light traffic applications, only standard Proctor density is required. Modified Proctor requires more compaction force and expense and is not needed for the light loads to which grid pavements are constructed.
- For open-graded aggregate bases, compact with a minimum 10-ton roller with the first two passes in vibratory mode and the last two in static mode until there is no visible movement of the aggregate.

Top Course Installation

- Grid should be installed immediately after base preparation to minimize introduction of sediment and to reduce the displacement of base material from ongoing activity.
- Place grid with rings up and interlock male/female connectors along unit edges.
- Install anchors if not integral to the plastic grid. Higher speed and transition areas (e.g. where vehicles enter a parking lot from an asphalt road) or where heavy vehicles execute tight turns will require additional anchors.
- Aggregate fill should be back dumped to a minimum depth of 6 inches so that delivery vehicle exits over aggregate. Sharp turning on rings should be avoided.

Aggregate Fill

- Spread gravel using power brooms, flat bottom shovels or wide asphalt rakes. A stiff bristle broom can be used for finishing.
- If necessary, aggregate can be compacted with a plate compactor to a level no less than the top of the rings or ≤ 0.25 inches above the top of the rings (Invisible Structures, 2003).

Grass Systems

- Spread sand or soil using power brooms, flat bottom shovels or wide asphalt rakes. A stiff bristle broom can be used for finishing.
- Lay sod or seed. Grass installation procedures vary by product. Consult manufacturer or supplier for specific grass installation guidelines.
- Provide edge constraints along edges that may have vehicle loads (particularly tight radius turning). Cast-in-place or precast concrete is preferred.

- Concrete grids require edge restraints along edges in all applications. Plastic grids require restraints when exposed to vehicles. Edge restraints for concrete or plastic grids in such applications should be cast-in-place or precast concrete.

Maintenance

See Appendix 6-A: BMP Maintenance Tables.

Maintenance Recommendations for all Permeable Pavement Types

- Erosion and introduction of sediment from surrounding land uses should be strictly controlled after construction by amending exposed soil with compost and mulch, planting exposed areas as soon as possible, and armoring outfall areas.
- Surrounding landscaped areas should be inspected regularly and possible sediment sources controlled immediately.
- Installations can be monitored for adequate or designed minimum infiltration rates by observing drainage immediately after heavier rainstorms for standing water or infiltration tests using ASTM C1701.
- Clean permeable pavement surfaces to maintain infiltration capacity at least once or twice annually following recommendations below.
- Utility cuts should be backfilled with the same aggregate base used under the permeable paving to allow continued conveyance of stormwater through the base, and to prevent migration of fines from the standard base aggregate to the more open graded permeable base material (Diniz, 1980).
- Ice build up on permeable pavement is reduced and the surface becomes free and clear more rapidly compared to conventional pavement.
- Deicing and sand application is not recommended. The permeable pavement installation should be assessed during winter months and the winter traction program developed from those observations. Vacuum and sweeping frequency will likely be required more often if sand is applied.

Porous Asphalt and Pervious Concrete Maintenance Recommendations

- Clean surfaces using suction, sweeping with suction or high-pressure wash and suction (sweeping alone is minimally effective). Hand held pressure washers are effective for cleaning void spaces and appropriate for smaller areas such as sidewalks.
- For large scale cleaning use vacuum surface cleaning machines (such as Cyclone, Elgin, etc.) for cleaning pervious concrete and porous asphalt.
- Small utility cuts can be repaired with conventional asphalt or concrete if small batches of permeable material are not available or are too expensive.

Permeable Paver Maintenance Recommendations

- ICPI recommends cleaning if the measured infiltration rate falls below 10 in/hr.
- Use sweeping with suction one to two times annually when surface and debris are dry (see next bullet for exception for badly clogged installations).
    - Apply vacuum to a paver test section and adjust settings to remove all visible sediment without excess uptake of aggregate from paver openings or joints.
    - If necessary, replace rock with appropriate type (per deisgn) and to specified depth within the paver openings.
    - Washing or power washing should not be used to remove debris and sediment in the openings between the pavers (Smith, 2000).
- For badly clogged installations, wet the surface and vacuumed aggregate to a depth that removes all visible fine sediment and replace with clean aggregate.
- If necessary, use No. 8, No. 89, or No. 9 rock for winter traction rather than sand (sand will accelerate clogging).
- Pavers can be removed individually and replaced when utility work is complete.
- Replace broken pavers as necessary to prevent structural instability in the surface.
- The structure of the top edge of the paver blocks reduces chipping from snowplows. For additional protection, skids on the corner of plow blades are recommended.
- For a model maintenance agreement see *Permeable Interlocking Concrete Pavements: Design, Specifications, Construction, Maintenance* (Smith, 2011).

Plastic or Concrete Grid System Maintenance Recommendations

- Remove and replace top course aggregate if clogged with sediment or contaminated (vacuum trucks for stormwater collection basins can be used to remove aggregate).
- Remove and replace grid segments where three or more adjacent rings are broken or damaged.
- Replenish aggregate material in grid as needed.
- Snowplows should use skids to elevate blades slightly above the gravel surface to prevent loss of top course aggregate and damage to plastic grid.
- For grass installations, use normal turf maintenance procedures except do not aerate. Use very slow release fertilizers if needed.

Runoff Model Representation

To determine the maximum water surface elevation, model the permeable pavement with level-pool routing per 4.7 Level-Pool Routing Method with the subgrade infiltration rate. Account for the void space in the storage bed.

Modeling Approach for Porous Asphalt or Concrete

1. Base material laid above surrounding grade
    a. Without underlying perforated drain pipes
        - Model surface as: grass over underlying soil type (e.g. Hydrologic Soil Group A, B, C, D)

    b. With underlying perforated drain pipes
        - Model surface as: impervious surface

2. Base material laid partially or completely below surrounding grade
    a. Without underlying perforated drain pipes
        - Model surface as:
            - Option 1: grass over underlying soil type
            - Option 2: impervious surface routed to an infiltration BMP

    b. With underlying perforated drain pipes at or below bottom of base layer
        - Model surface as: impervious surface

    c. With underlying perforated drain pipes elevated within the base course
        - Model surface as:
            - If the perforated pipes are designed to distribute runoff directly below the wearing surface and the pipes are above the surrounding grade, then follow directions for 2a Option 1 above;
            - otherwise, follow directions for 2a Option 2

Modeling Approach for Plastic or Concrete Grids or PICP

1. Base material laid above surrounding grade
    a. Without underlying perforated drain pipes
        - Plastic or concrete grids model surface as: grass over underlying soil type
        - PICP model surface as: 50% grass on underlying soil; 50% impervious

    b. With underlying perforated drain pipes
        - Model surface as: impervious surface

2. Base material laid partially or completely below surrounding grade

a. Without underlying perforated drain pipes

- Model surface as:
  - Option 1 (plastic or concrete grids): grass over underlying soil type
  - Option 1 (PICP): 50% grass; 50% impervious
  - Option 2: impervious surface routed to an infiltration BMP

b. With underlying perforated drain pipes at or below bottom of base layer

- Model surface as: impervious surface

c. With underlying perforated drain pipes to collect stormwater elevated within the base course

- Model surface as:
  - If the perforated pipes are designed to distribute runoff directly below the wearing surface and the pipes are above the surrounding grade, then follow directions for 2a above;
  - otherwise, model surface as impervious surface routed to infiltration BMP

In the runoff modeling, similar permeable pavement designs throughout a development can be summed and represented as one large BMP. For instance, walkways can be summed into one BMP. Driveways with similar designs (and enforced through deed restrictions) can be modeled as a single BMP. In these instances, a weighted average of the design infiltration rates for each location may be used. The averages are weighted by the size of their contributing area. The design infiltration rate for each site is the measured infiltration rate multiplied by the appropriate correction factors (see 6.5.4 Determining the Design Infiltration Rate of the Native Soils). A site variability correction factor should be considered for native soils below permeable pavement.

As an alternative, walks, patios, and driveways with little storage capacity in the underlying aggregate base underdrain can be entered as lawn/landscape areas in the model.

6.6 Evaporation BMPs

6.6.1 Introduction to Evaporation BMPs

Evaporation BMPs are an alternative form of Flow Control that reduce the flow offsite through a combination surface evaporation, plant evapotranspiration, ground infiltration, or any other qualified outflow. This differs from traditional Flow Control methods (i.e. detention) which aim to detain and release the flows at a designed rate via an orifice structure, or infiltration where flows are reduced by directing water into the ground from a pond or through a UIC well.

BMP F6.30: Evaporation Ponds

Purpose and Definition

This section provides the methods for the design of evaporation ponds, which can be used to collect and dispose of stormwater when surface discharge is not available or the soils are not conducive to infiltration BMPs.

Evaporation ponds are primarily used as Flow Control BMPs. However, because they have no outlet, they may provide additional environmental benefits by eliminating discharge(s) of pollutants to the MS4.

Design Guidelines

For the design of evaporation ponds, a water budget is required. A cumulative, month-by-month water budget is performed as follows:

Equation 6.8: Evaporation Pond Water Budget

$$V_{in} - V_{out} = \Delta V_{month}$$

$$\Sigma V_{month} = \Delta V_{year}$$

where:

V_{in} = Volume of water into the evaporation pond, usually in cubic feet (cf)/month. V_{in} is a combination of stormwater runoff, direct rainfall onto the pond surface, groundwater seepage into the evaporation pond, and any other source of water into the pond.

V_{out} = Volume of water out of the evaporation pond, usually in cf/month. V_{out} is all outflows; it can be a combination surface evaporation, plant evapotranspiration, ground infiltration, or any other qualified outflow.

ΔV_{month} = Net volume of storage increase (or decrease) into the evaporation pond, usually in cf/month.

ΔV_{year} = Cumulative net volume of storage in the evaporation pond until storage equilibrium is obtained. Equilibrium is obtained when the volume of water at the end of the calculation cycle is less than the volume stored at the beginning of the cycle, evaluated over at least 2 calendar years.

It is recommended that a freeboard greater than or equal to 1 foot be maintained in the pond at all times. The use of a spreadsheet to perform the calculations can be helpful.

The water budget cycle should be performed on a month-by-month basis, until a steady-state condition occurs (i.e. the volume at the end of the cycle is less than or equal to the volume at the start of the cycle). The minimum duration of the water budget cycle is to be 2 years. The cycle is to start in the month which yields the greatest net storage volume for the year. Normally, beginning the water budget in September, October, or November produces the largest required storage volume. Contributing off-site areas are to be included in the analysis, considering existing locations.

The climatological data source for evaporation and mean annual precipitation rates used in the water budget are available from the National Oceanic and Atmospheric Administration (NOAA), or other reliable sources. The Western Regional Climate Center is another source of precipitation data (http://www.wrcc.dri.edu/summary/climsmwa.html). Average monthly precipitation rates and average monthly evaporation rates should be used in the water budget analysis, as a minimum.

Runoff Volume Determinations

Runoff volume from the basin directing stormwater into the evaporation ponds shall be included in the water budget analysis. Runoff volume can be determined using the Soil Conservation Service (SCS) hydrograph method or other methods approved by the local jurisdiction.

When preparing the water budget, antecedent moisture conditions (AMCs) need to be considered during the months of the year when the ground may be saturated or frozen.

For the SCS method, the curve numbers (CNs) should be adjusted as shown in Table 6.28: Curve Number Adjustment for Antecedent Moisture Condition. This requirement is applicable in Climate Regions 1, 3, and 4 only. Climate Region 2 should use AMC II CNs throughout the year.

Table 6.28: Curve Number Adjustment for Antecedent Moisture Condition

Month	Antecedent Moisture Condition (AMC)	Minimum Runoff Curve Number (CN)
April - October	Normal (AMC = II)	See Table 4.14: Runoff Curve Numbers (CNs) for Selected Agricultural, Suburban, and Urban Areas (continued)
November, March	Wet (AMC = III)	See Table 4.16: Curve Number Conversions for Antecedent Moisture Conditions (Case Ia = 0.2S) (continued)
December - February	N/A	95

Water loss through evaporation from overland surface areas is normally not to be considered in the water budget, for the areas contributing runoff to the evaporation pond(s), due to the wide variation in evaporation rates which occur over these types of surfaces. The only reduction which can be considered in the analysis is runoff interception and surface infiltration, which are normally accounted for in the SCS CNs or rational coefficients.

Disposal is primarily through evaporation from the pond surface. Credit for infiltration through soils will not be considered in the water budget analysis in the absence of any site-specific infiltration testing work being performed.

Geosynthetic or natural liners may be used to limit infiltration outflow volumes in areas where this is desired, or in locations where the seasonal water table will adversely impact the pond. See 6.1.9 Liners and Geotextiles.

Other Design Considerations

When credit for infiltration is proposed, site characterization, testing, and reporting must be done in accordance with 6.5 Infiltration BMPs.

The design of the evaporation pond will need to evaluate the potential of groundwater seeping into the pond from the surrounding area for an unlined pond and evaluate the potential for groundwater mounding or uplift for a lined pond. A geotechnical evaluation should be performed, evaluating this potential adverse impact, and, if needed, mitigation measures should be provided.

Sources of imported water need to be considered in the water budget design and calculations. Other sources may include irrigation, sewer septic tank/drain field systems, natural springs, foundation drains, dewatering wells, etc. The qualified professional preparing the water budget shall include sources of any imported water in the water budget analysis.

The maximum water surface elevation permissible in the water budget is to be below the finish floor elevations of the surrounding buildings (existing or proposed). Privately owned parking lot areas can be used for temporary storage of stormwater and considered in the water budget analysis. If ponding is proposed in parking lot areas, the maximum water depth should not exceed 1 foot.

If snow removal operations deposit snow into an evaporation pond, this added factor must be considered in the water budget, especially if snow from another basin is put into the system. Temporary sediment ponds or other treatment BMPs should be included in the design, to prevent sediment-laden runoff from entering the pond and stormwater conveyance system during construction.

Example Calculations

An example of the inputs and results for a sample project site is shown in Figure 6.58: Example Calculations for Sizing an Evaporation Pond at a Site in the Spokane Area.

For this scenario, the overall drainage basin is 8.00 acres (on-site and off-site, Type B soils, with off-site being uphill and flowing onto the site). The example shown is for full evaporation without discharge via detention to a natural or existing drainage channel.

The example uses data from the nearest station with average monthly precipitation and pan evaporation data available. The monthly precipitation value is adjusted based on the site location. Because evaporation data is collected using a shallow, metal evaporation pan that is fully exposed to sun and wind and affected by heat exchanges within the pan, the pan evaporation rate must be adjusted; the adjustment coefficient should be between 70% and 80%.

The total site area assumes that no off-site property is available for locating the pond; thus the calculations will need to be adjusted as the pond size goes up or down. The starting point for the pond bottom area is generally to assume 25% of the total site for a typical commercial development.

The pond bottom perimeter is calculated as a square but can be entered manually if the pond perimeter is known. Remember that the perimeter will change if the pond bottom area is increased or decreased during design iterations. As the proposed pond bottom area changes, the portion of the impervious basin area attributed to the pond surface will also change.

The calculations are iterated for 2 or more years in order to see when the pond has reached a steady state: there should be a decrease the following year in the month with the largest storage (March in the example shown). The calculations assume that the pond contains a dead storage of the equivalent of the 100-year design flow volume because typically, the only time a full evaporation pond is needed is when there is no discharge point, no infiltrative capacity available, existing high groundwater, or potential for adjacent or downgradient property damage from additional stormwater being injected into the subsurface. The extra capacity provides emergency storage in the event that a site experiences above average total annual precipitation.

Some of the design criteria for this example may need to be adjusted for local requirements. For example, the Spokane County guidelines state the following:

- For impervious surfaces such as roads, sidewalks, and driveways, the AMC II CN is 98, and the AMC III CN is 99. From December through February, the assumption is that if the CN of 98 goes up to 99 during the wet months, it will not revert to 98 during frozen ground conditions.
- During December through February, the CN for permeable surfaces is 95 regardless of the AMC II or III CNs, meant to approximate runoff from permeable surfaces during snowpack buildup and snowmelt.
- One foot of freeboard is needed above the maximum water surface elevation of the pond.

Figure 6.58: Example Calculations for Sizing an Evaporation Pond at a Site in the Spokane Area

Project:	EXAMPLE SITE IN SPOKANE AREA		
Plat / BSP / Proj No:	###	Engineer:	initials
Date:	8/10/2004		
Pond Bottom Area:		112,000	sq. ft.
Pond Bottom Perimeter:		1,339	ft
Pond Side Slopes:		3	: 1
Impervious Basin Size (Constant):		2.00	acres
Impervious Basin Size (Pond Area):		2.57	acres
Permeable Basin Size:		2.43	acres
Off-Site Upstream Basin:		1.00	acres
Total Basin Size:	8.00	8.00	acres
Mean Annual Prec. - Airport:		16.11	in
Mean Annual Prec. - Site:		19.70	in
Multiplier:		1.22	
100-Year, 24 Hour, Prec.:		2.70	in

Evaporative Pond to Accommodate 100% of Post-Developed Runoff Volume

(no infiltration allowed)

CONDITION: FULL CONTAINMENT

	AMC II Apr-Oct	AMC III Nov&Mar	--- Dec-Feb
Impervious CN:	98	99	99
Permeable CN:	61	78	95
Off-Site CN:	58	76	95
Impervious S:	0.20	0.10	0.10
Permeable S:	6.39	2.82	0.53
Off-Site S:	7.24	3.16	0.53

RESULTS:		
Pond Volume:	246,080	cu ft
Pond Depth:	2.20	ft
Add 1' freeboard:	3.20	ft

						INFLOW				OUTFLOW		STORAGE	POND DATA	
Month	Precip. (in)	Adjusted Precip. (in)	Impervious Runoff Depth (in)	Permeable Runoff Depth (in)	Off-Site Runoff Depth (in)	Impervious Runoff Volume (cu ft)	Permeable Runoff Volume (cu ft)	Off-Site Runoff Volume (cu ft)	NET Runoff Volume (cu ft)	Pan Evap. (in)	Evap. Vol. Out; 72% Adj. (cu ft)	Volume Stored in Pond (cu ft)	Pond Depth (ft)	Pond Capacity (%)
												20,878	0.19	8
Oct.	1.22	1.49	1.27	0.01	0.00	21,109	61	1	21,171	2.58	17,453	24,595	0.22	10
Nov.	2.02	2.47	2.35	0.77	0.68	39,043	6,777	2,456	48,276	0.92	6,231	66,640	0.59	26
Dec.	2.22	2.71	2.60	2.17	2.17	43,095	19,145	7,882	70,123	0.51	3,500	133,263	1.19	52
Jan.	2.05	2.51	2.39	1.97	1.97	39,651	17,368	7,151	64,169	0.61	4,274	193,157	1.72	76
Feb.	1.57	1.92	1.80	1.41	1.41	29,930	12,402	5,106	47,438	1.11	7,920	232,675	2.08	91
Mar.	**1.38**	**1.69**	**1.57**	**0.32**	**0.26**	**26,086**	**2,821**	**961**	**29,868**	**2.28**	**16,463**	**246,080**	**2.20**	**96**
Apr.	1.11	1.36	1.14	0.00	0.00	18,914	8	0	18,922	4.45	32,260	232,742	2.08	91
May	1.37	1.68	1.45	0.02	0.01	24,111	204	25	24,340	6.69	48,307	208,776	1.86	82
June	1.27	1.55	1.33	0.01	0.00	22,109	100	5	22,214	8.14	58,357	172,633	1.54	67
July	0.50	0.61	0.42	0.00	0.00	6,974	0	0	6,974	10.70	75,878	103,728	0.93	41
Aug.	0.60	0.73	0.54	0.00	0.00	8,881	0	0	8,881	9.42	65,405	47,205	0.42	18
Sept.	0.80	0.98	0.77	0.00	0.00	12,775	0	0	12,775	5.90	40,247	19,733	0.18	8
Oct.	1.22	1.49	1.27	0.01	0.00	21,109	61	1	21,171	2.58	17,447	23,456	0.21	9
Nov.	2.02	2.47	2.35	0.77	0.68	39,043	6,777	2,456	48,276	0.92	6,229	65,503	0.58	26
Dec.	2.22	2.71	2.60	2.17	2.17	43,095	19,145	7,882	70,123	0.51	3,499	132,127	1.18	52
Jan.	2.05	2.51	2.39	1.97	1.97	39,651	17,368	7,151	64,169	0.61	4,273	192,023	1.71	75
Feb.	1.57	1.92	1.80	1.41	1.41	29,930	12,402	5,106	47,438	1.11	7,918	231,543	2.07	91
Mar.	**1.38**	**1.69**	**1.57**	**0.32**	**0.26**	**26,086**	**2,821**	**961**	**29,868**	**2.28**	**16,457**	**244,954**	**2.19**	**96**
Apr.	1.11	1.36	1.14	0.00	0.00	18,914	8	0	18,922	4.45	32,249	231,627	2.07	91
May	1.37	1.68	1.45	0.02	0.01	24,111	204	25	24,340	6.69	48,291	207,677	1.85	81
June	1.27	1.55	1.33	0.01	0.00	22,109	100	5	22,214	8.14	58,338	171,552	1.53	67
July	0.50	0.61	0.42	0.00	0.00	6,974	0	0	6,974	10.70	75,853	102,673	0.92	40
Aug.	0.60	0.73	0.54	0.00	0.00	8,881	0	0	8,881	9.42	65,383	46,171	0.41	18
Sept.	0.80	0.98	0.77	0.00	0.00	12,775	0	0	12,775	5.90	40,234	18,712	0.17	7

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Example Calculations for Sizing an Evaporation Pond at a Site in the Spokane Area

Revised November 2023

Operation and Maintenance Criteria

Provisions to facilitate maintenance operations must be built into the project when it is installed. Maintenance, including weed control and moving, must be a basic consideration in design and in determination of first cost.

For more information, see Appendix 6-A: BMP Maintenance Tables.

6.7 Filtration BMPs

6.7.1 Introduction to Filtration BMPs

Filtration BMPs collect and treat stormwater runoff to reduce total suspended solids (TSS), phosphorous, and insoluble organics (including oils).

Sand Filtration

A typical sand filtration system consists of a pretreatment system, flow spreader(s), sand bed, and underdrain piping. The sand filter bed includes a geotextile fabric between the sand bed and the bottom underdrain system.

Provide an impermeable liner under the facility if the filtered runoff requires additional treatment to remove soluble groundwater pollutants; or where additional groundwater protection is mandated.

The variations of a sand filter include BMP T5.80: Basic Sand Filter Basin, BMP T5.81: Large Sand Filter Basin, BMP T5.82: Sand Filter Vault, and BMP T5.83: Linear Sand Filter.

Filtration with Media Filter Drains

The Media Filter Drain (MFD) has four basic components: a gravel no-vegetation zone, a grass strip, the MFD mix bed, and a conveyance system for flows leaving the MFD mix. The MFD mix is composed of gravel, perlite, dolomite, and gypsum. See BMP T5.84: Media Filter Drain.

Applications and Limitations

Filtration BMPs can be used in most residential, commercial, and industrial developments where debris, heavy sediment loads, and oils and greases will not clog or prematurely overload the sand, or where adequate pretreatment is provided for these pollutants. Specific applications include residential subdivisions, parking lots for commercial and industrial establishments, gas stations, sites that require oil control BMPs, high-density multifamily housing, roadways, and bridge decks.

Locate sand filter BMPs off-line before or after detention (Chang, 2000). See 6.1.5 Sizing Your Runoff Treatment BMPs for guidance for off-line BMPs. BMP T5.82: Sand Filter Vault is also suited for locations with space constraints in retrofit, and new/re-development situations. Design overflow or bypass structures to handle the larger storms.

Prolonged flows from a detention BMP may cause extended saturation periods within the sand filter. Saturated sand can lose all oxygen and become anoxic. If that occurs, some amount of phosphorus captured within the filter may become soluble and released. To prevent long periods of saturation, adjustments may be necessary after the sand filter is in operation to bypass some areas of the filter. This bypassing will allow them to drain completely. It may also be possible to use a different type of BMP that is less sensitive to prolonged flows.

A pretreatment BMP is necessary to reduce velocities to the sand filter BMP and remove debris, floatables, large particulate matter, and oils. In high water table areas, adequate drainage of the sand filter BMP may require additional engineering analysis and design considerations. Consider an underground sand filter in areas subject to freezing conditions (Urbonas, 1997).

Cold Weather Climate Considerations

Surface filters will not provide treatment in the winter if the ground is frozen, but may still provide adequate treatment during warmer months. An underground filter should be considered in areas subject to freezing conditions (Urbonas, 1997b). See 6.1.8 Cold Weather Considerations for additional detailed information on cold weather climate considerations.

Arid/Semiarid Climate Considerations

Sand filtration BMPs are widely used in arid/semiarid regions. A majority of the filtration BMPs described in this section are unvegetated; however, if the filtration BMP (such as the MFD) is vegetated, then grasses should be selected for drought tolerance.

BMP T5.80: Basic Sand Filter Basin

Description

A basic sand filter basin is constructed so that its surface is at grade and open to the elements, similar to BMP F6.21: Infiltration Ponds. However, instead of infiltrating into native soils, stormwater filters through a constructed sand bed with an underdrain system. See Figure 6.59: Sand Filter, Figure 6.60: Sand Filtration Basin Preceded by Presettling Basin (Variation of a Basic Sand Filter), Figure 6.61: Sand Filter with Pretreatment Cell (Plan View), Figure 6.62: Sand Filter with Pretreatment Cell (Section View), Figure 6.63: Sand Filter with Level Spreader (Plan View), and Figure 6.64: Sand Filter with Level Spreader (Section View) for more details.

Applications and Limitations

Basic sand filter basins should be sized to pass the Water Quality Design Flow Rate (as described in 6.1.5 Sizing Your Runoff Treatment BMPs) through the sand filter.

Design sand filters using the off-line flow rate either upstream or downstream of detention BMPs. Use the on-line flow rate for sand filters only located downstream of detention BMPs to prevent exposure of the sand filter surface to high flow rates that could cause loss of media and previously removed pollutants.

The basic sand filter is a Runoff Treatment BMP. See 6.1.2 Choosing Your Runoff Treatment BMPs for guidance on the Runoff Treatment Performance Goals, and which goals the basic sand filter is presumed to meet.

Site Suitability

Consider the following site characteristics when siting a basic sand filter:

- Space availability, including a presettling basin
- Sufficient hydraulic head, at least 4 feet from inlet to outlet

- Average winter conditions at the project site that do not create snow or ice conditions preventing the filter from operating as designed
- Adequate operation and maintenance capability, including accessibility for operation and maintenance
- Sufficient pretreatment of oil, debris and solids in the runoff from the contributing area

Design Criteria

Hydraulics

The objective of designing a basic sand filter is to capture and treat the Water Quality Design Volume. This is accomplished by sizing the filter to pass the Water Quality Design Flow Rate. See 6.1.5 Sizing Your Runoff Treatment BMPs for details on the Water Quality Design Volume and Water Quality Design Flow Rate.

Assume a design filtration rate of 1 inch per hour. Though the sand medium specified below will initially infiltrate at a much higher rate, that rate will slow as the sand filter accumulates sediment. When the filtration rate falls to 1 inch per hour, removal of sediment or replacement of the sand is necessary to maintain rates above the rate assumed for sizing purposes.

If the drainage area maintains a base flow between storm events, bypass the base flow around the basic sand filter BMP to keep the sand from remaining saturated for extended periods.

On-line Basic Sand Filter Design

- Do NOT place an on-line basic sand filter BMP upstream of a detention BMP. This restriction is to prevent exposure of the sand filter surface to high flow rates that could cause loss of media and previously removed pollutants.
- Size on-line sand filter BMPs placed downstream of a detention BMP to filter the Water Quality Design Flow Rate as described in 6.1.5 Sizing Your Runoff Treatment BMPs.
- Include an overflow in the design. The overflow height should be at the maximum hydraulic head of the pond above the sand bed. On-line sand filter BMPs shall have overflows (primary, secondary, and emergency) in accordance with the design criteria for BMP F6.10: Detention Ponds.

Off-line Basic Sand Filter Design

- Off-line sand filter BMPs placed upstream of a detention BMP must have a flow splitter designed to send all flows at or below the Water Quality Design Flow Rate, as detailed in 6.1.5 Sizing Your Runoff Treatment BMPs, to the sand filter BMP.
- Size the basic sand filter BMP to filter all the runoff sent to it (no overflows from the BMP should occur).
- Off-line sand filter BMPs placed downstream of a detention BMP must have a flow splitter designed to send all flows at or below the 2-year flow frequency from the detention BMP to the basic sand filter BMP. The basic sand filter BMP must be sized to filter all the runoff sent

to it (no overflows from the basic sand filter BMP should occur).

- For off-line sand filter BMPs downstream of a detention BMP, design the underdrain structure to pass the 2-year peak inflow rate.

Simple Sizing Method

This method applies to the off-line placement of a sand filter upstream or downstream of detention BMPs. A conservative design approach is provided below using a routing adjustment factor that does not require flow routing computations through the filter. An alternative simple approach for off-line placement downstream of detention BMPs is to route the full 2-year release rate from the detention BMP (sized for 2.4.6 CE6: Flow Control) to a sand filter with sufficient surface area for infiltration at that flow rate.

Basic Sand Filter Sizing

For sizing a basic sand filter, a 0.7 routing adjustment factor is applied to compensate for routing through the sand bed at the maximum pond depth. A flow splitter should be designed to route the Water Quality Design Flow Rate to the sand filter and send higher flows around the filter.

Note: An overflow should be included in the design of the sand filter pond. The overflow height should be at the maximum hydraulic head of the pond above the sand bed.

The stepwise procedure for designing basic sand filters for Runoff Treatment includes the following:

1. Determine the Water Quality Design Flow Rate (Q) to the basic sand filter BMP for the given contributing area (A_t). See Chapter 4 - Hydrologic Analysis and Design.
2. Define initial BMP geometry, including the maximum sand filter pond depth (d) and sand bed depth (L).
3. Calculate the flow rate at which runoff is filtered by the sand filter bed and the sand filter surface area using Darcy's Law to account for the increased flow through the sand bed caused by the hydraulic head variations in the pond above the sand bed, as follows:

Equation 6.9: Basic Sand Filter Flow Rate

$$Q_{sf} = K * i * A_{sf} = F * A_{sf}$$

Equation 6.10: Basic Sand Filter Surface Area

$$A_{sf} = A_t * Q_d * R / (K * [h + L] / [L * t])$$

where:

Q_{sf}=flow rate at which runoff is filtered by the sand filter bed (cubic feet [cf]/day or cubic feet per second [cfs])

K=hydraulic conductivity of the sand bed. Use 2 feet per day (ft/day) or 1.0 inch per hour (in/hr) at full presedimentation

I=hydraulic gradient of the pond above the filter; (h + L) / L, (feet per foot [ft/ft])

A_{sf}=sand filter surface area (sf)

F=filtration rate (ft/day or in/hr)

A_t=contributing area (sf)

Q_d=design storm runoff depth (ft) for the water quality design storm (Q). See Chapter 4 - Hydrologic Analysis and Design.

R=routing adjustment factor

h=d/2 (ft)

d=maximum sand filter pond depth (ft)

L=sand bed depth (ft)

t=maximum drawdown time (hrs). Use 24 hours from the completion of inflow into the sand filter pond (assume ponded presettling basin) of a discrete storm event to the completion of outflow from the sand filter underdrain of that same storm event

Table 6.29: Sizing Methods and Assumptions for Basic Sand Filter BMPs (continued) summarizes the methods and assumptions for the above steps for sizing basic sand filter BMPs.

Table 6.29: Sizing Methods and Assumptions for Basic Sand Filter BMPs

Steps	Variable	Methods and Assumptions
1	Water Quality Design Flow Rate (Q)[a]	See Chapter 4 - Hydrologic Analysis and Design for methods for computing design storms.
1, 3	Contributing Area (A_t)	Per design
2, 3	Maximum Sand Filter Pond Depth (d)	Per design
2, 3	Sand Bed Depth (L)	L = 1.5 ft (typical, may vary per design)
2, 3	Flow Rate at Which Runoff is Filtered by the Sand Filter Bed (Q_{sf})	Calculate using Darcy's Law
2, 3	Sand Filter Surface Area (A_{sf})	Calculate using Darcy's Law
3	Hydraulic Conductivity of the Sand Bed (K)	K = 2 ft/day or 1.0 in/hr
3	Hydraulic Gradient of Pond Above the Filter (i)	Calculate, i = (h + L) / L, where h = d/2
	Design Storm Runoff Depth (Q_d)	Calculated for Q using the SCS Curve Number equations. See Chapter 4 - Hydrologic Analysis and Design.
3	Routing Adjustment Factor (R)	R = 0.7

Table 6.29: Sizing Methods and Assumptions for Basic Sand Filter BMPs (continued)

Steps	Variable	Methods and Assumptions
3	Filtration Rate (F)	Calculate, F = K * i
3	Maximum Drawdown Time (t)	t = 24 hours
[a]See local jurisdiction requirements for calculating peak flow rates.		

Example Calculation

- Sedimentation basin fully ponded and no pond water above sand filter
- Full sedimentation prior to sand filter – 24 hours residence of water quality storm runoff
- A_t = 10 acres
- Q_d = 0.92 inches (0.0767 ft), for Yakima rainfall
- Curve number = 96.2 for 85% impervious and 15% grass tributary surfaces
- R = 0.7
- t = 24 hr
- d = 3 ft
- h = 1.5 ft
- K = 2.0 ft/day (1 in/hr)

Using Equation 6.10: Basic Sand Filter Surface Area:

$$A_{sf} = (10 \text{ acres} * 43{,}560 \text{ sf/acre} * 0.0767 \text{ ft}) / ([0.7 / 2.0 \text{ ft/day}] * [1.5 \text{ ft} + 1.5 \text{ ft}] / [1.5 \text{ ft} * 1 \text{ day}]) = 5{,}846 \text{ sf}$$

Therefore, A_{sf} = 5,846 sf at pond depth of 3 ft

Additional Design Criteria

1. Pretreat (see 6.10 Pretreatment BMPs) runoff directed to the basic sand filter BMP to remove debris and other solids. For sites that require oil control per 6.1.2 Choosing Your Runoff Treatment BMPs, the pretreatment should be an appropriate oil control BMP as described in 6.1.2 Choosing Your Runoff Treatment BMPs.
2. Design inlet bypass and flow spreading structures (see 6.1.10.1 Flow Splitters and 6.1.10.2 Flow Spreaders) to capture the applicable design flow rate, minimize turbulence, and to spread the flow uniformly across the surface of the sand filter. Install stone riprap or other energy dissipation devices to prevent gouging of the sand medium and to promote uniform flow. Include an emergency spillway or overflow structure(s).

a. If the sand filter is curved or an irregular shape, provide a flow spreader for a minimum of 20 percent of the sand filter perimeter.

b. If the length-to-width ration of the sand filter is 2:1 or greater, locate a flow spreader on the longer side of the sand filter and for a minimum length of 20 percent of the sand filter perimeter.

c. Provide erosion protection along the first foot of the sand filter adjacent to the flow spreader. Methods for this include geotextile weighted with sand bags at 15-foot intervals and quarry spalls.

3. The following are design criteria for the underdrain piping:

- Types of acceptable underdrains:
  - A central collector pipe with lateral feeder pipes in an 8-inch gravel backfill or drain rock bed.
  - A central collector pipe with a geotextile drain strip in an 8-inch gravel backfill or drain rock bed.
  - Longitudinal pipes in an 8-inch gravel backfill or drain rock with a collector pipe at the outlet end.
- Size the underdrain piping for the 2-year design storm (whether upstream or downstream of a detention BMP). Provide at least one (1) foot of hydraulic head above the invert of the upstream end of the collector pipe. (King County, 1998)
- Use underdrain pipe with a minimum internal diameter of six (6) inches, with two rows of ½-inch holes spaced 6 inches apart longitudinally (maximum), and rows 120 degrees apart (laid with holes downward). Maintain a maximum perpendicular distance between two feeder pipes, or the edge of the sand filter and a feeder pipe, of 15 feet. For all piping use schedule 40 PVC or piping with a greater wall thickness. Drain piping could be installed in basin and trench configurations. Minimum underdrain size should be 8 inches in diameter if filter is subject to freezing for a month or more.
- Slope the main collector underdrain pipe at 0.5 percent minimum (1% if subject to freezing for a month or more). (King County, 1998)
- Use a geotextile fabric (specifications in 6.1.9.4 Geotextile Specifications) between the sand layer and drain rock or gravel. Cover the geotextile fabric with 1-inch of drain rock/gravel. Use 0.75-1.5 inch drain rock or gravel backfill, washed free of clay and organic material. Increase gravel depth at base of filter to 18 inches if subject to freezing for a month or more. (King County, 1998)
- Place cleanout wyes with caps or junction boxes at both ends of the collector pipes. Extend cleanouts to the surface of the sand filter BMP. Supply a valve box for access to the cleanouts. Provide access for cleaning all underdrain piping. This may consist of installing cleanout ports, which tee into the underdrain system and surface above the top of the sand filter. To facilitate maintenance of the sand filter an inlet shutoff/bypass valve is recommended.

4. Sand medium specification: The sand medium shall be 18 inches minimum in depth and must consist of sand meeting the size gradation (by weight) given in Table 6.30: Sand Medium Specification. The contractor must obtain a grain size analysis from the supplier to certify that the sand meets the No. 100 and No. 200 sieve requirements.

   Note: Standard backfill for sand drains, WSDOT Std. Spec. 9-03.13, does not meet the sand medium specification. Do not use Spec 9-03.13 for sand filter BMPs.

Table 6.30: Sand Medium Specification

Sieve Number	Percent Passing
4	95-100
8	70-100
16	40-90
30	25-75
50	2-25
100	<4
200	<2
Source: (King County, 1998)	

5. Impermeable liners for sand bed bottom: Impermeable liners are generally required for soluble pollutants such as metals and toxic organics and where the underflow could cause problems with structures. Impermeable liners may consist of clay, concrete or geomembrane. Clay liners should have a minimum thickness of 12 inches and meet the specifications give in Table 6.31: Clay Liner Specifications:

Table 6.31: Clay Liner Specifications

Property	Test Method	Unit	Specification
Permeability	ASTM D-2434	cm/sec	1×10^{-6} max.
Plasticity Index of Clay	ASTM D-423 & D-424	percent	Not less than 15
Liquid Limit of Clay	ASTM D-2216	percent	Not less than 30
Clay Particles Passing	ASTM D-422	percent	Not less than 30
Clay Compaction	ASTM D-2216	percent	95% of Standard Proctor Density
Source: (City of Austin, 1988)			

   - If a geomembrane liner is used it should have a minimum thickness of 30 mils and be ultraviolet resistant. Protect the geomembrane liner from puncture, tearing, and abrasion by installing geotextile fabric on the top and bottom of the geomembrane.
   - Concrete liners may also be used for sedimentation chambers and for sedimentation and sand filter basins less than 1,000 square feet in area. Concrete should be 5

inches thick Class A or better and reinforced by steel wire mesh. The steel wire mesh should be 6 gauge wire or larger and 6-inch by 6-inch mesh or smaller. An "Ordinary Surface Finish" is required. When the underlying soil is clay or has an unconfined compressive strength of 0.25 ton per square foot or less, the concrete should have a minimum 6-inch compacted aggregate base. This base must consist of coarse sand and river stone, crushed stone or equivalent with diameter of 0.75- to 1-inch.

- If an impermeable liner is not required then a geotextile fabric liner should be installed that retains the sand and meets the specifications listed in 6.1.9.4 Geotextile Specifications, unless the basin has been excavated to bedrock.
- If an impermeable liner is not provided, then an analysis should be made of possible adverse effects of seepage zones on groundwater, and near building foundations, basements, roads, parking lots and sloping sites. Sand filters without impermeable liners should not be built on fill sites and should be located at least 20-feet downslope and 100-feet upslope from building foundations.

6. Include an access ramp with a slope not to exceed 7:1, for maintenance purposes at the inlet and the outlet of a surface sand filter. Consider an access port for inspection and maintenance.
7. Side slopes for earthen/grass embankments should not exceed 3:1 to facilitate mowing.
8. High groundwater may damage underground structures or affect the performance of sand filter BMP underdrain systems. There should be sufficient clearance (at least 2 feet is recommended) between the seasonal high groundwater level (highest level of groundwater observed) and the bottom of the sand filter to obtain adequate drainage.

Construction Criteria

No runoff should enter the sand filter BMP prior to completion of construction and approval of site stabilization by the responsible inspector. Construction runoff may be routed to BMP C240: Sediment Trap or BMP C241: Sediment Pond (Temporary), but discharge from those should bypass downstream sand filter BMPs.

Careful level placement of the sand is necessary to avoid formation of voids within the sand filter that could lead to short-circuiting, (particularly around penetrations for underdrain cleanouts) and to prevent damage to the underlying geomembranes and underdrain system.

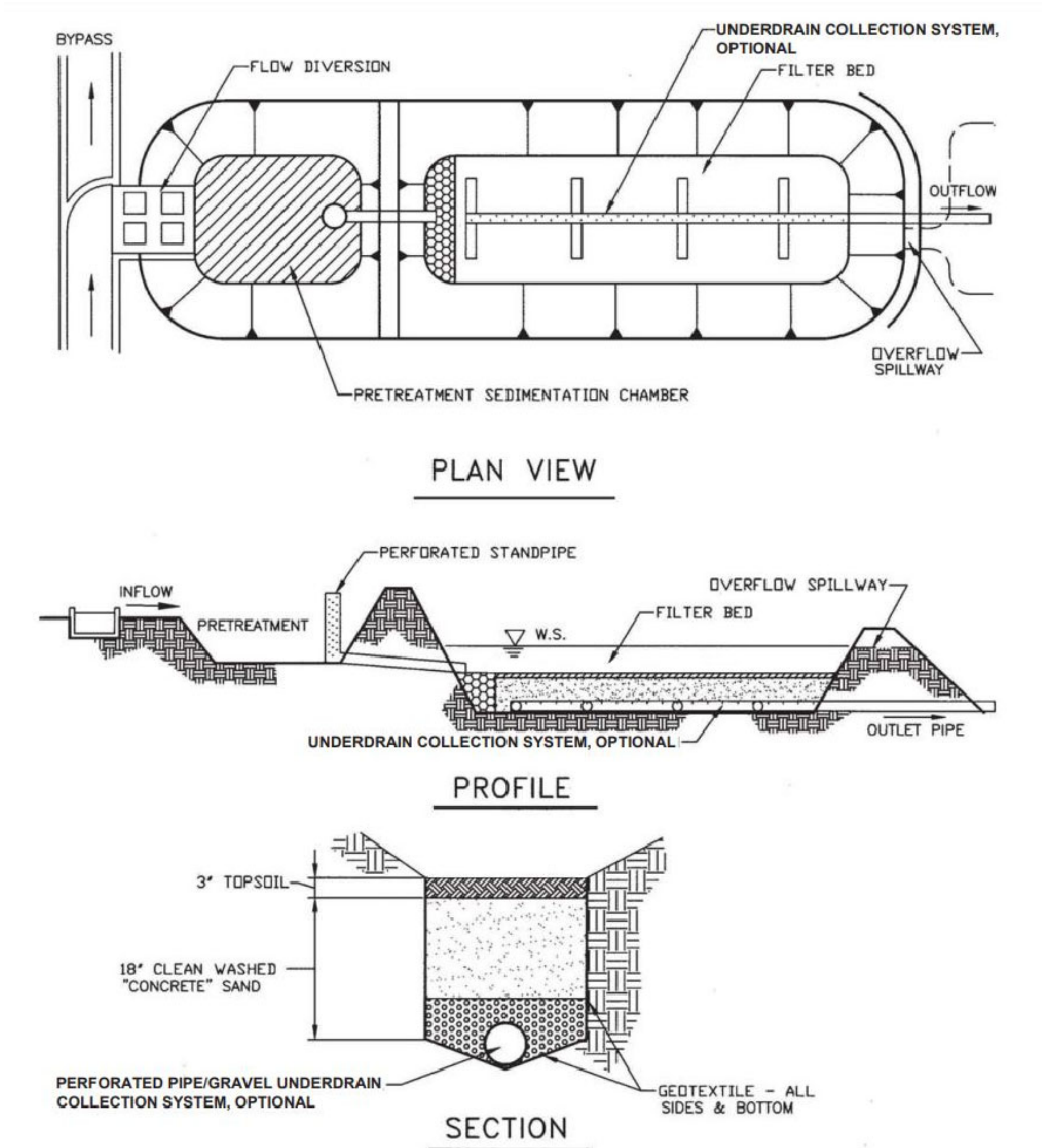
Over-compaction should be avoided to ensure adequate filtration capacity. Sand is best placed with a low ground pressure bulldozer (4 psig or less). After the sand layer is placed, water settling is recommended. Flood the sand with 10-15 gallons of water per cubic foot of sand.

Maintenance Criteria

Inspections of sand filters and pretreatment systems should be conducted every 6 months and after storm events as needed during the first year of operation, and annually thereafter if the sand filter performs as designed. Repairs should be performed as necessary. Suggestions for maintenance include:

- Accumulated silt and debris on top of the sand filter should be removed when their depth exceeds 1/2-inch. The silt should be scraped off during dry periods with steel rakes or other devices. Once sediment is removed, the design permeability of the sand medium can typically be restored by then striating the surface layer of the media. Finer sediments that have penetrated deeper into the sand medium can reduce the permeability to unacceptable levels, necessitating replacement of some or all of the sand.
- Sand replacement frequency is not well established and will depend on suspended solids levels entering the sand filter (the effectiveness of the pretreatment BMP can be a significant factor).
- Frequent overflow into the spillway or overflow structure or slow drawdown are indicators of plugging problems. A sand filter should empty in 24 hours following a storm event (24 hours for the pre-settling chamber), depending on pond depth. If the hydraulic conductivity drops to one (1) inch per hour corrective action is needed, e.g.:
    - Scraping the top layer of fine-grain sediment accumulation (mid-winter scraping is suggested)
    - Removal of vegetation
    - Aerating the sand filter surface
    - Tilling the sand filter surface (late-summer rototilling is suggested)
    - Replacing the top 4 inches of sand medium.
    - Inspecting geotextiles for clogging
- Rapid drawdown in the sand bed (greater than 12 inches per hour) indicates short-circuiting of the sand filter. Inspect the cleanouts on the underdrain pipes and along the base of the embankment for leakage.
- Drawdown tests for the sand bed could be conducted, as needed, during the wet season. These tests can be conducted by allowing the sand filter to fill (or partially fill) during a storm event, then measuring the decline in water level over a 4-8 hour period. An inlet and an underdrain outlet valve would be necessary to conduct such a test.
- Formation of rills and gullies on the surface of the sand filter indicates improper function of the inlet flow spreader, or poor sand compaction. Check for accumulation of debris on or in the flow spreader and refill rills and gullies with sand medium.
- Avoid driving heavy equipment on the sand filter to prevent compaction and rut formation.
- See Appendix 6-A: BMP Maintenance Tables for additional recommended maintenance criteria.

Figure 6.59: Sand Filter



Source: Low Impact Development Technical Guidance Manual for Puget Sound (WSU-PSP, 2012)

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Sand Filter

Revised August 2018

Figure 6.60: Sand Filtration Basin Preceded by Presettling Basin (Variation of a Basic Sand Filter)

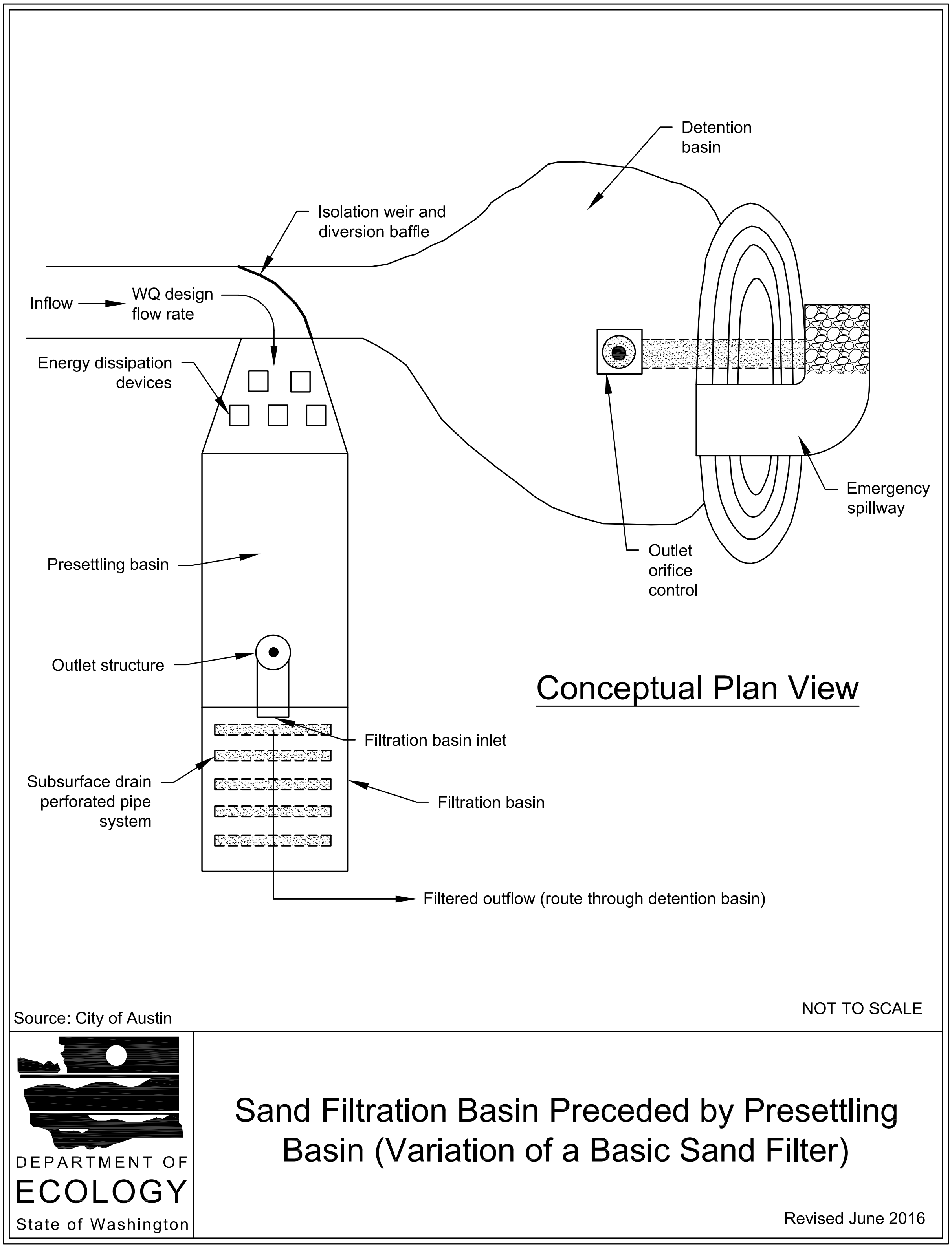


Figure 6.61: Sand Filter with Pretreatment Cell (Plan View)

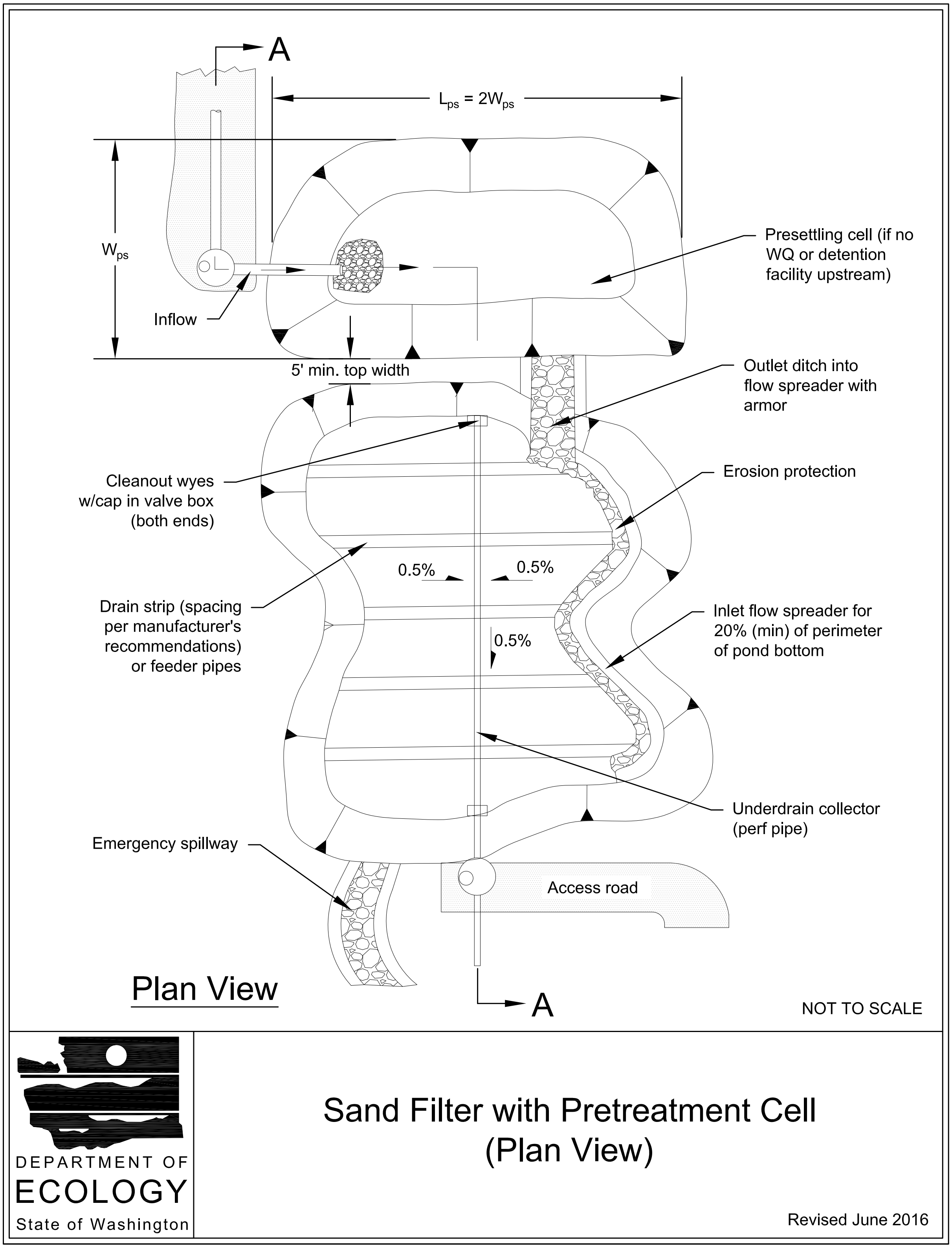


Figure 6.62: Sand Filter with Pretreatment Cell (Section View)

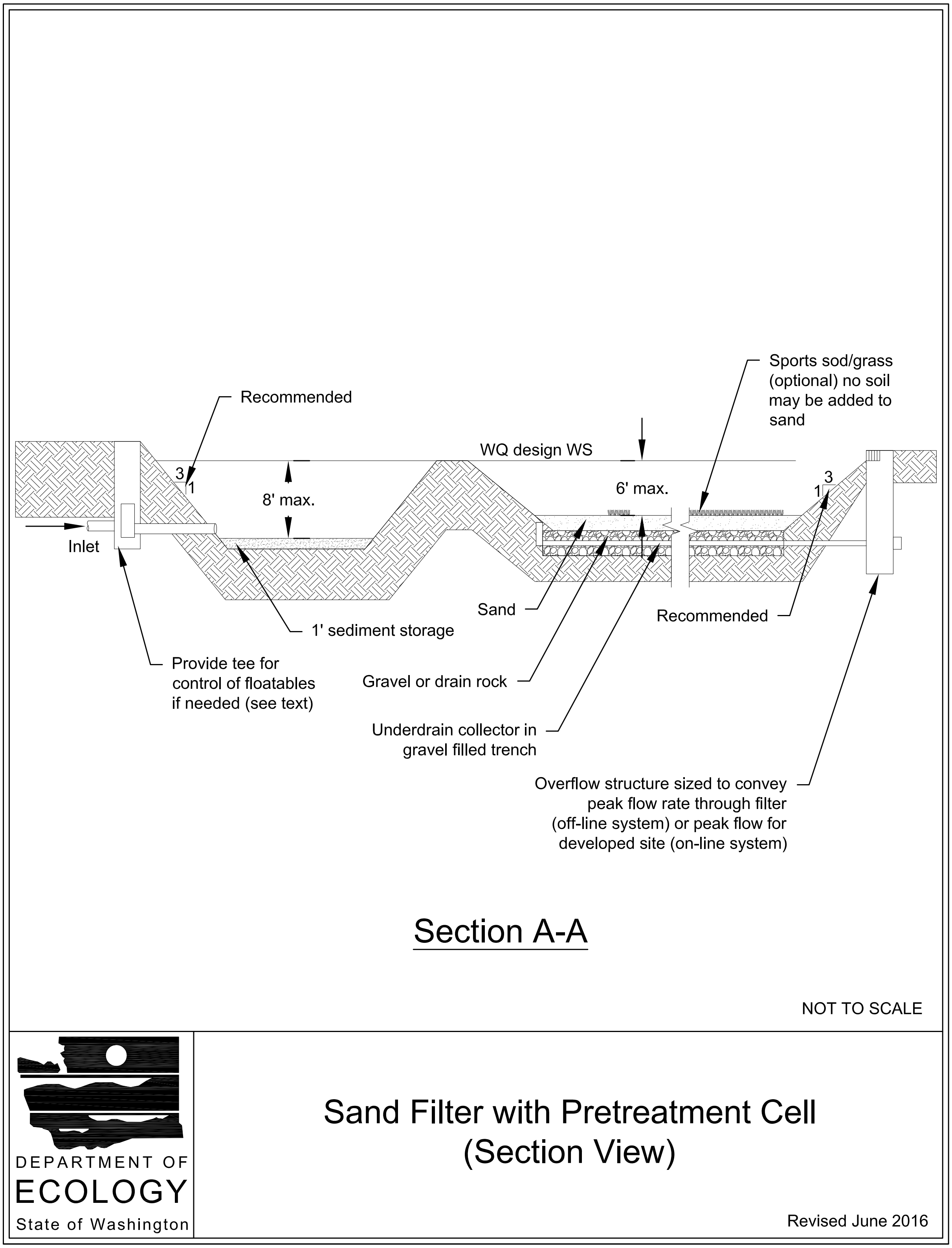


Figure 6.63: Sand Filter with Level Spreader (Plan View)

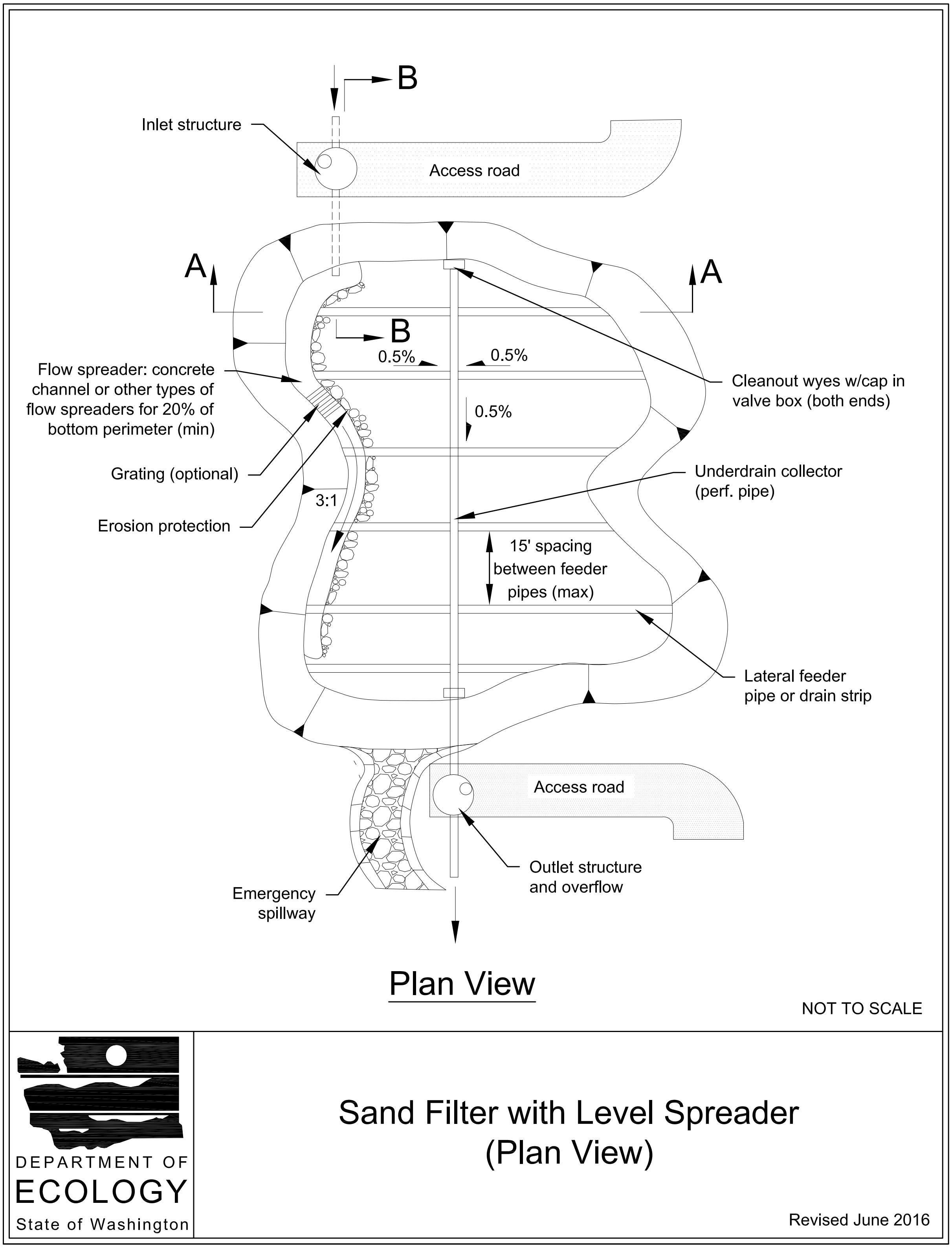
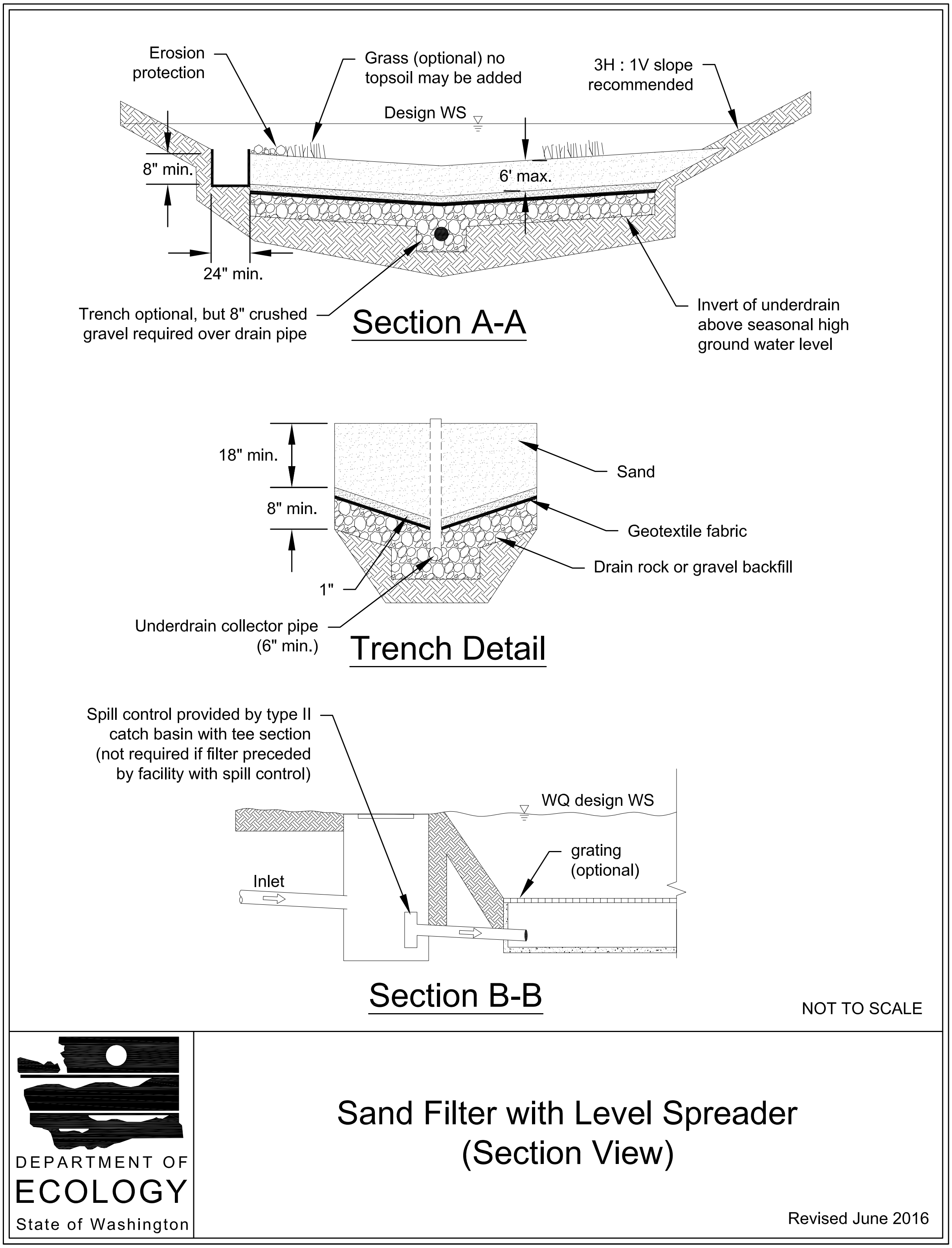


Figure 6.64: Sand Filter with Level Spreader (Section View)



BMP T5.81: Large Sand Filter Basin

Description

A large sand filter basin is virtually identical to BMP T5.80: Basic Sand Filter Basin except that it is sized to provide a higher level of Runoff Treatment. While BMP T5.80: Basic Sand Filter Basin meets the basic treatment performance goal, a large sand filter basin (this BMP) meets the metals treatment and phosphorus treatment performance goals. See 6.1.2 Choosing Your Runoff Treatment BMPs for details.

Applications and Limitations

The large sand filter basin is generally subject to the same Applications and Limitations as BMP T5.80: Basic Sand Filter Basin. The difference is that the large sand filter basin uses a higher Water Quality Design Volume: 95% of the runoff volume. Only 5% of the total runoff volume would bypass or overflow from a large sand filter basin.

Site Suitability

The site suitability for the large sand filter basin is the same as BMP T5.80: Basic Sand Filter Basin.

Design Criteria

Sizing

As stated above, a large sand filter basin should be sized to filter 95% of the runoff volume. Note that this volume is larger than the standard Water Quality Design Volume described in 6.1.5 Sizing Your Runoff Treatment BMPs and used for sizing other BMPs.

For sizing a large sand filter, use the same procedure as outlined in BMP T5.80: Basic Sand Filter Basin. Then apply a scale-up factor of 1.6 to the surface area (A_{sf}). This is considered a reasonable average for various impervious tributary sources. For a large sand filter, the flow splitter upstream or downstream of the detention BMP should be designed to route the flow rate associated with conveying 95% of the annual runoff volume to the sand filter. Use the standard Water Quality Design Flow Rate multiplied by 1.2.

Overflow and Underdrains

The design flows for the overflow and underdrains must be increased from the sizes used BMP T5.80: Basic Sand Filter Basin.

BMP T5.80: Basic Sand Filter Basin uses the 91% runoff volume as the Water Quality Design Volume, a 2-year return interval peak flow. The corresponding overflow and underdrain design flow is the 2 Year Storm.

Thus, the overflow and underdrain design flow can be calculated for this BMP by increasing the 2 year return interval peak flow by the ratio of the 95% runoff volume (the Water Quality Design Volume for this BMP) and the 91% runoff volume (the Water Quality Design Volume for BMP T5.80: Basic Sand Filter Basin). In equation form:

Design Flow Rate for Large Sand Filter Overflow or Underdrain = (95% Runoff Volume)/(91% Runoff Volume) * 2 year return interval peak flow.

For all other design criteria refer to BMP T5.80: Basic Sand Filter Basin.

Construction Criteria

See the construction criteria for BMP T5.80: Basic Sand Filter Basin.

Operation and Maintenance Criteria

See the operation and maintenance criteria for BMP T5.80: Basic Sand Filter Basin.

BMP T5.82: Sand Filter Vault

Description

A sand filter vault is similar to BMP T5.80: Basic Sand Filter Basin and BMP T5.81: Large Sand Filter Basin, except that the sand layer and underdrains are installed below grade in a vault. It consists of presettling and sand filtration cells. See Figure 6.65: Example of an Isolation/Diversion Structure, Figure 6.66: Sand Filter Vault (Plan View) and Figure 6.67: Sand Filter Vault (Section View) for more details.

Application and Limitations

- Use sand filter vaults where space limitations preclude above ground BMPs.
- Sand filter vaults are not recommended where high water table and heavy sediment loads are expected.
- If you must use a sand filter vault in high water table areas, buoyancy and infiltration must be accounted for in the design.
- A minimum elevation difference of 4 feet between the inlet and outlet of the sand filter vault is needed.

Design Criteria

See the design criteria for BMP T5.80: Basic Sand Filter Basin or BMP T5.81: Large Sand Filter Basin.

Additional Design Criteria for Vaults

- Sand filter vaults may be designed as off-line systems or on-line for small drainages
- In an off-line system, a diversion structure should be installed to divert the design flow rate into the sediment chamber and bypass the remaining flow to a Flow Control BMP (if necessary to meet 2.4.6 CE6: Flow Control and/or 2.4.8 CE8: Wetlands Protection), or to surface water.
- Distribute flows at the inlet of the sand filtration cell to minimize disturbance to the sand bed. A maximum of 8-inch distance between the top of the flow spreader and the top of the sand bed is suggested. Flows may enter the sand bed by spilling over the top of the wall into a flow spreader pad, or alternatively a pipe and manifold system may be used. Any pipe and

manifold system must retain the required dead storage volume in the first cell, minimize turbulence, and be readily maintainable.

- If an inlet pipe and manifold system is used, the minimum pipe size should be 8 inches. Multiple inlets are recommended to minimize turbulence and reduce local flow velocities.
- Erosion protection must be provided along the first foot of the sand bed adjacent to the flow spreader. Geotextile fabric secured on the surface of the sand bed, or an equivalent method, may be used.
- The sand filter bed should consist of a sand top layer, and a geotextile fabric second layer with an underdrain system.
- Design the presettling cell for sediment collection and removal. A V-shaped bottom, removable bottom panels, or equivalent sludge handling system should be used. One-foot of sediment storage in the presettling cell must be provided.
- The presettling cell must be sealed to trap oil and trash. This cell is usually connected to the sand filtration cell through an inverted elbow or underflow baffle to protect the sand filter surface from oil and trash.
- If a retaining baffle is necessary for oil/floatables in the presettling cell, it must extend at least one foot above to one foot below the design flow water level. Provision for the passage of flows in the event of plugging must be provided. Access openings and ladders must be provided on both sides of the baffle.
- To prevent anoxic conditions, a minimum of 24 square feet of ventilation grate should be provided for each 250 square feet of sand bed surface area. For sufficient distribution of airflow across the sand bed, grates may be located in one area if the sand bed is small, but placement at each end is preferred. Small grates may also be dispersed over the entire sand bed area.
- Provision for access is the same as for BMP T5.72: Wetvaults. Removable panels must be provided over the entire sand bed.
- Sand filter vaults must conform to the materials and structural suitability criteria specified for BMP T5.72: Wetvaults.
- Provide a sand filter inlet shutoff/bypass valve for maintenance
- A geotextile fabric over the entire sand bed may be installed that is flexible, highly permeable, three-dimensional matrix, and adequately secured. This is useful in trapping trash and litter.

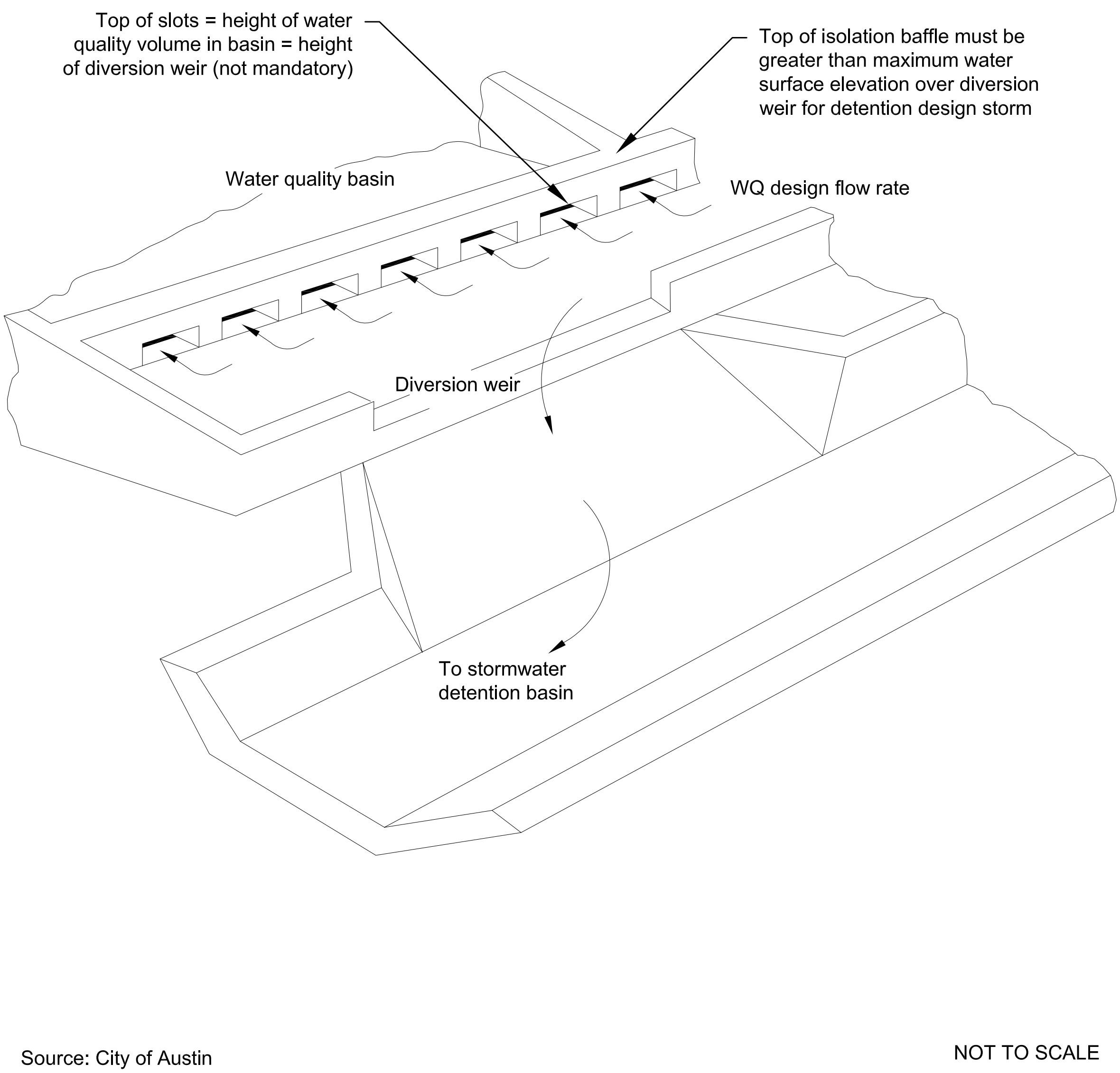
Construction Criteria

See BMP T5.80: Basic Sand Filter Basin and Appendix 6-A: BMP Maintenance Tables.

Maintenance Criteria

See BMP T5.80: Basic Sand Filter Basin and Appendix 6-A: BMP Maintenance Tables.

Figure 6.65: Example of an Isolation/Diversion Structure



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Example of an Isolation/Diversion Structure

Revised June 2016

Figure 6.66: Sand Filter Vault (Plan View)

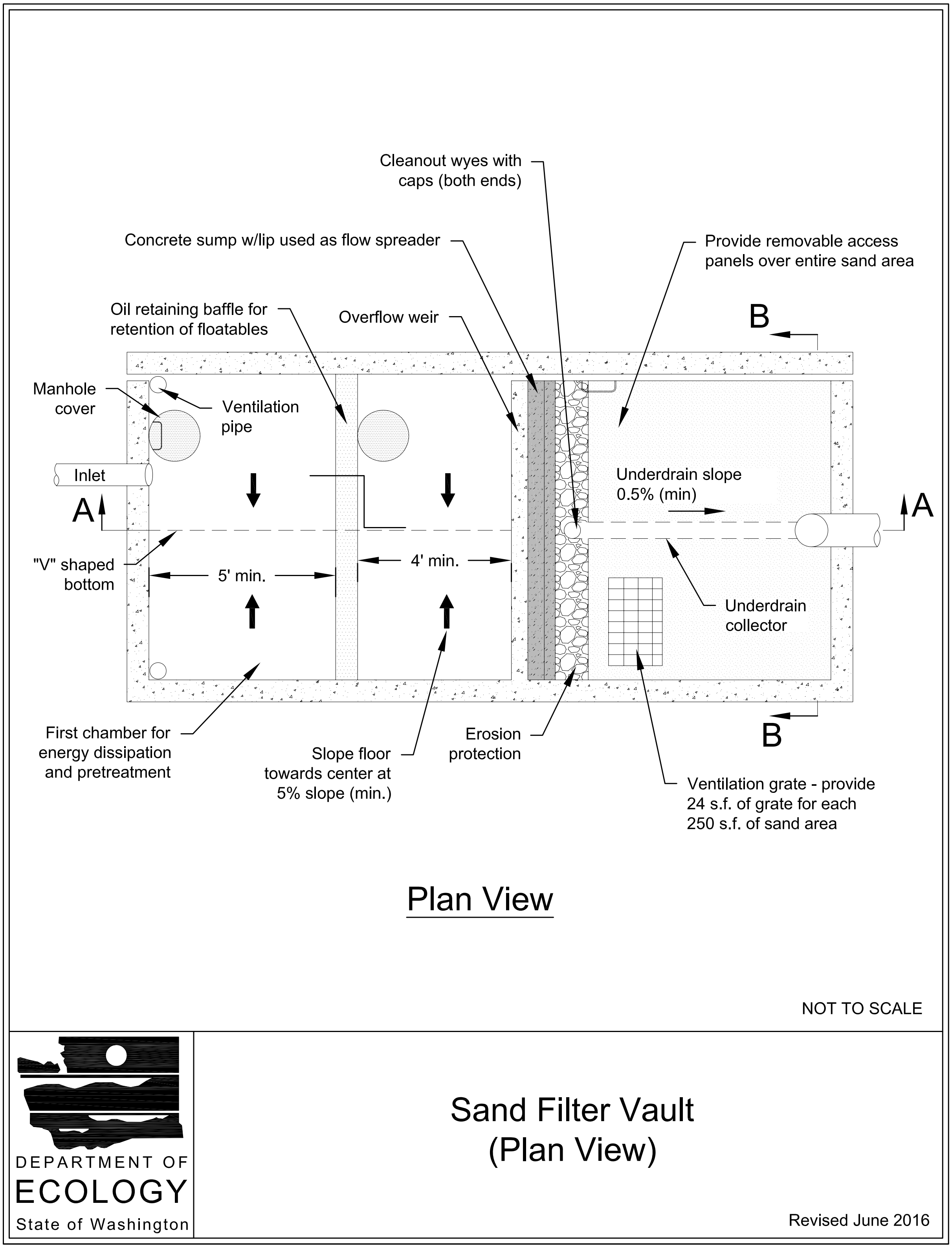


Figure 6.67: Sand Filter Vault (Section View)

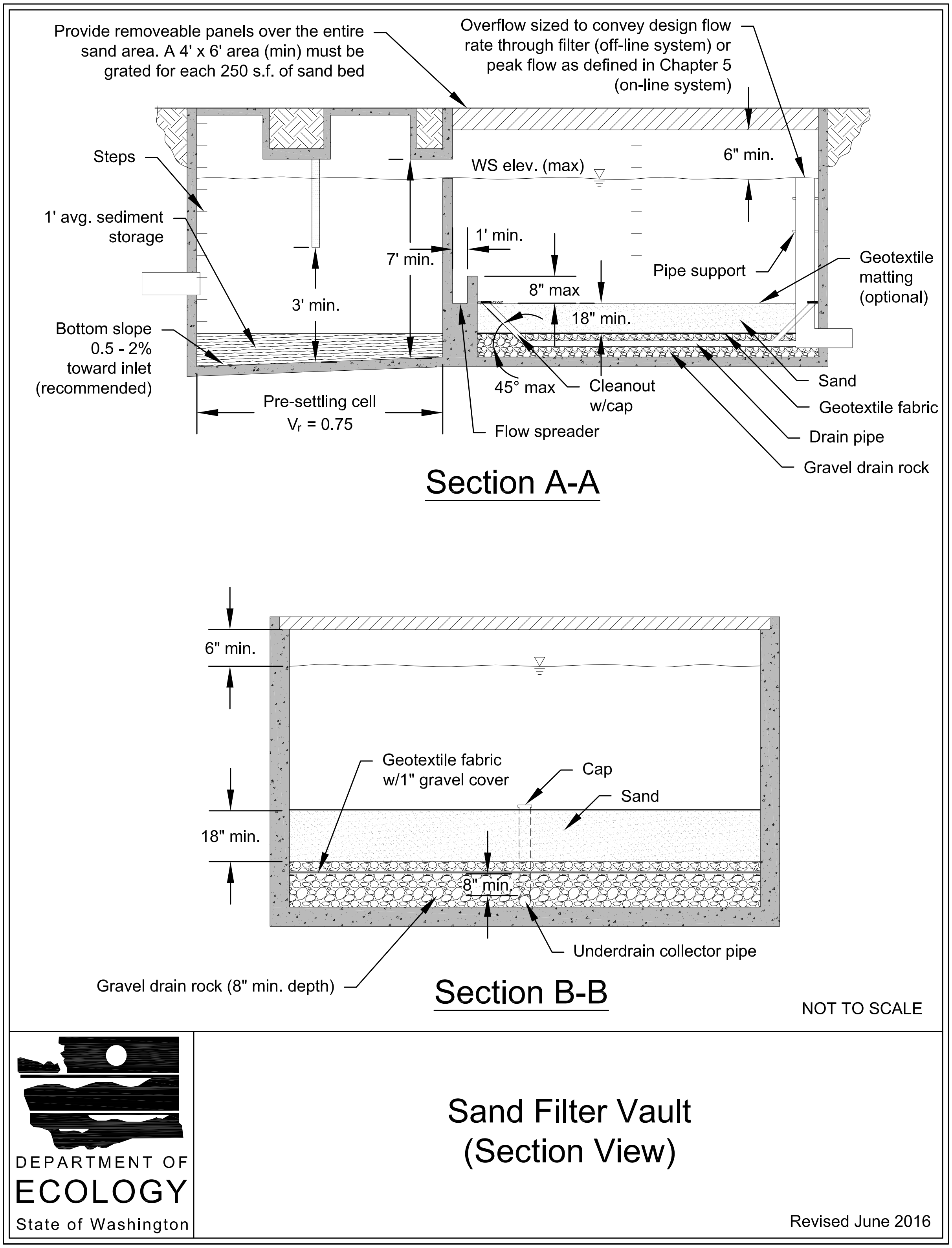
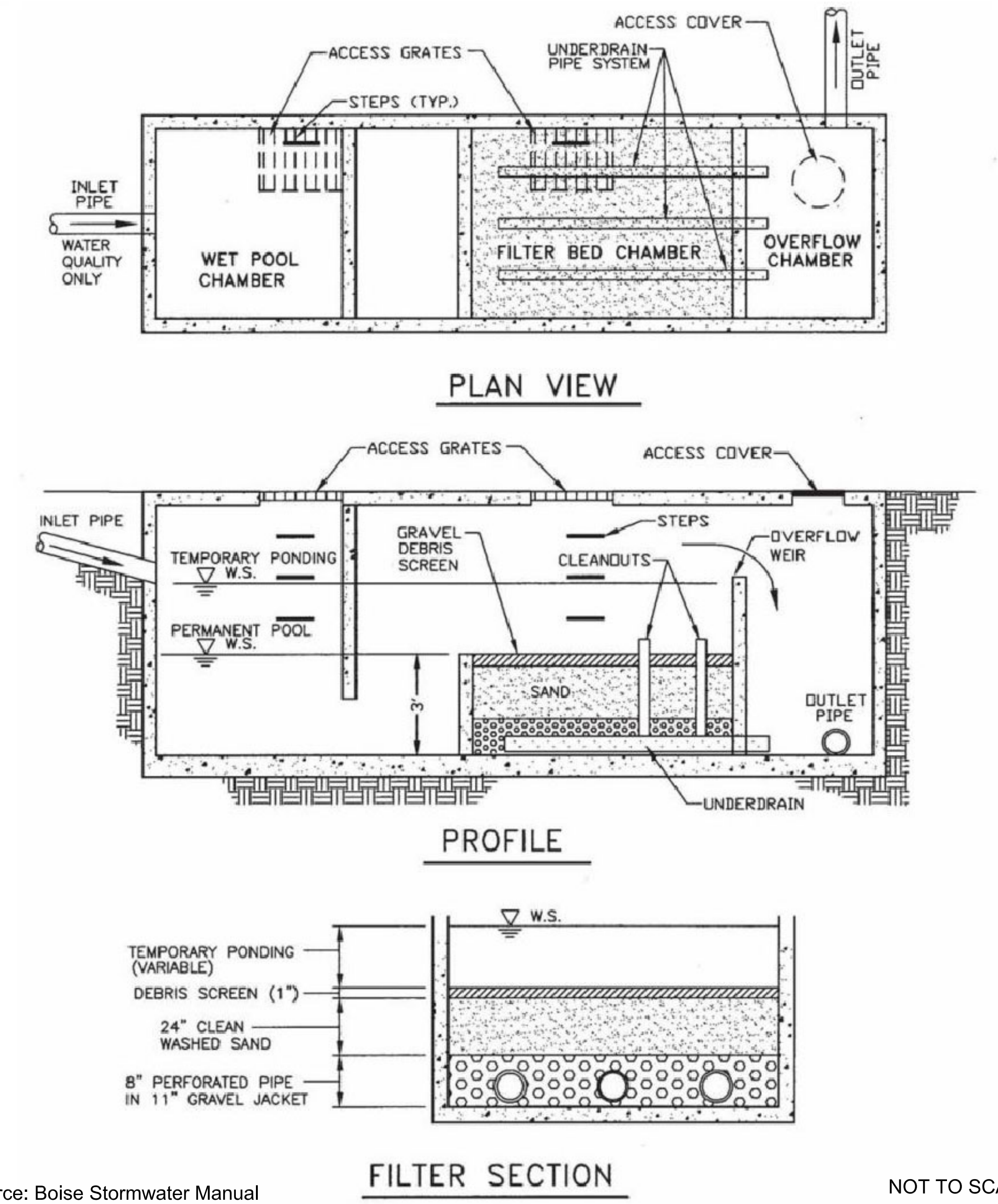


Figure 6.68: Sand Filter Vault (Also Called Underground Sand Filter)



Source: Boise Stormwater Manual

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Sand Filter Vault
(Also Called Underground Sand Filter)

Revised September 2004

BMP T5.83: Linear Sand Filter

Description

Linear sand filters are typically long, shallow, two-celled, rectangular vaults. The first cell is designed for settling coarse particles, and the second cell contains a sand filter bed. Stormwater flows into the second cell via a weir section that also functions as a flow spreader. See Figure 6.69: Linear Sand Filter.

Application and Limitations

- Linear sand filters are applicable in long narrow spaces such as the perimeter of a paved surface.
- Linear sand filters can be used as a part of a treatment train downstream of BMP T5.50: Vegetated Filter Strip, upstream of an infiltration BMP, or upstream of BMP T10.10: Wetponds - Basic and Large or a biofiltration BMP for oil control.
- Linear sand filters are appropriate to treat runoff from small contributing basins (less than 2 acres of impervious area).
- Linear sand filters are appropriate to treat runoff from sites that require an oil control BMP, per 6.1.2 Choosing Your Runoff Treatment BMPs.

Design Criteria

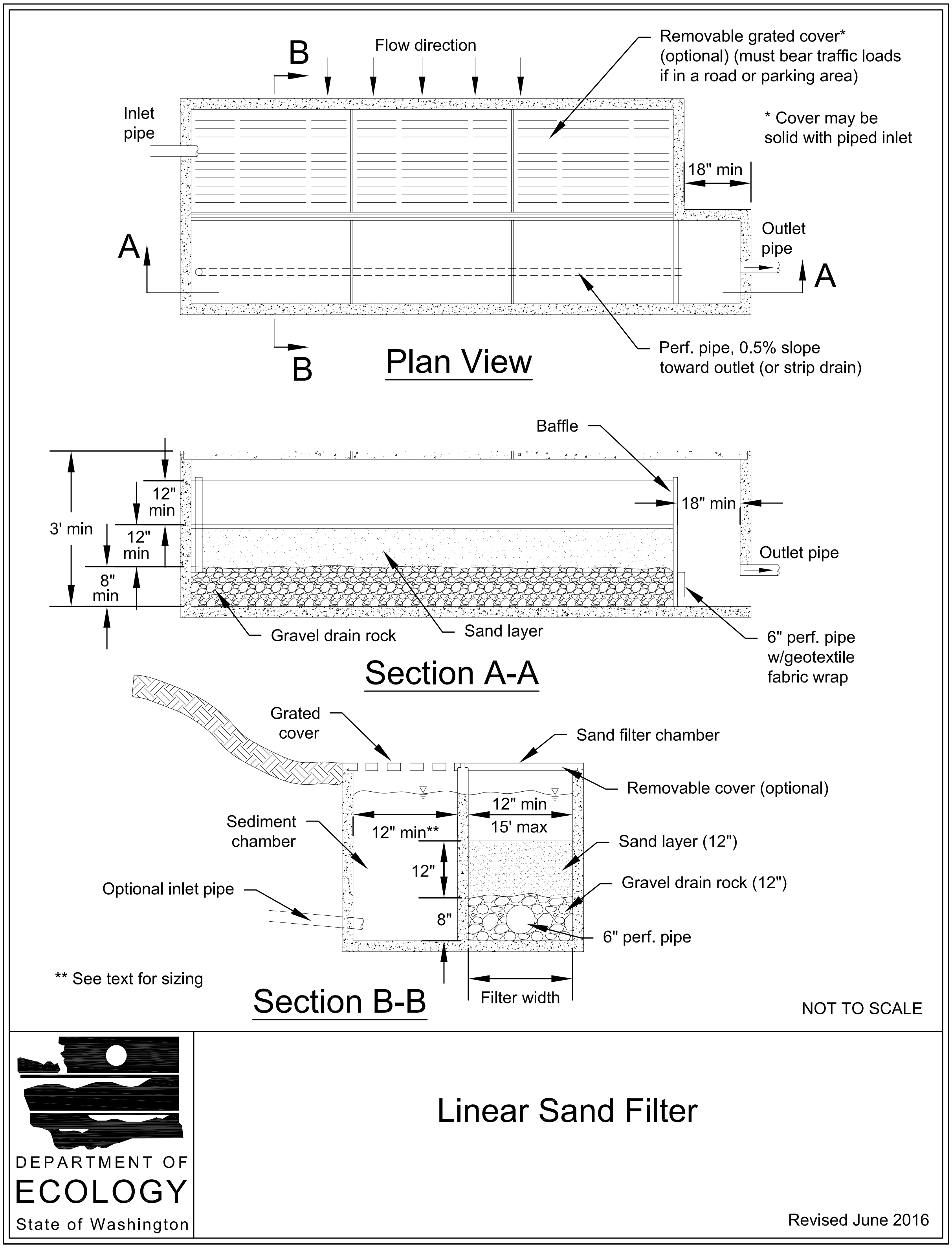
The following additional criteria apply to the design of linear sand filters:

- The two cells should be divided by a divider wall that is level and extends a minimum of 12 inches above the top of the sand bed.
- Stormwater may enter the presettling cell by sheet flow or a piped inlet.
- The width of the sand filter cell must be 1-foot minimum to 15 feet maximum.
- The sand filter bed must be a minimum of 12 inches deep and have an 8-inch layer of drain rock with perforated drainpipe beneath the sand layer.
- The drainpipe must be 6-inch diameter minimum and be wrapped in geotextile and sloped a minimum of 0.5 percent.
- Maximum sand bed ponding depth: 1-foot.
- Must be vented as described in BMP T5.82: Sand Filter Vault.
- Linear sand filters must conform to the materials and structural suitability criteria specified for BMP T5.72: Wetvaults.
- Set the presettling cell width as follows:

Table 6.32: Linear Sand Filter Presettling Cell Width

Item	Dimensions			
Sand filter width, (w) inches	12-24	24-48	48-72	72+
Presettling cell width, inches	12	18	24	w/3

Figure 6.69: Linear Sand Filter



BMP T5.84: Media Filter Drain

Ecology accepts the Media Filter Drain BMP, as detailed in the *2019 Highway Runoff Manual* (WSDOT, 2019) as a Runoff Treatment BMP. Ecology does not accept the Media Filter Drain BMP as a Flow Control BMP (i.e. the Media Filter Drain BMP may not be used to meet Flow Control based performance standards). Please refer to the *2019 Highway Runoff Manual* (WSDOT, 2019) for detailed design guidance.

6.8 Biofiltration BMPs

6.8.1 Introduction to Biofiltration BMPs

Biofiltration BMPs use vegetation in conjunction with slow and shallow-depth flow for Runoff Treatment. As runoff passes through the vegetation, pollutants are removed through the combined effects of sedimentation, filtration, infiltration, adsorption, settling, and/or plant uptake. These effects are aided by the reduction of the velocity of stormwater as it passes through the biofilter. Biofiltration BMPs include swales that are designed to convey and treat concentrated runoff at shallow depths and slow velocities, and filter strips that are broad areas of vegetation for treating sheet flow runoff.

Biofiltration BMPs remove low concentrations and quantities of total suspended solids (TSS), heavy metals, petroleum hydrocarbons, and/or nutrients from stormwater.

Biofiltration BMPs can be used as stand-alone Runoff Treatment BMPs for contaminated stormwater runoff from roadways, driveways, parking lots, and highly impervious ultra-urban areas or as the first stage of a treatment train. In cases where hydrocarbons, high TSS, or debris would be present in the runoff, such as sites requiring oil control BMPs (per 6.1.2 Choosing Your Runoff Treatment BMPs), a pretreatment BMP for those components would be necessary. Off-line placement is preferred to avoid flattening vegetation and the erosive effects of high flows. Consider biofiltration BMPs in retrofit situations where appropriate. (CWP, 1998)

Consider the following factors for determining site suitability for biofiltration BMPs:

- Are the target pollutants amenable to biofiltration treatment?
- Is there accessibility for Operation and Maintenance?
- Is there a suitable growth environment; (soil, etc.) for the vegetation?
- If high petroleum hydrocarbon levels (oil/grease) or high TSS loads could impair treatment capacity or efficiency, is there adequate siting for a pre-treatment and/or oil control BMP?
- If the biofilter within the biofiltration BMP can be impacted by snowmelts and ice, refer to (Caraco and Claytor, 1997) for additional design criteria.

Climate Considerations

Cold Weather Climate Considerations

Biofiltration BMPs have reduced effectiveness in the winter because of dormant vegetation. These BMPs can be effective for snow storage and meltwater infiltration if road salt/deicing chemicals/chlorides are not used excessively. See 6.1.8 Cold Weather Considerations for additional cold weather considerations related to cold temperatures, deep frost line, short growing season, and/or significant snowfall.

Arid/Semiarid Climate Considerations

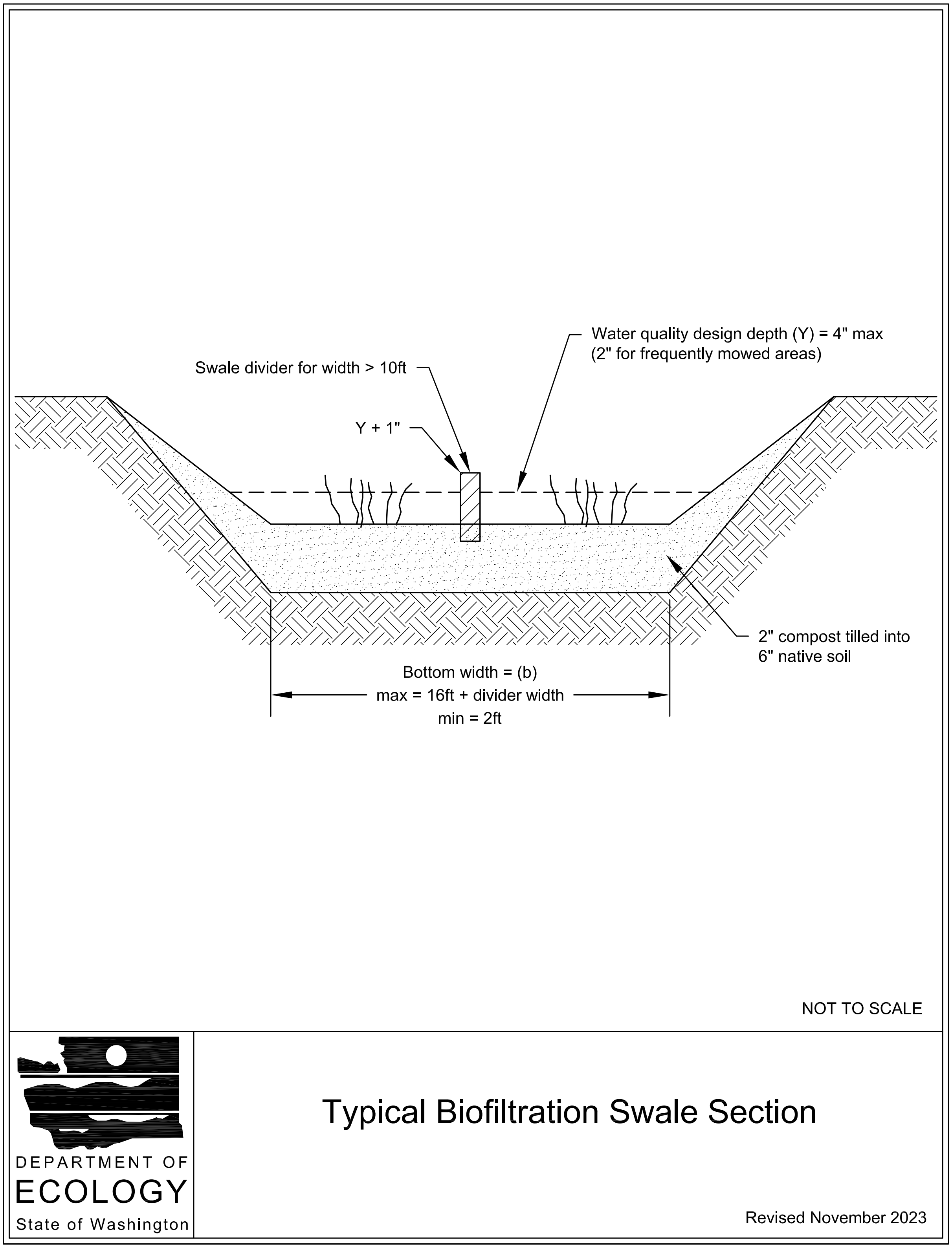
Vegetation is integral to the proper function of biofiltration BMPs. In arid/semiarid portions of eastern Washington, plants should be selected to be drought tolerant and not require watering after establishment (2 to 3 years) unless irrigation is planned. In more arid environments, watering may be needed during prolonged dry periods after plants are established.

BMP T5.40: Basic Biofiltration Swale

Description

Biofiltration is the simultaneous process of filtration, particle settling, adsorption, and biological uptake of pollutants in stormwater that occurs when runoff flows over and through vegetated areas. A biofiltration swale is a sloped, vegetated channel or ditch that provides both conveyance and Runoff Treatment to stormwater runoff. It does not provide Flow Control, but can convey runoff to Best Management Practices (BMPs) designed for that purpose.

Figure 6.70: Typical Biofiltration Swale Section



Limitations

Data suggests that the performance of biofiltration swales is highly variable from storm to storm. Ecology recommends considering other treatment methods that perform more consistently, such as BMP T5.80: Basic Sand Filter Basin and BMP T10.10: Wetponds - Basic and Large, before using a biofiltration swale. Biofiltration swales downstream of Runoff Treatment BMPs of equal or greater effectiveness can convey runoff; but the designer should not consider them to offer additional Runoff Treatment benefit (Horner, 2000).

General Criteria

- A biofiltration swale can be sized as both a Runoff Treatment BMP (for the Water Quality Design Flow Rate), and as a conveyance BMP to pass the peak hydraulic flows of the 25-year storm if it is located "online".
- The ideal cross section of a biofiltration swale is a trapezoid.
- Roadside ditches should be considered potential biofiltration swale sites, and should be used for this purpose whenever possible. In these cases, site conditions may require consideration of BMP T9.30: Continuous Inflow Biofiltration Swale.
- If flow is to be introduced through curb cuts, place pavement slightly above the biofiltration swale elevation. Curb cuts should be ≥ 12 inches wide to prevent clogging.
- When sizing the biofiltration swale, check the hydraulic capacity/stability for inflows greater than design flows. Bypass high flows, or control release rates into the biofiltration swale, if necessary.
- Install flow spreaders (min. 1-inch gravel, see 6.1.10.2 Flow Spreaders) at the entrance and every 50 feet thereafter in biofiltration swales that are greater than or equal to 4 feet in width. Include sediment cleanouts (weir, settling basin, or equivalent) at the entrance to the biofiltration swale as needed.

Soil Criteria

- Till the following top soil mix to a depth of at least 8-inches:
  - Sandy loam 60-90 %
  - Clay 0-10 %
  - Composted material, 10-30 %

    Use compost amended soil where practicable. Composted material shall meet the specifications for compost used in the Bioretention Soil Mix (BMP F6.23: Bioretention). This excludes use of biosolids and manures.
- If groundwater contamination is a concern, seal the bed with a low permeability liner per 6.1.9.3 Low Permeability Liners.

Vegetation Criteria

- Biofiltration swales must be vegetated in order to provide adequate Runoff Treatment. Select vegetation that does not require fertilizer inputs or frequent mowing.
- It is important to maximize water contact with vegetation and the soil surface. For general purposes, select fine, close-growing grasses (or other vegetation) that can withstand prolonged periods of wetting, as well as prolonged dry periods (to minimize the need for irrigation). Consult the local Natural Resources Conservation Service (NRCS) office or the County Extension Service for specific vegetation selection recommendations.
- Irrigate if moisture is insufficient during dry weather season.
- Use sod with low clay content and where needed to initiate adequate vegetative growth. Preferably sod should be laid to a minimum of one-foot vertical depth above the swale bottom.
- Consider sun/shade conditions for adequate vegetative growth and avoid prolonged shading of any portion not planted with shade tolerant vegetation.
- Stabilize soil areas upslope of the biofiltration swale to prevent erosion
- Fertilizing a biofiltration swale should be avoided if at all possible in any application where nutrient control is an objective. Test the soil for nitrogen, phosphorous, and potassium and consult with a landscape professional about the need for fertilizer in relation to soil nutrition and vegetation requirements. If use of a fertilizer cannot be avoided, use a slow-release fertilizer formulation in the least amount needed.

Bypassing Off-line Biofiltration Swales

Most biofiltration swales are currently designed to be on-line facilities. However, an off-line design is possible. Biofiltration swales designed as an off-line BMP should engage a bypass around the biofiltration swale when the flow rate entering the biofiltration swale exceeds theWater Quality Design Flow Rate (see 6.1.5 Sizing Your Runoff Treatment BMPs). The only advantage of designing a swale to be off-line is that the stability check, which may make the swale larger, is not necessary.

Sizing Criteria

To size a biofiltration swale, use the criteria in Table 6.33: Sizing Criteria for Biofiltration Swales (continued) and the sizing steps detailed below.

Table 6.33: Sizing Criteria for Biofiltration Swales

Design parameter	Biofiltration Swale Sizing
Longitudinal Slope	0.015 - 0.025[1] feet per foot
Maximum velocity	• 1 ft/sec at Q_{biofil} • for stability check, 3 ft/sec max.
Maximum water depth[2]	• Default = 3" for dryland grasses

Table 6.33: Sizing Criteria for Biofiltration Swales (continued)

Design parameter	Biofiltration Swale Sizing
Manning coefficient (n)	see Table 6.34: Manning's Coefficient for Various Soil and Cover Types
Swale Bottom Width	2 - 10 ft[3]
Freeboard height	1 ft
Minimum length	100 ft
Maximum side slope (for trapezoidal cross section)	3H:1V (4H:1V preferred)

1. Slopes greater than 2.5% need check dams (riprap) at vertical drops of 12-15 inches.

2. Below the design water depth install an erosion control blanket, at least 4" of topsoil, and the selected biofiltration mix. Above the water line use a straw mulch or sod.

3. Multiple parallel swales can be constructed when the calculated swale bottom width exceeds 10 feet. Swales with bottom calculated widths up to 16 feet can be divided in half using a non-erodible weather-resistant material such as plastic lumber. See Figure 6.71: Biofiltration Swale Dividing Berm.

Table 6.34: Manning's Coefficient for Various Soil and Cover Types

Soil and Cover	Manning's Coefficient
Grass-legume mix on compacted native soil	0.20
Grass-legume mix on lightly compacted topsoil[1]	0.22
Grass-legume mix on lightly compacted, topsoil with 3-inch medium compost blanket[2]	0.35

Notes:

1. Specify that topsoil extends to at least an 8-inch depth.
2. If using compost, it cannot contain biosolids or manure, and must meet the specifications for compost per BMP F6.23: Bioretention. Note that swales do not require a mulch layer and that compost amendments shall be a 3-inch-thick medium compost blanket over the topsoil.

Sizing Steps (D)

D-1: Determine the Water Quality Design Flow Rate (Q_{wq}) (see 6.1.5 Sizing Your Runoff Treatment BMPs).

D-2: Determine the biofiltration design flow rate (Q_{biofil}):

$$Q_{biofil} = k * Q_{wq}$$

- For western Washington, k is the ratio determined in BMP T5.40: Basic Biofiltration Swale or BMP T5.40: Basic Biofiltration Swale. The variable k modifies the Water Quality Design Flow Rate, as determined by a continuous simulation model, to an estimate of the Water Quality Design Flow Rate determined by using SBUH procedures.
- For eastern Washington, k = 1.0.

D-3: Establish the longitudinal slope of the proposed biofiltration swale (see Table 6.33: Sizing Criteria for Biofiltration Swales (continued)).

D-4: Select a soil and vegetation cover suitable for the biofiltration swale (see Table 6.34: Manning's Coefficient for Various Soil and Cover Types).

D-5: Select the design depth of flow, y (see Table 6.33: Sizing Criteria for Biofiltration Swales (continued)).

D-6: Set the swale cross-sectional shape as trapezoidal.

D-7: Use Manning’s equation and first approximations relating hydraulic radius and dimensions for the trapezoidal swale to obtain a value for the bottom width of the biofiltration swale:

$$Q_{biofil} = \frac{1.49 * A * R^{2/3} * s^{1/2}}{n}$$

where:

Q_{biofil} = biofiltration design flow rate (cfs)

A = wetted area (ft^2)

R = hydraulic radius (ft)

s = longitudinal slope of swale (ft/ft)

n = Manning’s coefficient (see Table 6.34: Manning's Coefficient for Various Soil and Cover Types)

To solve for the bottom width of the swale, use the following method:

- Rearrange the above equation as follows: $AR^{0.67} = Q_{biofil}\, n / (1.49s^{0.5})$
- Substitute for A and R for the trapezoidal cross-sectional geometry:

$$A = (b + zy) * y$$

and

$$R = \frac{(b+zy)y}{b+2y\sqrt{1+z^2}}$$

where:

b = the bottom width of the swale

z = the side slope of the swale, V:H = 1:z

y = the design depth of flow

- The variables z, y, Q_{biofil}, n, and s are all known values. The equation should then contain only a single unknown (b). Solve for b.
- If the calculated value for b is less than 2 feet, then set bottom swale width to 2 feet.

D-8: Compute A at Q_{biofil} by using the equation for A above (for a trapezoid).

D-9: Compute the flow velocity (V_{biofil}) at Q_{biofil}:

$$V_{biofil} = \frac{Q_{biofil}}{A}$$

where: V_{biofil} = flow velocity at Q_{biofil} (ft/sec)

If V_{biofil} > 1.0 ft/sec, increase bottom width (b) or investigate ways to reduce Q_{wq} and then repeat Steps D-7, D-8, and D-9 until $V_{biofil} \leq 1.0$ ft/sec. A velocity greater than 1.0 ft/sec was found to flatten grasses, thus reducing filtration.

D-10: Compute the swale length, L (ft):

$$L = V_{biofil} * t * (60 \text{ sec/min})$$

where: t = hydraulic residence time (use 9 minutes for basic biofiltration swales)

If the calculated swale length is less than 100 feet, specify the length to be 100 feet.

D-11: If there is not sufficient space for the biofiltration swale, consider the following solutions:

- Divide the site drainage to flow to multiple biofiltration swales.
- Use infiltration or dispersion upstream of the biofiltration swale to provide a lower Q_{biofil}.
- Alter the design depth of flow if possible (see Table 6.33: Sizing Criteria for Biofiltration Swales (continued)).
- Reduce the developed surface area to gain space for the biofiltration swale.
- Reduce the longitudinal slope by meandering the biofiltration swale.
- Nest the biofiltration swale within or around another stormwater BMP.

Freeboard Check (FC)

The designer must perform a freeboard check for the combination of highest expected flow and least vegetation coverage and height.

For eastern Washington, Q_{convey} is the 25-year, 24-hour storm (a 10-year storm is acceptable, provided that reparative maintenance will be performed following every 10-year event).

The freeboard check is not necessary for biofiltration swales that are located off-line from the primary conveyance and detention system (that is, when flows in excess of Q_{biofil} bypass the biofiltration swale). Offline is the preferred configuration of biofiltration swales.

Note: Use the same units as in the biofiltration swale design steps.

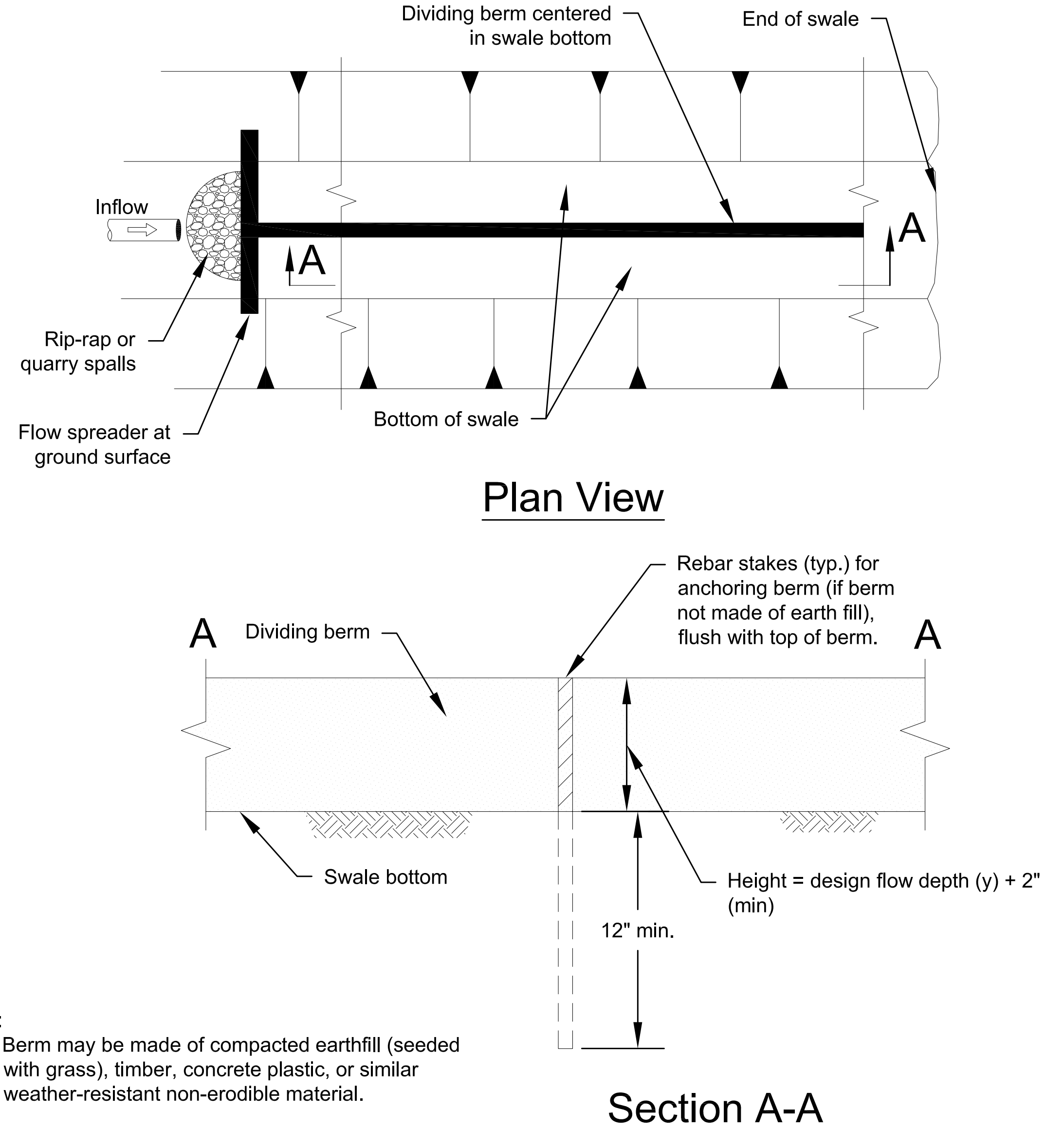
FC-1: Unless runoff at rates higher than Q_{biofil} will bypass the biofiltration swale, perform a freeboard check for Q_{convey}.

FC-2: Select the lowest possible roughness coefficient for the biofiltration swale (assume n = 0.03).

FC-3: Again, use the implicit equation $AR^{0.67} = Q_{convey}\ n / (1.49s^{0.5})$ (see Step D-7, above) and with a known b, solve for the depth, y. Select the lowest y that provides a solution.

FC-4: Ensure the depth at Q_{convey} exceeds the design depth at Q_{biofil} by a minimum of 1 foot (1-foot minimum freeboard).

Figure 6.71: Biofiltration Swale Dividing Berm



Notes:

1. Berm may be made of compacted earthfill (seeded with grass), timber, concrete plastic, or similar weather-resistant non-erodible material.

2. Rebar stakes or similar berm anchoring materials needed if berm made of timber, plastic, or concrete curbing - stake placement required at both ends of each individual member (at a minimum).

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Biofiltration Swale Dividing Berm

Revised November 2023

Figure 6.72: Geometric Formulas for Common Swale Shapes

Source: Livingston, et al, 1984

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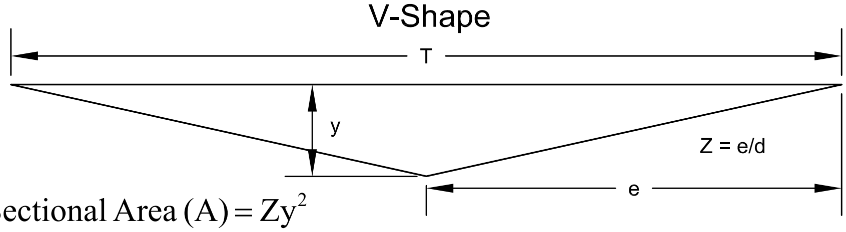
Channel Geometry

V-Shape

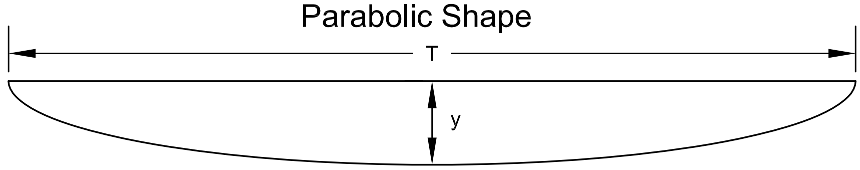


$$\text{Cross-Sectional Area (A)} = Zy^2$$

$$\text{Top Width (T)} = 2yZ$$

$$\text{Hydraulic Radius (R)} = \frac{Zy}{2\sqrt{Z^2+1}}$$

Parabolic Shape

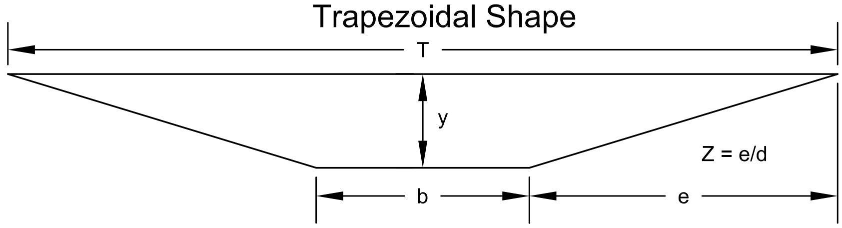


$$\text{Cross-Sectional Area (A)} = \frac{2}{3}Ty$$

$$\text{Top Width (T)} = \frac{1.5A}{y}$$

$$\text{Hydraulic Radius (R)} = \frac{T^2y}{1.5T^2+4y^2}$$

Trapezoidal Shape



$$\text{Cross-Sectional Area (A)} = by + Zy^2$$

$$\text{Top Width (T)} = b + 2yz$$

$$\text{Hydraulic Radius (R)} = \frac{by+Zy^2}{b+2y\sqrt{Z^2+1}}$$

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Geometric Formulas for Common Swale Shapes

Revised June 2016

Construction Criteria

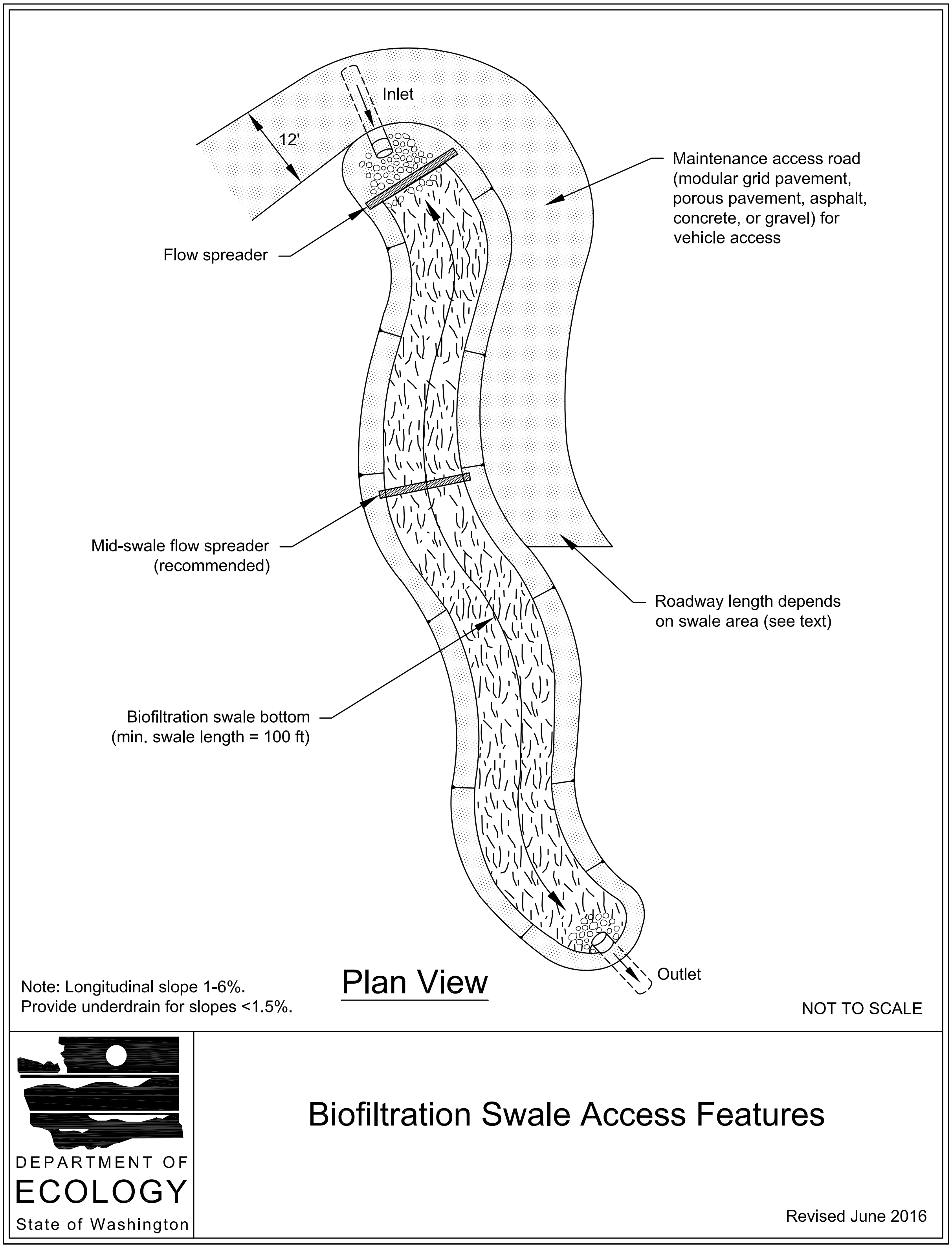
The biofiltration swale should not be put into operation until areas of exposed soil in the contributing drainage catchment have been sufficiently stabilized. Deposition of eroded soils can impede the growth of grass in the biofiltration swale and reduce Runoff Treatment effectiveness. Thus, effective erosion and sediment control measures should remain in place until the biofiltration swale vegetation is established (see Chapter 7 - Construction Stormwater Pollution Prevention for erosion and sediment control BMPs). Avoid compaction during construction. Grade biofiltration swales to attain uniform longitudinal and lateral slopes.

Maintenance Criteria

- Inspect biofiltration swales at least once every 6 months, preferably during storm events, and also after storm events of > 0.5 inch rainfall in 24 hours. Maintain adequate grass growth and eliminate bare spots.
- Mow grasses, if needed for good growth (typically maintain at 4 – 9 inches and not below design flow level (King County, 1998)).
- Remove sediment as needed at the entrance to the biofiltration swale if grass growth is inhibited in greater than 10 percent of the swale, or if the sediment is blocking the distribution and entry of the water (King County, 1998).
- Remove leaves, litter, and oily materials, and re-seed or resod, and regrade, as needed. Clean curb cuts and level spreaders as needed.
- Prevent scouring and soil erosion in the biofiltration swale. If flow channeling occurs, regrade and reseed the biofiltration swale, as necessary.
- Maintain access to the biofiltration swale inlet, outlet, and to mowing (see Figure 6.73: Biofiltration Swale Access Features).
- Avoid using fertilizer within the biofiltration swales wherever possible.

See Appendix 6-A: BMP Maintenance Tables for additional recommended maintenance criteria.

Figure 6.73: Biofiltration Swale Access Features

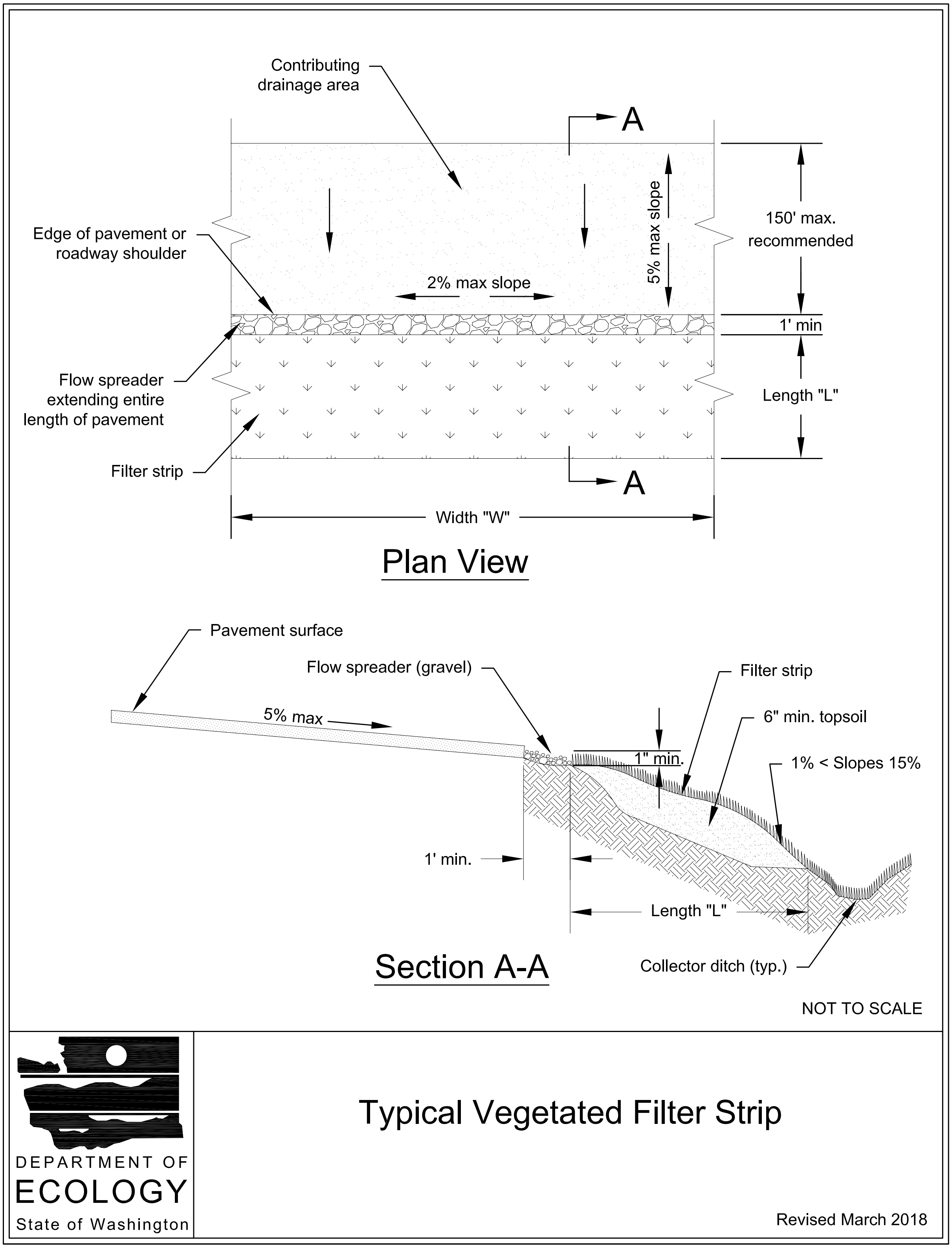


BMP T5.50: Vegetated Filter Strip

Description

A vegetated filter strip is flat with no side slopes (see Figure 6.74: Typical Vegetated Filter Strip). Contaminated stormwater is distributed as sheet flow across the inlet width of the vegetated filter strip. Runoff Treatment is provided by passage of water over the surface and through grass.

Figure 6.74: Typical Vegetated Filter Strip



Applications and Limitations

The vegetated filter strip is typically used on-line and adjacent and parallel to a paved area such as parking lots, driveways, and roadways.

General Criteria

- Along roadways, vegetated filter strip BMPs should include a gravel flow spreader that is at least 1 foot wide, and preferably 3 to 4 feet wide. Water should sheet flow from the paved area, through the (vegetation free) gravel flow spreader, and over the vegetated filter strip.
- Once stormwater runoff has been treated by a vegetated filter strip, it may need to be collected and conveyed to a Flow Control BMP.
- The flow from the roadway must enter the vegetated filter strip as sheet flow.
- If necessary, use curb cuts ≥ 12-inch wide and 1-inch above the vegetated filter strip inlet (i.e. the inlet to the flow spreader portion of the BMP).
- Vegetated filter strips must not receive concentrated flow discharges.
- Contributing area flow path length:
    - The contributing area to the vegetated filter strip can have a maximum flow path length of 30 feet, if using the Design Procedure (Method 1) below.
    - The contributing area to the vegetated filter strip can have a maximum flow path length of 150 feet, if using the Design Procedure (Method 2) below.
- Vegetated filter strips should be used where the average daily traffic (ADT) on the roadway is < 30,000.
- Vegetated filter strips should not be used on roadways with longitudinal slopes > 5% because of the difficulty in maintaining the necessary sheet flow conditions.
- Vegetated filter strips should be constructed after other portions of the project are completed.
- Vegetated filter strip beds should have a final organic content of 5% for grass and 10% for shrub areas.
- Vegetated filter strips should be constructed outside the natural stream buffer area whenever possible to maintain a more natural buffer along the streambank.

Design Procedure - Method 1

This method may be used when the contributing area to the vegetated filter strip has a maximum flow path length of 30 feet.

The sizing of the vegetated filter strip is based on a 3-step procedure:

1. Determine the length of the flow path from the contributing area (FL), defined as the length of the flow path from the upstream to the downstream edge of the area draining to the BMP.

2. Calculate the average longitudinal or cross slope (S) of the filter strip (along the direction of sheet flow), averaged over the total width of the filter strip.

3. Determine the required length of the filter strip (L, along the direction of sheet flow over the vegetated filter strip). The width of the vegetated filter strip should equal the width of the area draining to it.

Table 6.35: Vegetated Filter Strips Method 1 Design summarizes the methods and assumptions for the above steps for sizing vegetated filter strips.

Table 6.35: Vegetated Filter Strips Method 1 Design

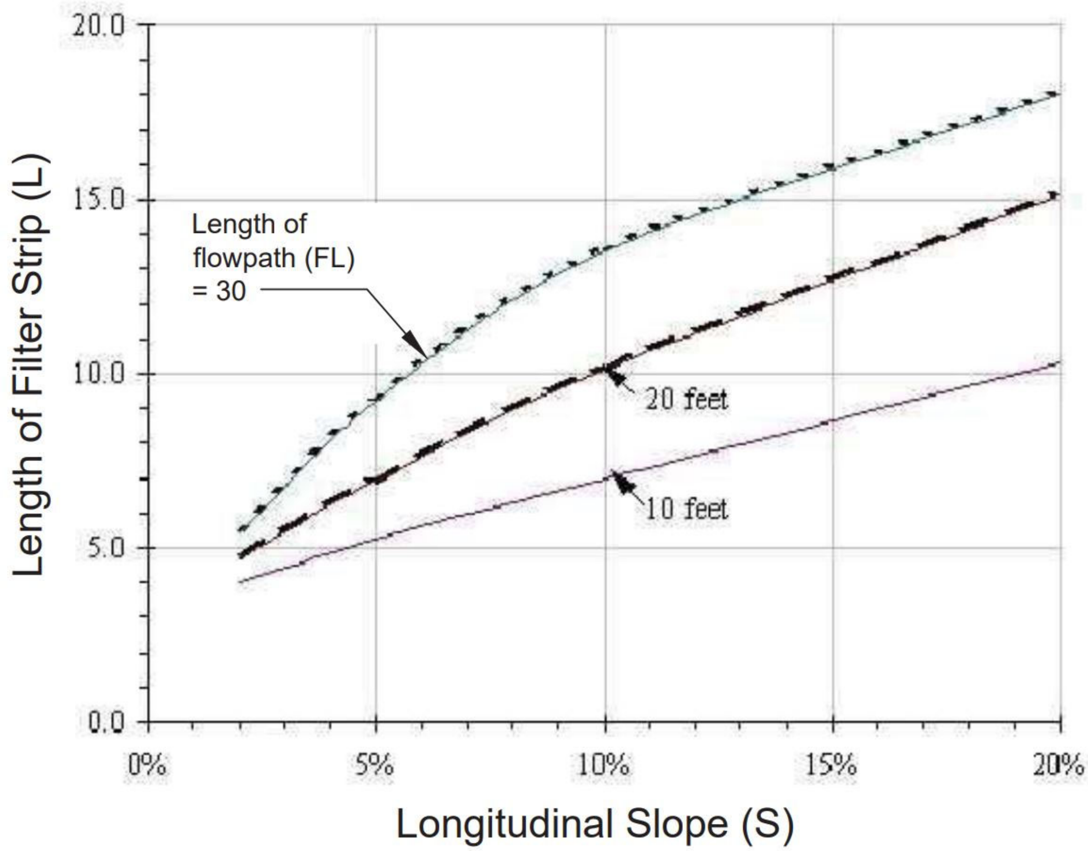
Step	Variable	Methods[a] and Assumptions
1	Length of the Flow Path from the contributing area (FL)	• Defined as the length of the flow path from the upstream to the downstream edge of the area draining to the BMP

2	Longitudinal or Cross-Slope (S) of the Vegetated Filter Strip	• S must be between 2% and 20%
		• The vegetated filter strip can be stepped down so that the S ≤ 20% criterion is not exceeded.
		   ◦ Drop sections must be provided with erosion protection at the base and flow spreaders to re-spread flows.
		   ◦ Drops must be less than 12 inches in height.

3	Length of Filter Strip (L)	• Use Figure 6.75: Vegetated Filter Strip Design Graph to determine the required length of the vegetated filter strip.
		   ◦ Find the curve representing the appropriate length of the flow path (FL).
		   ◦ Interpolate between curves as necessary.
		• Find the point along the curve where the design longitudinal or cross slope (S) of the filter strip is directly below and read the filter strip length (L) to the left on the y axis.
		• Minimum required filter strip length (L):
		   ◦ 4 feet for FL ≤ 10 feet
		   ◦ 4.5 feet for FL = 25 feet
		   ◦ 5.5 feet for FL = 30 feet
		• Provide the minimum required length or more along the entire stretch of pavement draining to it.

[a]Sizing procedure is based on the narrow area filter strips presented in the King County Surface Water Design Manual (King County, 2016).

Figure 6.75: Vegetated Filter Strip Design Graph



Source: King County Surface Water Design Manual (2016)

NOT TO SCALE

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Vegetated Filter Strip Design Graph

Revised March 2018

Design Procedure - Method 2

This method may be used when the contributing area to the vegetated filter strip has a maximum flow path length of 150 feet.

- Use the design criteria specified in Table 6.36: Vegetated Filter Strips Method 2 Design.
- Calculate the design flow depth using Manning's equation as follows:

$$Q = (1.49AR^{0.67}\, s^{0.5})/n$$

Substituting for AR:

$$Q = (1.49Ty^{1.67}\, s^{0.5})/n$$

Where:

$Ty = A_{rectangle}$, ft^2

$y \approx R_{rectangle}$, design depth of flow, ft. (1 inch maximum)

Q = peak Water Quality Design Flow Rate as described in 6.1.5 Sizing Your Runoff Treatment BMPs, ft^3/sec

n = Manning's roughness coefficient

s = Longitudinal slope of the vegetated filter strip, parallel to the direction of flow

T = Width of the vegetated filter strip, perpendicular to the direction of flow, ft.

A = Vegetated filter strip inlet cross-sectional flow area (rectangular), ft^2

R = hydraulic radius, ft.

Rearranging for y:

$$y = [Qn/1.49Ts^{0.5}]^{0.6}$$

y must not exceed 1 inch

- Calculate the design flow velocity V, ft./sec., through the filter strip:

$$V = Q/Ty$$

V must not exceed 0.5 ft./sec

- Calculate the required length, ft., of the vegetated filter strip at the minimum hydraulic residence time, t, of 9 minutes:

$$L = tV = 540V$$

Table 6.36: Vegetated Filter Strips Method 2 Design

Design Parameter	Vegetated Filter Strip Sizing
Longitudinal Slope	0.01 - 0.33
Maximum velocity	0.5 ft / sec @ the WQ Design Flow Rate
Maximum water depth[1]	1-inch max.
Manning coefficient	0.35
Minimum hydraulic residence time at Water Quality Design Flow Rate	9 minutes
Minimum length	Sufficient to achieve hydraulic residence time in the vegetated filter strip
Maximum side slope	Inlet edge ≥ 1 inch lower than contributing paved area
Max. tributary drainage flowpath	150 feet
Max. longitudinal slope of contributing area	0.05 (steeper than 0.05 needs upslope flow spreader and energy dissipation)
Max. lateral slope of contributing area	0.02 (at the edge of the vegetated filter strip inlet)

Notes:

1. Below the design water depth install an erosion control blanket, at least 4” of topsoil, and the selected biofiltration seed mix. Above the water line use a straw mulch or sod.

Construction Criteria

The filter strip should not be put into operation until areas of exposed soil in the contributing drainage catchment have been sufficiently stabilized. Deposition of eroded soils can impede the growth of grass in the filter strip and reduce filter strip treatment effectiveness. Thus, effective erosion and sediment control measures should remain in place until the filter strip vegetation is established (see Chapter 7 - Construction Stormwater Pollution Prevention for erosion and sediment control BMPs). Avoid compaction during construction.

Operation and Maintenance Criteria

- Grass filter strips should be mowed during the summer to promote growth.
- Inspect filter strips periodically, especially after periods of heavy runoff. Remove sediments and reseed as necessary. Catch basins or sediment sumps that precede filter strips should be cleaned to maintain proper function.

For more information: See Appendix 6-A: BMP Maintenance Tables for recommended maintenance criteria.

BMP T5.60: Compost-Amended Vegetated Filter Strips (CAVFS)

Ecology accepts the CAVFS BMP, as detailed in the *2019 Highway Runoff Manual* (WSDOT, 2019) as a Runoff Treatment BMP. Ecology does not accept the CAVFS BMP as a Flow Control BMP (i.e. the CAVFS BMP may not be used to meet Flow Control based performance standards). Please refer to the *2019 Highway Runoff Manual* (WSDOT, 2019) for detailed design guidance.

BMP T9.20: Wet Biofiltration Swale

Description

A wet biofiltration swale is a variation of BMP T5.40: Basic Biofiltration Swale. Designers can use wet biofiltration swales when the longitudinal slope is slight, water tables are high, or a continuous low base flow is likely to result in saturated soil. Where saturation exceeds about 2 weeks, typical grasses will die. Thus, use vegetation specifically adapted to saturated soil conditions. Different vegetation in turn requires modification of several of the design parameters for BMP T5.40: Basic Biofiltration Swale.

Wet biofiltration swales are Runoff Treatment BMPs that remove low concentrations of pollutants such as TSS, heavy metals, nutrients, and petroleum hydrocarbons. They are presumed to meet the Basic Treatment Performance Goal, as detailed in 6.1.2 Choosing Your Runoff Treatment BMPs.

Applications and Limitations

Wet biofiltration swales are applied where BMP T5.40: 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 BMP providing Flow Control.
- Saturated soil conditions are likely because of seeps or base flows on the site.
- Longitudinal slopes are slight (generally less than 2 percent).

Design Criteria

Use the same design approach as for BMP T5.40: Basic Biofiltration Swale, except to add the following:

Adjustment for Extended Wet Season Flow

If the wet biofiltration swale will be downstream of a detention pond providing Flow Control, multiply the treatment area (the bottom width times the bottom length) of the swale by 2, and readjust the swale length, if desired. Maintain a 5:1 length to width ratio.

Intent: An increase in the treatment area of biofiltration swales following detention BMPs is required because of the differences in vegetation established in a constant flow environment. Flows following detention are much more prolonged. These prolonged flows result in more stream-like conditions than are typical for other wet biofiltration swale situations. Since vegetation growing in streams is often less dense, this increase in treatment area is needed to ensure that equivalent pollutant removal is achieved in extended flow situations.

Swale Geometry

Same as specified for BMP T5.40: Basic Biofiltration Swale, except for the following modifications:

- The bottom width may be increased to 25 feet maximum, but a minimum length-to-width ratio of 5:1 must be provided. No longitudinal dividing berm is needed. The minimum swale length is still 100 feet.
- If longitudinal slopes are greater than 2 percent, the wet biofiltration swale must be stepped so that the slope within the stepped sections averages 2 percent. Steps may be made of retaining walls, log check dams, or short riprap sections.

High-Flow Bypass

Wet biofiltration swales must be designed as off-line facilities.

A high-flow bypass (i.e. an off-line design) is required for flows greater than Q_{biofil} (as defined in BMP T5.40: Basic Biofiltration Swale). The bypass is necessary to protect wetland vegetation from damage. Unlike grass, wetland vegetation will not quickly regain an upright attitude after being laid down by high flows. New growth, usually from the base of the plant, often taking several weeks, is required to regain its upright form.

Water Depth and Base Flow

Same as for BMP T5.40: Basic Biofiltration Swale, except the design water depth shall be 4 inches for all wetland vegetation selections.

Flow Velocity, Energy Dissipation, and Flow Spreading

Same as for BMP T5.40: Basic Biofiltration Swale, except no flow spreader is needed.

Access

Same as for BMP T5.40: Basic Biofiltration Swale, except access is only required to the inflow and the outflow of the wet biofiltration swale; access along the length of the wet biofiltration swale is not required. Also, wheel strips may not be used for access in the wet biofiltration swale.

Intent: An access road is not required along the length of a wet biofiltration swale because of infrequent access needs. Frequent mowing or harvesting is not desirable. In addition, wetland plants are fairly resilient to sediment-induced changes in water depth, so the need for access should be infrequent.

Soil Criteria

Same as for BMP T5.40: Basic Biofiltration Swale.

Vegetation Criteria

Same as for BMP T5.40: Basic Biofiltration Swale, except for the following modifications:

1. The designer may use the plants recommended in 6.B.4 Stormwater Treatment Wetlands Plant List for wet biofiltration swales, or the recommendations of a wetland specialist.
2. A wetland seed mix may be applied by hydroseeding, but if coverage is poor, planting of rootstock or nursery stock is required. Poor coverage is considered to be more than 30 percent bare area through the upper 2/3 of the swale after four weeks.

Construction Criteria

Same as for BMP T5.40: Basic Biofiltration Swale.

Maintenance Criteria

Same as for BMP T5.40: Basic Biofiltration Swale, except mowing of wetland vegetation is not required. However, harvesting of very dense vegetation may be desirable in the fall after plant die-back to prevent the sloughing of excess organic material into receiving waters. Many native *Juncus* species remain green throughout the winter; therefore, fall harvesting of *Juncus* species is not recommended.

BMP T9.30: Continuous Inflow Biofiltration Swale

Description

In situations where water enters a biofiltration swale continuously along the side slope rather than discretely at the head, a different design approach – the continuous inflow biofiltration swale (this BMP) – is needed. The basic biofiltration swale design presented in BMP T5.40: Basic Biofiltration Swale is modified by increasing the biofiltration swale length to achieve an equivalent average residence time.

Applications

A continuous inflow biofiltration swale is to be used when inflows are not concentrated, such as locations along the shoulder of a road without curbs.

This design may also be used where frequent, small point flows enter a biofiltration swale, such as through curb inlet ports spaced at intervals along a road, or from a parking lot with frequent curb cuts. In general, no inlet port should carry more than about 10 percent of the flow.

A continuous inflow biofiltration swale is not appropriate for a situation in which significant lateral flows enter a biofiltration swale at some point downstream from the head of the biofiltration swale. In this situation, the biofiltration swale width and length must be recalculated from the point of confluence to the discharge point in order to provide adequate treatment for the increased flows.

Design Criteria

Same as specified for BMP T5.40: Basic Biofiltration Swale except for the following:

- The design flow for continuous inflow biofiltration swales must include runoff from the pervious side slopes draining to the swale along the entire swale length. Therefore, they must be on-line facilities.
- If only a single design flow is used, it should be the flow rate at the outlet. The goal is to achieve an average residence time through the continuous inflow biofiltration swale of 9

minutes as calculated using Q_{biofil} (as defined in BMP T5.40: Basic Biofiltration Swale). Assuming an even distribution of inflow into the side of the swale, double the hydraulic residence time to a minimum of 18 minutes.

- For continuous inflow biofiltration swales, interior side slopes above the WQ design treatment elevation shall be planted in grass. A typical lawn seed mix or the seed mixes presented in BMP T5.40: Basic Biofiltration Swale are acceptable. Landscape plants or groundcovers other than grass may not be used anywhere between the runoff inflow elevation and the exit of the swale.

  Intent: The use of grass on interior side slopes reduces the chance of soil erosion and transfer of pollutants from landscape areas to the continuous inflow biofiltration swale treatment area.

6.9 Wetpool BMPs

6.9.1 Introduction to Wetpool BMPs

Wetpools provide Runoff Treatment by allowing settling of particulates during quiescent conditions (sedimentation), by biological uptake, and/or by vegetative filtration.

A wetpool is a constructed stormwater pond or portion of BMP that retains a pool of water. In some areas the wetpool may be permanent, at least during the wet season. The volume of the wetpool is related to the effectiveness of the pond in settling particulate pollutants. As an option, a shallow marsh area can be created within the permanent pool volume to provide additional treatment for nutrient removal.

Wetpool BMPs are recognized as effective Runoff Treatment BMPs. Refer to 6.1.2 Choosing Your Runoff Treatment BMPs for the level of Runoff Treatment achieved by each individual BMP. Wetpool BMPs may be single-purpose facilities, providing only Runoff Treatment, or they may be combined with a detention pond or vault to also provide Flow Control. If combined, the wetpool BMP can often be stacked under the detention BMP with little to no further loss of development area.

Wetpool BMPs are designed as on-line BMPs. See 6.1.5 Sizing Your Runoff Treatment BMPs for more information about "off-line" and "on-line" BMPs.

Wetpool BMPs are volume based Runoff Treatment BMPs, and are sized by calculating the Water Quality Design Volume as described in 6.1.5 Sizing Your Runoff Treatment BMPs.

Cold Weather Climate Considerations

Wetpool BMPs are generally effective in cold climates, with some modifications needed to prevent freezing of outlet pipes and selection of plants that are tolerant of cold and freezing conditions. Wetvaults should be designed with pool elevation below the frost line or per the manufacturer’s recommendation.

Because pollutant removal is by adsorption and settling, cold weather considerations regarding the changes in viscosity, and subsequently the settling velocity of particles, should be factored into the final design. See 6.1.8 Cold Weather Considerations for additional cold weather considerations related to cold temperatures, deep frost line, short growing season, and/or significant snowfall.

Arid/Semiarid Climate Considerations

Wetponds are not recommended in arid environments, where evaporation rates may be too high to maintain a normal pond without extensive use of scarce water. In semiarid environments, wetponds may be used with liners to help minimize water loss and with aeration to help minimize stagnation. See Table 6.6: Recommended Stormwater Treatment BMPs Based on Climate Type (continued) for additional considerations based on average annual rainfall.

For stormwater treatment wetlands, a source of irrigation water may be needed in arid/semiarid portions of eastern Washington. Since water depths are shallower than in wetponds, water loss by evaporation is an important concern and must be properly addressed in planning and design.

BMP T5.72: Wetvaults

Purpose and Definition

A wetvault is an underground structure similar in appearance to a detention vault, except that a wetvault has a permanent pool of water (wetpool) which dissipates energy and improves the settling of particulate pollutants (see the wetvault details in Figure 6.76: Wetvault). Being underground, the wetvault lacks the biological pollutant removal mechanisms, such as algae uptake, present in BMP T10.10: Wetponds - Basic and Large and BMP T5.73: Stormwater Treatment Wetlands.

Applications and Limitations

A wetvault may be used for commercial, industrial, or roadway projects if there are space limitations precluding the use of other Runoff Treatment BMPs. The use of wetvaults for residential development is highly discouraged. Combined detention and wetvaults are allowed; see BMP T10.40: Combined Detention and Wetpool Facilities.

A wetvault is believed to be ineffective in removing dissolved pollutants such as soluble phosphorus or metals such as copper. There is also concern that oxygen levels will decline, especially in warm summer months, because of limited contact with air and wind. However, the extent to which this potential problem occurs has not been documented.

Below-ground structures like wetvaults are relatively difficult and expensive to maintain. The need for maintenance is often not seen, and as a result routine maintenance does not occur.

If an Oil Control BMP is required for a project, a wetvault may be combined with BMP T5.100: API (Baffle type) Separator.

Design Criteria

Sizing Procedure (Standard Design)

As with wetponds, the primary design factor that determines the removal efficiency of a wetvault is the volume of the wetpool. 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 sizing procedure for a wetvault is identical to the sizing procedure for BMP T10.10: Wetponds - Basic and Large. Refer to BMP T10.10: Wetponds - Basic and Large for sizing guidance.

Typical design details and concepts for the wetvault are shown in Figure 6.76: Wetvault.

Sizing Procedure (Modified for Combining With a Baffle Oil and Water Separator)

If the project site requires an Oil Control BMP and a wetvault is proposed, the vault may be combined with BMP T5.100: API (Baffle type) Separator to meet the Runoff Treatment requirements with one facility rather than two. Structural modifications and added design criteria are given below. However, the maintenance requirements for BMP T5.100: API (Baffle type) Separator must be adhered to, in addition to those for a wetvault. This will result in more frequent inspection and cleaning than for a wetvault used only for TSS removal. See BMP T5.100: API (Baffle type) Separator for information on maintenance of baffle oil/water separators.

1. The sizing procedures for the baffle oil/water separator (BMP T5.100: API (Baffle type) Separator) should be run as a check to ensure the wetvault is large enough. If the oil/water separator sizing procedures result in a larger vault size, increase the wetvault size to match.

2. An oil retaining baffle shall be provided in the second cell near the vault outlet. The baffle should not contain a high-flow overflow, or else the retained oil will be washed out of the vault during large storms.

3. The vault shall have a minimum length-to-width ratio of 5:1.

4. The vault shall have a design water depth-to-width ratio of between 1:3 to 1:2.

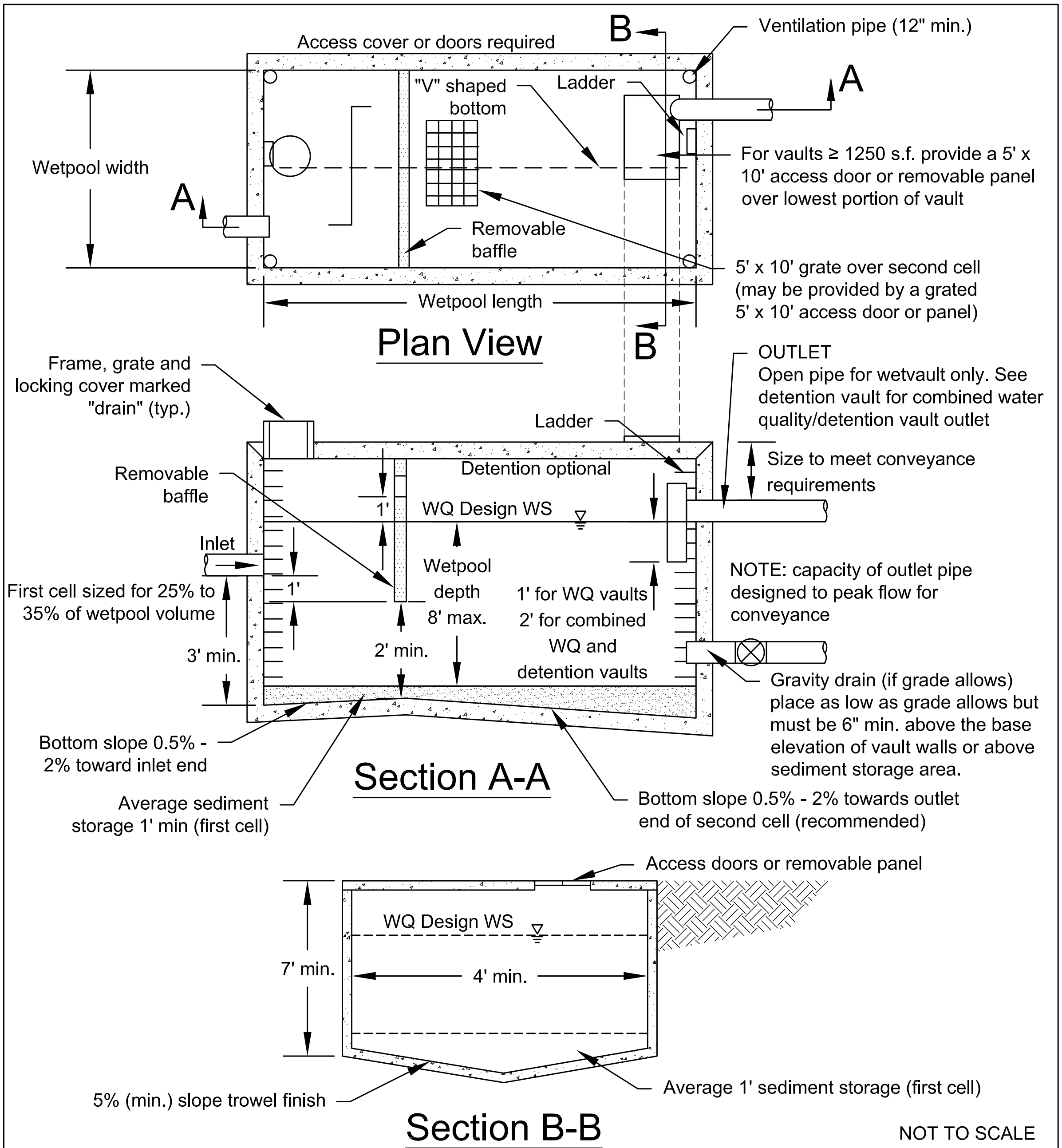
5. The vault shall be watertight and shall be coated to protect from corrosion.

6. Separator vaults shall 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 shall also be provided.

7. Wetvaults used as oil/water separators must be off-line and must bypass flows greater than the WQ design flow around the oil/water separator and into the second cell.

   Intent: This design minimizes the entrainment and/or emulsification of previously captured oil during very high flow events.

Figure 6.76: Wetvault



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Wetvault

Revised June 2016

Wetpool Geometry

The geometry of the wetpool within the wetvault is the same as specified for wetponds (see BMP T10.10: Wetponds - Basic and Large), except for the following two modifications:

- The sediment storage depth in the first cell shall be an average of 1 foot. Because of the v-shaped bottom, the depth of sediment storage needed above the bottom of the side wall is roughly proportional to the vault width according to Table 6.37: Sediment Storage Depth Requirements for Wetvaults
- The second cell shall be a minimum of 3 feet deep since planting cannot be used to prevent resuspension of sediment in shallow water as it can in open ponds.

Table 6.37: Sediment Storage Depth Requirements for Wetvaults

Vault Width (feet)	Sediment Depth (From Bottom of Sidewall) (inches)
15	10
20	9
40	6
60	4

Vault Structure

- The vault shall be separated into two cells by a wall or a removable baffle. If a wall is used, a 5-foot by 10-foot removable maintenance access must be provided for both cells. If a removable baffle is used, the following criteria apply:
    1. The baffle shall extend from a minimum of 1-foot above the WQ design water surface to a minimum of 1-foot below the invert elevation of the inlet pipe.
    2. The lowest point of the baffle shall be a minimum of 2 feet from the bottom of the vault, and greater if feasible.
- If the vault is less than 2,000 cubic feet (inside dimensions), or if the length-to-width ratio of the vault pool is 5:1 or greater, the baffle or wall may be omitted and the vault may be one-celled.
- The two wetpool cells of a wetvault should 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 wetpool cells must be positioned so as to lengthen, rather than divide, the flowpath.

  Intent: Treatment effectiveness in wetpool 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 wetpool cells can interfere with plug flow and create significant dead zones, reducing treatment effectiveness.

- The bottom of the first cell shall be sloped toward the access opening. The slope should be between 0.5 percent (minimum) and 2 percent (maximum). The second cell may be level (longitudinally) sloped toward the outlet, with a high point between the first and second cells. The intent of sloping the bottom is to direct the sediment accumulation to the closest access point for maintenance purposes. Sloping the second cell towards the access opening for the first cell is also acceptable.
- The vault bottom shall slope laterally a minimum of 5 percent from each side towards the center, forming a broad "v" to facilitate sediment removal. Note: More than one "v" may be used to minimize vault depth.

  The local jurisdiction may allow the vault bottom to be flat if removable panels are provided over the entire vault. Removable panels should be at grade, have stainless steel lifting eyes, and weigh no more than 5 tons per panel.
- The highest point of a vault bottom must be at least 6 inches below the outlet elevation to provide for sediment storage over the entire bottom.
- The design must provide for passage of flows should the outlet plug.
- Wetvaults may be constructed using arch culvert sections provided the top area at the WQ design water surface is, at a minimum, equal to that of a vault with vertical walls designed with an average depth of 6 feet.

  Intent: To prevent decreasing the surface area available for oxygen exchange.
- Wetvaults shall conform with the Materials and Structural Stability criteria specified for detention vaults in BMP F6.12: Detention Vaults.
- Where pipes enter and leave the wetvault below the WQ design water surface, they shall be sealed using a non-porous, non-shrinking grout.

Inlet and Outlet

- The inlet to the wetvault shall be submerged with the inlet pipe invert a minimum of 3 feet from the vault bottom. The top of the inlet pipe should be submerged at least 1-foot, if possible.

  Intent: 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.
- The capacity of the outlet pipe and available head above the outlet pipe should be designed to convey the 100-year design flow rate for developed site conditions without overtopping the vault. The available head above the outlet pipe must be a minimum of 6 inches.
- The outlet pipe shall be back-sloped or have a tee section, the lower arm of which should extend 1 foot below the WQ design water surface to provide for trapping of oils and floatables in the vault.
- The local jurisdiction may require a bypass/shutoff valve to enable the vault to be taken offline for maintenance.

Access Requirements

The access requirements for wetvaults are the same as for detention vaults (see BMP F6.12: Detention Vaults), except for the following additional requirement:

- A minimum of 50 square feet of grate should be provided over the second cell. For wetvaults in which the surface area of the second cell is greater than 1,250 square feet, 4 percent of the top should 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.

  Intent: The grate allows air contact with the wetpool in order to minimize stagnant conditions, which can result in oxygen depletion, especially in warm weather.

Access Roads, Right of Way, and Setbacks

The requirements for access roads, right of way, and setbacks for wetvaults are the same as for detention vaults (see BMP F6.12: Detention Vaults).

Recommended Design Features

The following design features should be incorporated into wetvaults where feasible, but they are not specifically required:

- The inlet and outlet should be at opposing corners of the vault to increase the flowpath.
- A flow length-to-width ratio greater than 3:1 minimum is desirable.
- Lockable grates instead of solid manhole covers are recommended to increase air contact with the wetpool.
- Galvanized materials shall not be used unless unavoidable.
- The number of inlets to the wetvault should be limited, and the flowpath length should be maximized from inlet to outlet for all inlets to the vault.

Construction Criteria

Sediment that has accumulated in the vault must be removed after construction in the contributing area to the wetvault is complete. If less than 12 inches of sediment have accumulated after the infrastructure is built, cleaning may be left until after building construction is complete. In general, sediment accumulation from stabilized contributing areas is not expected to exceed an average of 4 inches per year in the first cell. If sediment accumulation is greater than this amount, it will be assumed to be from construction unless it can be shown otherwise.

Operation and Maintenance Criteria

- Accumulated sediment and stagnant conditions may cause noxious gases to form and accumulate in the vault. Vault maintenance procedures must meet OSHA confined space entry requirements, which include clearly marking entrances to confined space areas. This may be accomplished by hanging a removable sign in the access riser(s), just under the access lid.

- Wetvaultss should be inspected annually. The maintenance standards contained in Appendix 6-A: BMP Maintenance Tables are measures for determining if maintenance actions are required as identified through the annual inspection.
- Sediment should be removed when the 1-foot sediment zone is full plus 6 inches. Sediments should be tested for toxicants in compliance with current disposal requirements. Sediments must be disposed in accordance with current local health department requirements and the Minimum Functional Standards for Solid Waste Handling (Chapter 173-304 WAC). See Appendix 8-B: Management of Street Waste Solids and Liquids for additional guidance.
- Any standing water removed during the maintenance operation must be properly disposed of. The preferred disposal option is discharge to a sanitary sewer at an approved location. Other disposal options include discharge back into the wetvault or the storm sewer system if certain conditions are met. See Appendix 8-B: Management of Street Waste Solids and Liquids for additional guidance.

BMP T5.73: Stormwater Treatment Wetlands

Purpose and Definition

In land development situations, wetlands are usually constructed for one of 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, this BMP). Stormwater treatment wetlands are shallow man-made ponds that are designed to treat stormwater through the biological processes associated with emergent aquatic plants (see the stormwater wetland details in Figure 6.77: Stormwater Wetland — Option One and Figure 6.78: Stormwater Wetland — Option Two).

Wetlands created to mitigate disturbance impacts, such as filling, may not also be used as stormwater treatment BMPs. This is because of the different, incompatible functions of the two kinds of wetlands. Mitigation wetlands are intended to function as full replacement habitat for fish and wildlife, providing the same functions and harboring the same species diversity and biotic richness as the wetlands they replace. Stormwater treatment wetlands are used to capture and transform pollutants, just as wetponds are, and over time pollutants will concentrate in the sediment. This is not a healthy environment for aquatic life. Stormwater treatment wetlands are used to capture pollutants in a managed environment so that they will not reach natural wetlands and other ecologically important habitats. In addition, vegetation must occasionally be harvested and sediment dredged in stormwater treatment wetlands, further interfering with use for wildlife habitat.

In general, stormwater treatment wetlands perform well to remove sediment, metals, and pollutants that bind to humic or organic acids. Phosphorus removal in stormwater treatment wetlands is highly variable.

Applications and Limitations

The stormwater treatment wetland design occupies about the same surface area as wetponds, but has the potential to be better integrated aesthetically into a site because of the abundance of emergent aquatic vegetation. The most critical factor for a successful design is the provision of an adequate supply of water for most of the year. Careful planning is needed to be sure sufficient water will be retained to sustain good wetland plant growth. A source of irrigation water may be needed. Since water depths are shallower than in wetponds, water loss by evaporation is an important concern. Stormwater treatment wetlands are a good Runoff Treatment BMP choice in areas with high winter groundwater levels.

Design Criteria

When used for Runoff Treatment, stormwater treatment wetlands employ some of the same design features as wetponds. However, instead of gravity settling being the dominant treatment process, pollutant removal mediated by aquatic vegetation and the microbiological community associated with that vegetation becomes the dominant treatment process. Thus, when designing wetlands, water volume is not the dominant design criteria. Rather, factors that affect plant vigor and biomass are the primary concerns.

Sizing Procedure

The procedure for determining a stormwater treatment wetland's dimensions and volume are outlined below.

1. The volume of a basic wetpond (see BMP T10.10: Wetponds - Basic and Large) is used as a template for sizing the stormwater treatment wetland. The design volume for the stormwater treatment wetland is the Water Quality Design Volume, as described in 6.1.5 Sizing Your Runoff Treatment BMPs.
2. The surface area of the stormwater treatment wetland shall be the same as the top area of a wetpond sized for the same site conditions. Calculate the surface area of the stormwater treatment wetland by using the volume from Step 1 and dividing by the average water depth (typically 3 feet).
3. Determine the surface area of the first cell (the presettling cell) of the stormwater treatment wetland. Use the volume determined from Criterion 2 under Wetland Geometry, and the actual depth of the first cell.
4. Determine the surface area of the second cell (the wetland cell). Subtract the surface area of the first cell (Step 3) from the total surface area (Step 2).
5. Determine the water depth distribution in the second cell. Decide if the top of the dividing berm will be at the surface or submerged (designer's choice). Adjust the distribution of water depths in the second cell according to Criterion 8 under Wetland Geometry below. Note: This will result in a facility that holds less volume than that determined in Step 1 above. This is acceptable.

   Intent: The surface area of the stormwater treatment wetland is set to be roughly equivalent to that of a wetpond designed for the same site so as not to discourage use of this option.

6. Choose plants. See Appendix 6-B: Planting Recommendations for a list of plants recommended for wetpond water depth zones, or consult a wetland scientist.

Wetland Geometry

The intent of these wetland geometry criteria should be generally met. Appropriate deviations may be necessary, based on site-specific considerations:

1. Stormwater treatment wetlands shall consist of two cells, a presettling cell and a wetland cell.
2. The presettling cell shall contain approximately 33 percent of the wetpool volume calculated in Step 1 of the sizing procedure (above).
3. The depth of the presettling cell shall be between 4 feet (minimum) and 8 feet (maximum), excluding sediment storage.
4. One-foot of sediment storage shall be provided in the presettling cell.
5. The permanent pool in the wetland cell shall have an average water depth of about 1.5 feet (plus or minus 3 inches). The average water depth required for the total storage volume is typically 3 feet.
6. The "berm" separating the two cells shall be shaped such that its downstream side gradually slopes to form the shallow wetland cell (see the section view in Figure 6.77: Stormwater Wetland — Option One). Alternatively, the wetland cell may be graded naturalistically from the top of the dividing berm (see Criterion 8 below).
7. The top of berm shall be either at the WQ design water surface or submerged 1-foot below the WQ design water surface, as with BMP T10.10: Wetponds - Basic and Large. Correspondingly, the side slopes of the berm must meet the following criteria:
    a. If the top of berm is at the WQ design water surface, the berm side slopes shall be no steeper than 3H:1V.
    b. If the top of berm is submerged 1-foot, the upstream side slope may be up to 2H:1V. If the berm is at the water surface, then for safety reasons, its slope should be not greater than 3:1, just as the pond banks should not be greater than 3:1 if the pond is not fenced. A steeper slope (2:1 rather than 3:1) is allowable if the berm is submerged in 1 foot of water. If submerged, the berm is not considered accessible, and the steeper slope is allowable.
8. Two examples are provided for grading the bottom of the wetland cell. One example is a shallow, evenly graded slope from the upstream to the downstream edge of the wetland cell (see Figure 6.77: Stormwater Wetland — Option One). The second example is a "naturalistic" alternative, with the specified range of depths intermixed throughout the second cell (see Figure 6.78: Stormwater Wetland — Option Two). A distribution of depths shall be provided in the wetland cell depending on whether the dividing berm is at the water surface or submerged (see Table 6.38: Distribution of Depths in Wetland Cell). The maximum depth is 2.5 feet in either configuration. Other configurations within the wetland geometry constraints listed above may be approved by the local jurisdiction.

9. A minimum length-to-width ratio of 2:1 is recommended. The shape is generally dictated by the surrounding site geometry, but the purpose of this recommendation is to prevent short-circuiting of water across the pond. Baffles, islands, and creative inlet structures can be used to promote adequate mixing in challenging settings.

Table 6.38: Distribution of Depths in Wetland Cell

Dividing Berm at WQ Design Water Surface		Dividing Berm Submerged 1-Foot	
Depth Range (feet)	**Percent**	**Depth Range (feet)**	**Percent**
0.1 to 1	25	1 to 1.5	40
1 to 2	55	1.5 to 2	40
2 to 2.5	20	2 to 2.5	20

Figure 6.77: Stormwater Wetland — Option One

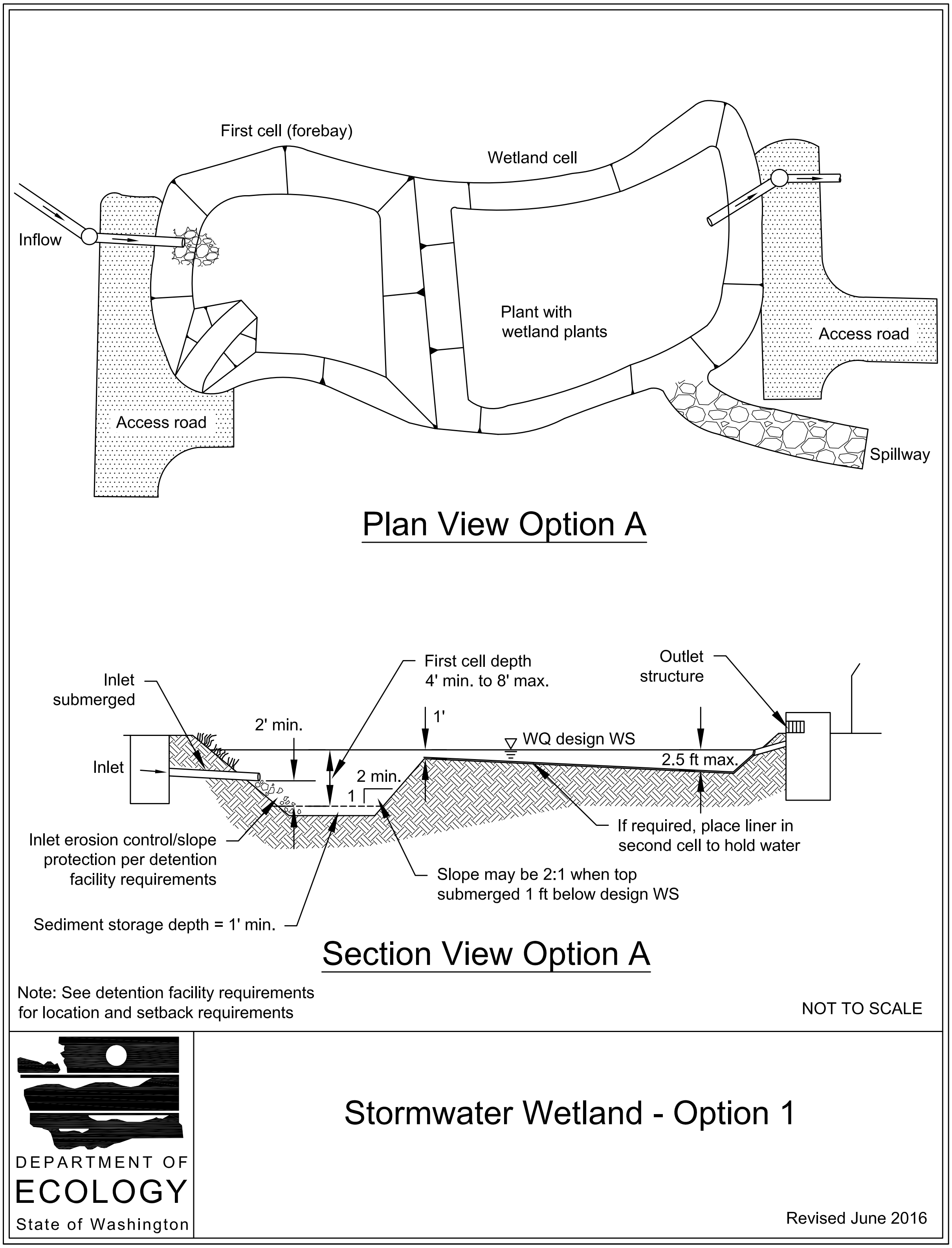
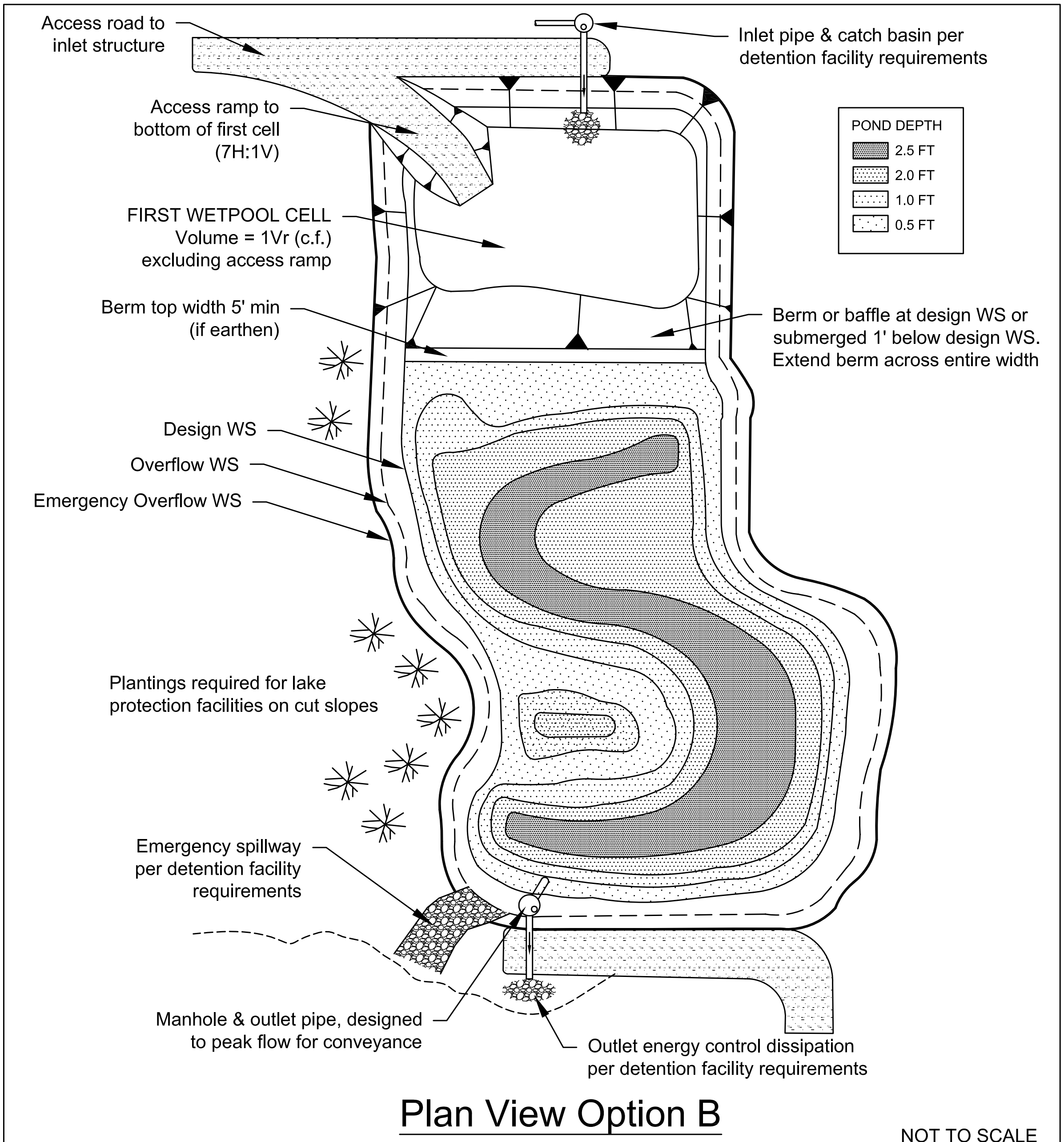


Figure 6.78: Stormwater Wetland — Option Two



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Stormwater Wetland - Option 2

Revised June 2016

Lining Requirements

Stormwater treatment wetlands are not intended to infiltrate. In infiltrative soils, both cells of the stormwater treatment wetland shall be lined. To determine whether a low-permeability liner or a treatment liner is required, determine whether the following conditions will be met. If soil permeability will allow sufficient water retention, the lining requirement may be waived.

1. The second cell (the wetland cell) must retain water for at least 2 consecutive months of the year.
2. The first cell (the presettling cell) must retain at least three feet of water year-round.
3. A complete precipitation record shall be used when establishing these conditions. Evapotranspiration losses shall be taken into account as well as infiltration losses.

Intent: Many wetland plants can adapt to periods of summer drought, so a limited drought period is allowed in the second cell. This may allow a treatment liner rather than a low permeability liner to be used for the second cell. The first cell must retain water year-round in order for the presettling function to be effective.

If a low permeability liner is used, a minimum of 18 inches of native soil amended with good topsoil or compost (one part compost mixed with 3 parts native soil) must be placed over the liner. The compost must not contain biosolids or manure. For geomembrane liners, a soil depth of 3 feet is recommended to prevent damage to the liner during planting. Hydric soils are not required.

The criteria for liners given in 6.1.9 Liners and Geotextiles must be observed.

Inlet and Outlet

The design guidance for inlets and outlets to stormwater treatment wetlands is the same as for wetponds (see BMP T10.10: Wetponds - Basic and Large).

Access and Setbacks

- Location of the stormwater treatment wetland relative to site constraints (e.g. buildings, property lines) shall be the same as for BMP F6.10: Detention Ponds. See 6.1.7 Setbacks, Slopes, and Embankments for typical setback requirements for Runoff Treatment BMPs.
- Access and maintenance roads shall be provided and designed according to the requirements for BMP F6.10: Detention Ponds. Access and maintenance roads shall extend to both the wetland inlet and outlet structures. An access ramp (7H minimum:1V) shall be provided to the bottom of the first cell unless all portions of the cell can be reached and sediment loaded from the top of the wetland side slopes.
- If the dividing berm is also used for access, it should be built to sustain loads of up to 80,000 pounds.

Planting Requirements

The wetland cell shall be planted with emergent wetland plants following the recommendations given in Appendix 6-B: Planting Recommendations or the recommendations of a wetland specialist. Note: Cattails (Typha latifolia) are not recommended. They tend to escape to natural wetlands and crowd out other species. In addition, the shoots die back each fall and will result in oxygen depletion in the wetpool unless they are removed.

Construction Criteria

- Construction and maintenance considerations are the same as for BMP T10.10: Wetponds - Basic and Large.
- Construction of the naturalistic alternative (see Figure 6.78: Stormwater Wetland — Option Two) can be easily done by first excavating the entire area to the 1.5-foot average depth. Then soil subsequently excavated to form deeper areas can be deposited to raise other areas until the distribution of depths indicated in the design is achieved.

Operation and Maintenance Criteria

- Stormwater treatment wetlands should be inspected at least twice per year during the first three years during both growing and non-growing seasons to observe plant species presence, abundance, and condition; bottom contours and water depths relative to the plans; and sediment, outlet, and buffer conditions.
- Maintenance should be scheduled around sensitive wildlife and vegetation seasons.
- Plants may require watering, physical support, mulching, weed removal, or replanting during the first three years.
- Plants may require additional watering during extended dry periods
- Nuisance plant species should be removed and desirable species should be replanted.
- The effectiveness of harvesting for nutrient control is not well documented. There are many drawbacks to harvesting, including possible damage to the wetlands and the inability to remove nutrients in the below-ground biomass. If harvesting is practiced, it should be done in the late summer.

BMP T10.10: Wetponds - Basic and Large

Purpose and Definition

A wetpond is a constructed stormwater pond that retains a permanent pool of water ("wetpool") at least during the wet season. The volume of the wetpool is related to the effectiveness of the pond in settling particulate pollutants. As an option, a shallow marsh area can be created within the permanent pool volume to provide additional treatment for nutrient removal. Figure 6.79: Wetpond (Plan View) and Figure 6.80: Wetpond (Section View) illustrates a typical wet pond BMP.

The following design, construction, and operation and maintenance criteria cover two wetpond applications - the basic wetpond and the large wetpond. Large wetponds are designed for higher levels of pollutant removal.

Applications and Limitations

A wetpond requires a larger area than a biofiltration swale (see 6.8 Biofiltration BMPs) or a sand filter (see 6.7 Filtration BMPs), but it can be integrated to the contours of a site fairly easily. In till soils, the wetpond holds a permanent pool of water that provides an attractive aesthetic feature. In more porous soils, wetponds may still be used, but water seepage from unlined cells could result in a dry pond, particularly in the summer months. Lining the first cell with a low permeability liner (see 6.1.9.3 Low Permeability Liners) is one way to deal with this situation. As long as the first cell retains a permanent pool of water, the pond will function as an effective Runoff Treatment BMP.

Wetponds 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 wetpool storage of wetponds 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.

Wetponds may be single-purpose BMPs, providing only Runoff Treatment, or they may be combined with a detention pond to also provide Flow Control. If combined, the wetpool can often be stacked under the detention pond with little further loss of development area. See BMP T10.40: Combined Detention and Wetpool Facilities.

Wetponds are not recommended in arid environments.

Design Criteria

General Criteria

The primary design factor that determines a wetpond's treatment efficiency is the volume of the wetpool. The larger the wetpool volume, the greater the potential for pollutant removal.

Also important are the avoidance of short-circuiting and the promotion of plug flow. Plug flow describes the hypothetical condition of stormwater moving through the pond as a unit, displacing the "old" water in the pond with incoming flows. To prevent short-circuiting and promote plug flow, the pond should be designed to force the water to flow, to the extent practical, to all potentially available flow routes, avoiding "dead zones" and maximizing the time the water stays in the pond during the active part of a storm.

Design features that encourage plug flow and avoid dead zones are:

- Dissipating energy at the inlet.
- Providing a large length-to-width ratio.
- Providing a broad surface for water exchange using a berm designed as a broad-crested weir to divide the wetpond into two cells rather than a constricted area such as a pipe.
- Maximizing the flow path between inlet and outlet, including the vertical path, which also enhances treatment by increasing residence time.

Sizing Procedure

Procedures for determining a wetpond's dimensions and volume are outlined below.

1. Identify the required wetpool volume within the wetpond using one of the methods described in 6.1.5 Sizing Your Runoff Treatment BMPs.
   - For a basic wetpond, the wetpool volume provided shall be equal to or greater than the Water Quality Design Volume, as described in 6.1.5 Sizing Your Runoff Treatment BMPs.
   - For a large wetpond, the wetpool volume provided shall be equal to or greater than 1.5 times the Water Quality Design Volume, as described in 6.1.5 Sizing Your Runoff Treatment BMPs.
2. Determine the wetpool dimensions to satisfy the design criteria outlined below and illustrated in Figure 6.79: Wetpond (Plan View) and Figure 6.80: Wetpond (Section View). A simple way to check the volume of each wetpool cell is to use the following equation:

   $$V = \frac{h(A_1 + A_2)}{2}$$

   where

   V = wetpool volume (cf)

   h = wetpool average depth (ft)

   A_1 = water quality design surface area of wetpool (sf)

   A_2 = bottom area of wetpool (sf)
3. Design the pond outlet pipe and determine the primary overflow water surface. The pond outlet pipe shall be placed on a reverse grade from the pond's second wetpool cell to the outlet structure. Use the following procedure to design the pond outlet pipe and determine the primary overflow water surface elevation:
   a. Use the nomographs in Figure 6.81: Headwater Depth for Smooth Interior Pipe Culverts with Inlet Control and Figure 6.82: Headwater Depth for Corrugated Pipe Culverts with Inlet Control to select a trial size for the pond outlet pipe sufficient to pass the Water Quality Design Flow Rate (as described in 6.1.5 Sizing Your Runoff Treatment BMPs), Q_{wq}.
   b. Use Figure 6.83: Critical Depth of Flow for Circular Culverts to determine the critical depth d_c at the outflow end of the pipe for Q_{wq}.
   c. Use Figure 6.84: Circular Channel Ratios to determine the flow area A_c at critical depth.
   d. Calculate the flow velocity at critical depth (V_c) using the continuity equation:

      $$V_c = Q_{wq} / A_c$$

   e. Calculate the velocity head (V_H):

$$V_H = V_c^2 / 2g$$

where g is the gravitational constant, 32.2 feet per second.

f. Determine the primary overflow water surface elevation by adding the velocity head (V_H) and critical depth (d_c) to the invert elevation at the outflow end of the pond outlet pipe:

$$\text{overflow water surface elevation} = \text{outflow invert} + d_c + V_H$$

g. Adjust the outlet pipe diameter as needed and repeat Steps (a) through (e).

4. Determine the wetpond dimensions that include the dimensions for the two wetpool cells. General wetpond design criteria and concepts are shown in Figure 6.79: Wetpond (Plan View) and Figure 6.80: Wetpond (Section View).

Figure 6.79: Wetpond (Plan View)

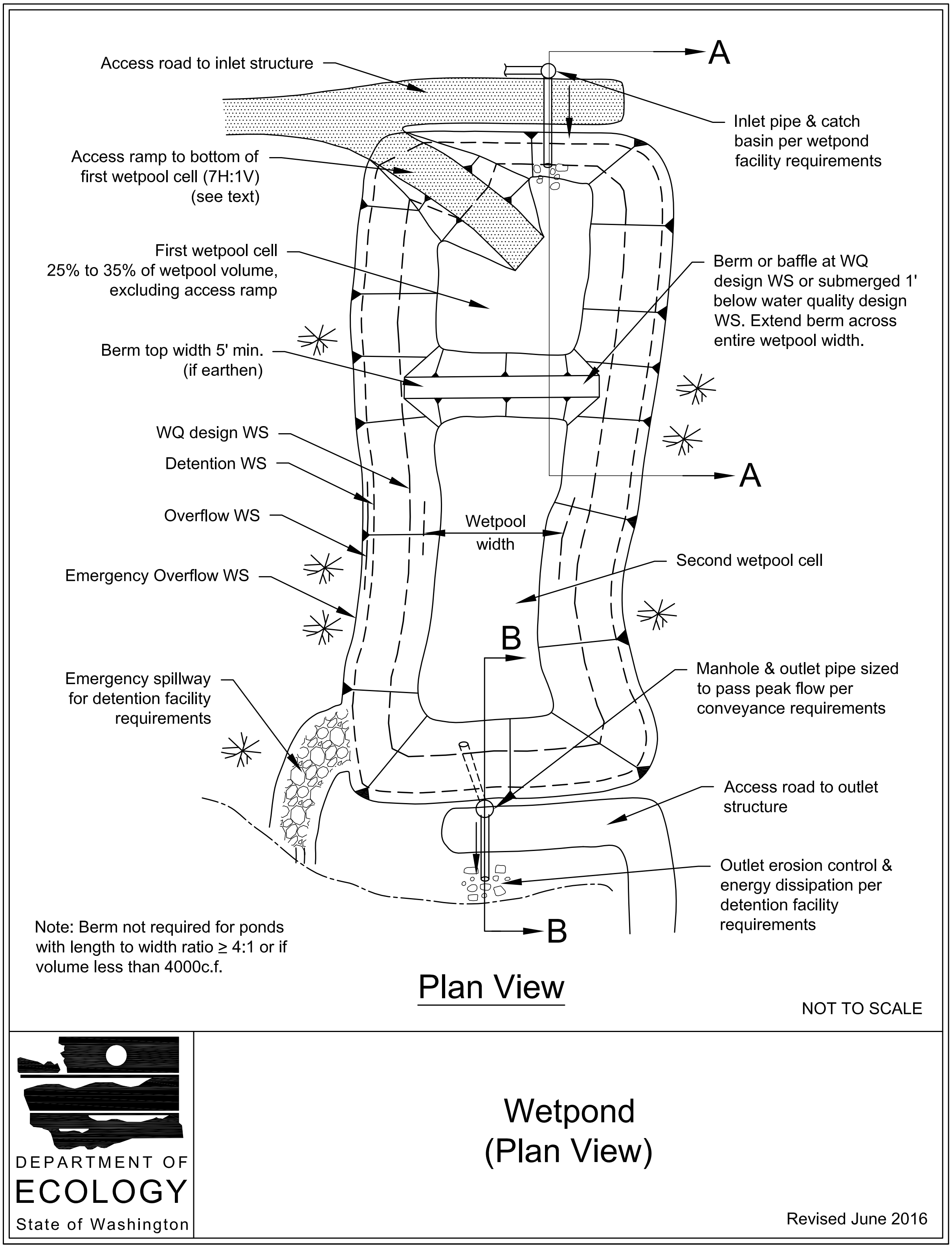
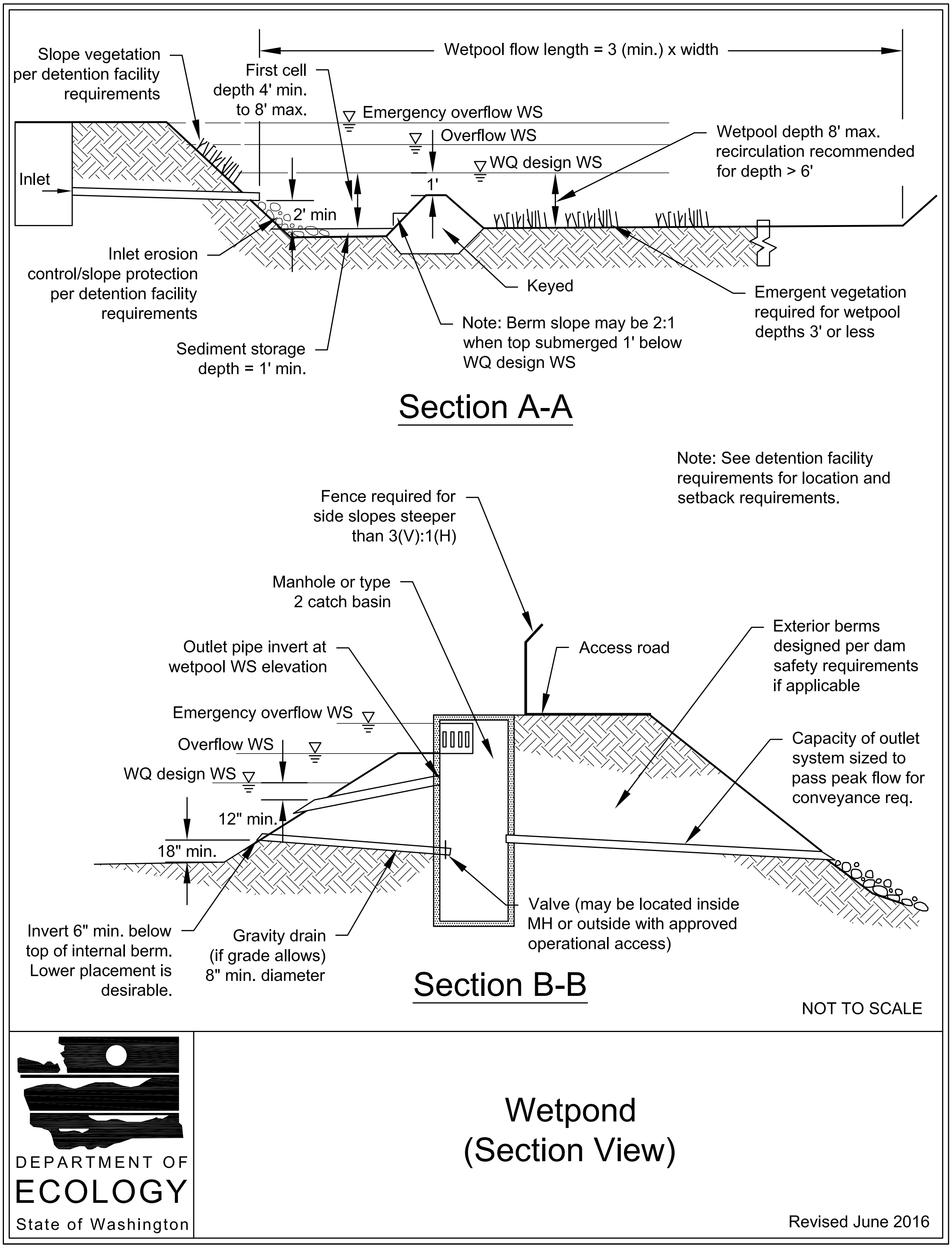


Figure 6.80: Wetpond (Section View)



Wetpool Geometry

- The total wetpool volume shall be divided into two cells within the wetpond, separated by a baffle or berm. The first wetpool cell shall contain 25 to 35 percent of the total wetpool volume. The baffle or berm volume shall not count as part of the total wetpool volume. The term baffle means 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.

  Intent: The full-length berm or baffle promotes plug flow and enhances quiescence and laminar flow through as much of the entire wetpool 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 local jurisdiction.

- Sediment storage shall be provided in the first cell. The sediment storage shall have a minimum depth of 1-foot. A fixed sediment depth monitor should be installed in the first cell to gauge sediment accumulation unless an alternative gauging method is proposed.
- The minimum depth of the first cell shall be 4 feet, exclusive of sediment storage requirements. The depth of the first cell may be greater than the depth of the second cell.
- The maximum depth of each cell shall not exceed 8 feet (exclusive of sediment storage in the first cell). Pool depths of 3 feet or shallower (second cell) shall be planted with emergent wetland vegetation (see Planting Requirements below).
- Inlets and outlets shall be placed to maximize the flowpath through the wetpool cells. The ratio of flowpath length to width from the inlet to the outlet shall be at least 3:1. The *flowpath length* is defined as the distance from the inlet to the outlet, as measured at mid-depth. The *width* at mid-depth can be found as follows:

  width = (average top width + average bottom width)/2

- Wetponds with wetpool 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 shall be at least 4:1 in single celled wetponds, but should preferably be 5:1.
- All inlets shall enter the first cell. If there are multiple inlets, the length-to-width ratio shall be based on the average flowpath length for all inlets.
- The first cell must be lined in accordance with the liner requirements contained in 6.1.9.1 General Liner Design.

Berms, Baffles, and Slopes

- A berm or baffle shall extend across the full width of the wetpool, and tie into the wetpond side slopes. If the berm embankments are greater than 4 feet in height, the berm must be constructed by excavating a key equal to 50 percent of the embankment cross-sectional height and width. This requirement may be waived if recommended by a geotechnical engineer for specific site conditions. The geotechnical analysis shall address situations in which one of the two cells is empty while the other remains full of water.

- The top of the berm may extend to the water quality (WQ) design water surface or be 1-foot below the WQ design water surface. If at the WQ design water surface, berm side slopes should be 3H:1V. Berm side slopes may be steeper (up to 2:1) if the berm is submerged 1-foot.

  Intent: Submerging the berm is intended to enhance safety by discouraging pedestrian access when side slopes are steeper than 3H:1V. An alternative to the submerged berm design is the use of barrier planting to prevent easy access to the divider berm in an unfenced wetpond.

- If good vegetation cover is not established on the berm, erosion control measures should be used to prevent erosion of the berm back-slope when the pond is initially filled.

- The interior berm or baffle may be a retaining wall provided that the design is prepared and stamped by a licensed engineer in the state of Washington. If a baffle or retaining wall is used, it should be submerged one foot below the design water surface to discourage access by pedestrians.

- Criteria for wetpond side slopes are included in 6.1.7 Setbacks, Slopes, and Embankments.

Embankments

Embankments that impound water must comply with the Washington State Dam Safety Regulations (Chapter 173-175 WAC).. See Dam Safety for Detention BMPs in BMP F6.10: Detention Ponds for details about dam safety requirements for stormwater ponds.

Inlet and Outlet

See Figure 6.79: Wetpond (Plan View) and Figure 6.80: Wetpond (Section View) for details on the following requirements:

- The inlet to the wetpond shall be submerged with the inlet pipe invert a minimum of two feet from the pond bottom (not including sediment storage). The top of the inlet pipe should be submerged at least 1-foot, if possible.

  Intent: The inlet is submerged to dissipate energy of the incoming flow. The distance from the bottom is set to minimize resuspension of settled sediments. Alternative inlet designs that accomplish these objectives are acceptable.

- An outlet structure shall be provided. Either a Type 2 catch basin with a grated opening (jail house window) or a manhole with a cone grate (birdcage) may be used (see Figure 6.107: Overflow Structure for an illustration). No sump is required in the outlet structure for wetponds that do not provide detention storage. The outlet structure receives flow from the pond outlet pipe. The grate or birdcage openings provide an overflow route should the pond outlet pipe become clogged. The overflow criteria provided below specifies the sizing and position of the grate opening.

- The pond outlet pipe (as opposed to the manhole or type 2 catch basin outlet pipe) shall be back-sloped or have a down-turned elbow, and extend 1 foot below the WQ design water surface. Note: A floating outlet, set to draw water from 1-foot below the water surface, is also acceptable if vandalism concerns are adequately addressed.

  Intent: The inverted outlet pipe provides for trapping of oils and floatables in the wetpond.

- The pond outlet pipe shall be sized, at a minimum, to pass the Water Quality Design Flow Rate. Note: The highest invert of the outlet pipe sets the WQ design water surface elevation.

- The overflow criteria for single-purpose (Runoff Treatment only, not combined with Flow Control) wetponds are as follows:

  a. The requirement for primary overflow is satisfied by either the grated inlet to the outlet structure or by a birdcage above the pond outlet structure.

  b. The bottom of the grate opening in the outlet structure shall be set at or above the height needed to pass the Water Quality Design Flow Rate through the pond outlet pipe. Note that the grate invert elevation sets the overflow water surface elevation.

  c. The grated opening should be sized to pass the 100-year design flow. The capacity of the outlet system should be sized to pass the peak flow for the conveyance requirements.

- An emergency spillway shall be provided and designed according to the requirements for detention ponds (see BMP F6.10: Detention Ponds).

- The local jurisdiction may require a bypass/shutoff valve to enable the pond to be taken offline for maintenance purposes.

- A gravity drain for maintenance is recommended, if grade allows.

  Intent: It is anticipated that sediment removal will only be needed for the first cell in the majority of cases. The gravity drain is intended to allow water from the first cell to be drained to the second cell when the first cell is pumped dry for cleaning.

  - The gravity drain invert shall be at least 6 inches below the top elevation of the dividing berm or baffle. Deeper drains are encouraged where feasible, but must be no deeper than 18 inches above the pond bottom.

    Intent: To prevent highly sediment-laden water from escaping the pond when drained for maintenance.

  - The gravity drain shall be at least 8 inches (minimum) diameter and shall be controlled by a valve. Use of a shear gate is allowed only at the inlet end of a pipe located within an approved structure.

    Intent: Shear gates often leak if water pressure pushes on the side of the gate opposite the seal. The gate should be situated so that water pressure pushes toward the seal.

- Operational access to the valve shall be provided to the finished ground surface.
- The valve location shall be accessible and well-marked with 1-foot of paving placed around the box. It must also be protected from damage and unauthorized operation.
- A valve box is allowed to a maximum depth of 5 feet without an access manhole. If over 5 feet deep, an access manhole or vault is required.

- All metal parts shall be corrosion-resistant. Galvanized materials should not be used unless unavoidable.

  Intent: Galvanized metal contributes zinc to stormwater, sometimes in very high concentrations.

Access and Setbacks

- Wetponds shall be a minimum of 20 feet from any structure, property line, and any vegetative buffer required by the local jurisdiction, and 100 feet from any septic tank/drainfield.
- Wetponds shall be a minimum of 50 feet from any steep (greater than 15 percent) slope. A geotechnical report must address the potential impact of a wetpond on a steep slope.
- Access and maintenance roads shall be provided and designed according to the requirements for BMP F6.10: Detention Ponds. Access and maintenance roads shall extend to both the wetpond inlet and outlet structures. An access ramp (7H minimum:1V) shall be provided to the bottom of the first cell unless all portions of the cell can be reached and sediment loaded from the top of the pond.
- If the dividing berm is also used for access, it should be built to sustain loads of up to 80,000 pounds.

Planting Requirements

Planting requirements for BMP F6.10: Detention Ponds also apply to wetponds.

- Large wetponds intended for use as a Phosphorus Treatment BMP should not be planted within the cells, as the plants will release phosphorus in the winter when they die off.
- If desired, the pond may be planted with dryland grasses. Sod or wetland plants should be avoided unless irrigation will be provided during the dry months. See Appendix 6-B: Planting Recommendations for planting recommendations.
- Cattails (Typha latifolia) are not recommended because they tend to crowd out other species and will typically establish themselves anyway.
- If the wetpond discharges to a phosphorus-sensitive lake or wetland, shrubs that form a dense cover should be planted on slopes above the WQ design water surface on at least three sides. For banks that are berms, no planting is allowed if the berm is regulated by dam safety requirements. The purpose of planting is to discourage waterfowl use of the pond

and to provide shading. Some suitable trees and shrubs include vine maple (*Acer circinatum*), wild cherry (*Prunus emarginata*), red osier dogwood (*Cornus stolonifera*), California myrtle (*Myrica californica*), Indian plum (*Oemleria cerasiformis*), and Pacific yew (*Taxus brevifolia*) as well as numerous ornamental species.

- Check with local jurisdiction and the Washington State Noxious Weed Control Board for an updated list of invasive species plants during plant selection.

Recommended Design Features

The following design features should be incorporated into the wetpond design where site conditions allow:

- The method of construction of soil/landscape systems can cause natural selection of specific plant species. Consult a soil restoration or wetland soil scientist for site-specific recommendations. The soil formulation will impact the plant species that will flourish or suffer on the site, and the formulation should be such that it encourages desired species and discourages undesired species.
- For wetpool depths in excess of 6 feet, it is recommended that some form of recirculation be provided in the summer, such as a fountain or aerator, to prevent stagnation and low dissolved oxygen conditions.
- A flow length-to-width ratio greater than the 3:1 minimum is desirable. If the ratio is 4:1 or greater, then the dividing berm is not required, and the pond may consist of one cell rather than two. A one-cell pond must provide at least 6-inches of sediment storage depth. A one cell pond must also provide a minimum depth of 4 feet for the volume equivalent to the first cell of a two-cell design.
- A tear-drop shape, with the inlet at the narrow end, rather than a rectangular pond is preferred since it minimizes dead zones caused by corners.
- A small amount of base flow is desirable to maintain circulation and reduce the potential for low oxygen conditions during late summer.
- Evergreen or columnar deciduous trees along the west and south sides of ponds are recommended to reduce thermal heating, except that no trees or shrubs may be planted on berms meeting the criteria of dams regulated for safety. In addition to shade, trees and shrubs also discourage waterfowl use and the attendant phosphorus enrichment problems they cause. Trees should be set back so that the branches will not extend over the pond.

  Intent: Evergreen trees or shrubs are preferred to avoid problems associated with leaf drop, except on the south and west sides, which may inhibit the melting of ice during the winter.. Columnar deciduous trees (e.g., hornbeam, Lombardy poplar) typically have fewer leaves than other deciduous trees.
- The number of inlets to the wetpond should be limited; ideally there should be only one inlet. The flowpath length should be maximized from inlet to outlet for all inlets to the wetpond.

- The access and maintenance road could be extended along the full length of the wetpond and could double as playcourts or picnic areas. Placing finely ground bark or other natural material over the road surface would render it more pedestrian friendly.
- The following design features should be incorporated to enhance aesthetics where possible:
  - Provide pedestrian access to shallow pool areas enhanced with emergent wetland vegetation. This allows the pond to be more accessible without incurring safety risks.
  - Provide side slopes that are sufficiently gentle to avoid the need for fencing (3:1 or flatter).
  - Create flat areas overlooking or adjoining the pond for picnic tables or seating that can be used by residents. Walking or jogging trails around the pond are easily integrated into site design.
  - Include fountains or integrated waterfall features for privately maintained facilities.
  - Provide visual enhancement with clusters of trees and shrubs. On most pond sites, it is important to amend the soil before planting since ponds are typically placed well below the native soil horizon in very poor soils. Make sure dam safety restrictions against planting do not apply.
  - Orient the pond length along the direction of prevailing summer winds (typically west or southwest) to enhance wind mixing.

Construction Criteria

- Sediment that has accumulated in the pond must be removed after construction in the contributing area of the pond is complete (unless used for a liner - see below).
- Sediment that has accumulated in the pond at the end of construction may be used in excessively drained soils to meet the liner requirements if the sediment meets the criteria for low permeability or treatment liners per 6.1.9 Liners and Geotextiles and is approved for use as such by a licensed engineer in the state of Washington with geotechnical expertise. Sediment used for a soil liner must be graded to provide uniform coverage and must meet the thickness specifications in 6.1.9 Liners and Geotextiles. The sediment must not reduce the volume of the wetpool. The wetpool must be over-excavated initially to provide sufficient room for the sediments to serve as a liner.

Operation and Maintenance

- Maintenance is of primary importance if wetponds are to continue to function as originally designed. A local jurisdiction, a designated group such as a homeowners' association, or a property owner shall accept the responsibility for maintaining the structures and the impoundment area. A specific maintenance plan shall be formulated outlining the schedule and scope of maintenance operations.
- The wetpond should be inspected by the local jurisdiction annually. The maintenance standards contained in Appendix 6-A: BMP Maintenance Tables are measures for determining if maintenance actions are required as identified through the annual inspection.

- Site vegetation should be trimmed as necessary to keep the wetpond free of leaves and to maintain the aesthetic appearance of the site. Slope areas that have become bare should be revegetated and eroded areas should be regraded prior to being revegetated.
- Sediment should be removed when the 1-foot sediment zone is full plus 6 inches. Sediments should be tested for toxicants in compliance with current disposal requirements. Sediments must be disposed in accordance with current local health department requirements and the Minimum Functional Standards for Solid Waste Handling (Chapter 173-304 WAC). See Appendix 8-B: Management of Street Waste Solids and Liquids for additional guidance.
- Any standing water removed during the maintenance operation must be properly disposed of. The preferred disposal option is discharge to a sanitary sewer at an approved location. Other disposal options include discharge back into the wetpool BMP or the storm sewer system if certain conditions are met. See Appendix 8-B: Management of Street Waste Solids and Liquids for additional guidance.

See Appendix 6-A: BMP Maintenance Tables for additional recommended maintenance criteria.

Figure 6.81: Headwater Depth for Smooth Interior Pipe Culverts with Inlet Control

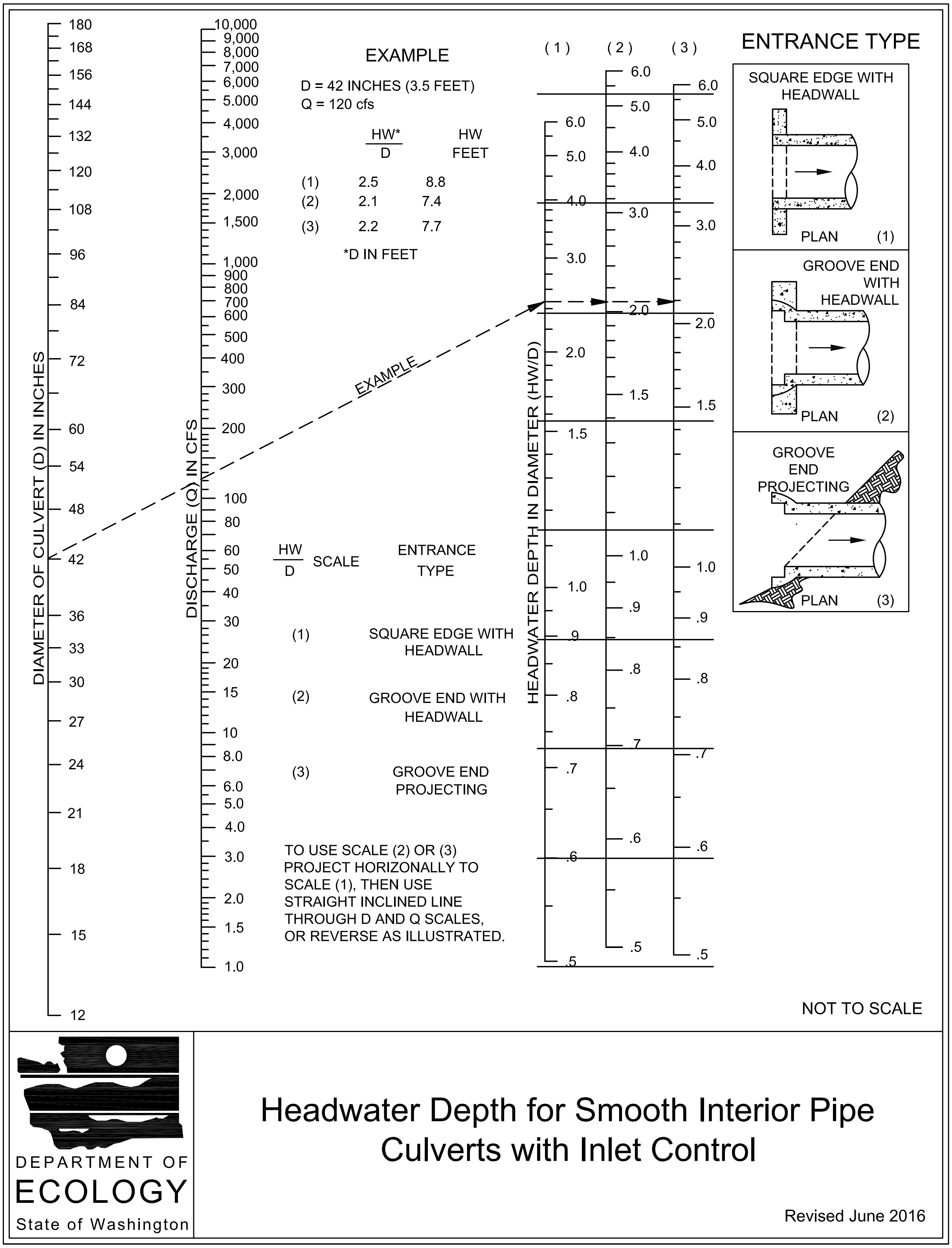
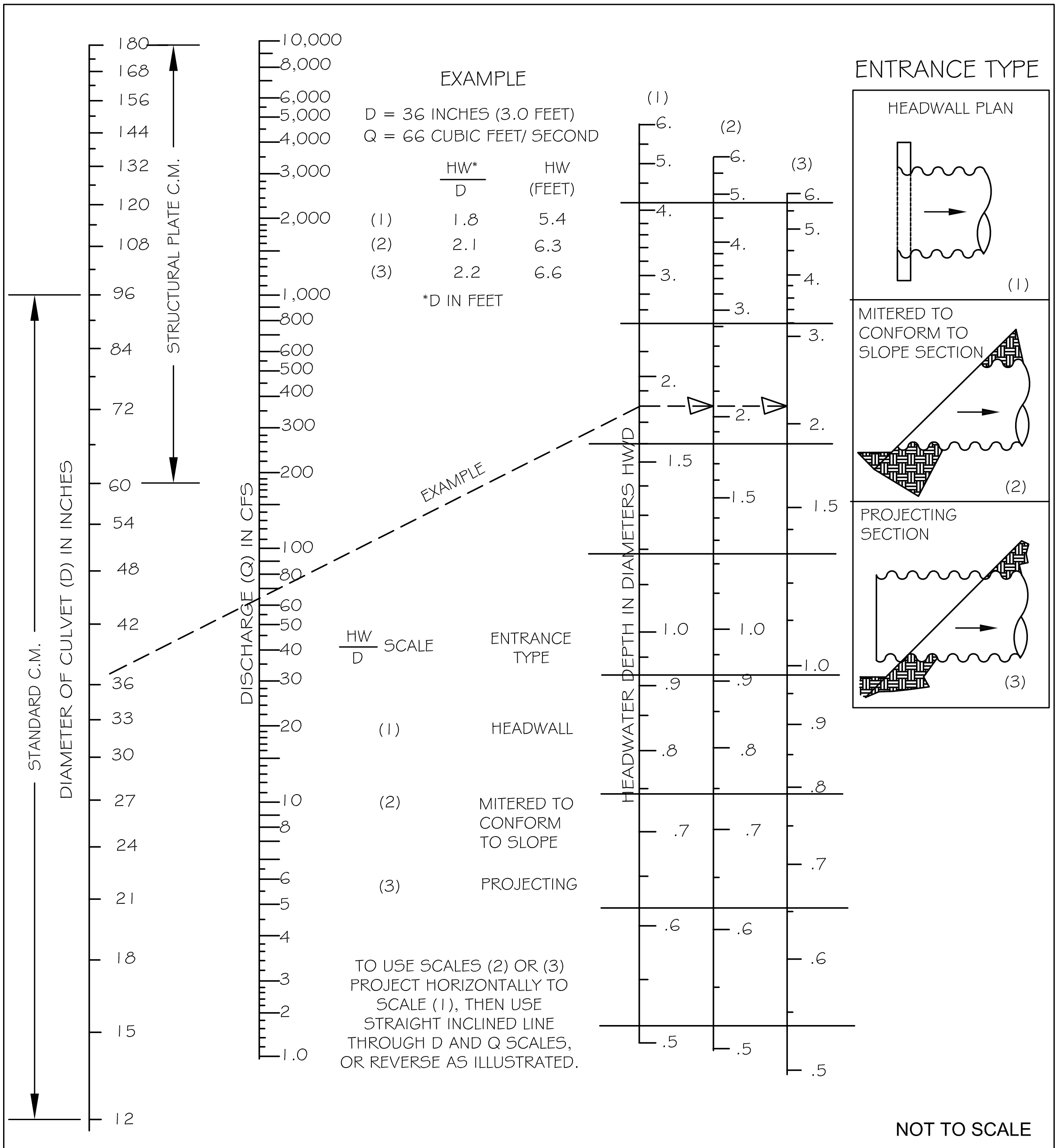


Figure 6.82: Headwater Depth for Corrugated Pipe Culverts with Inlet Control



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Headwater Depth for Corrugated Pipe Culverts with Inlet Control

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Figure 6.83: Critical Depth of Flow for Circular Culverts

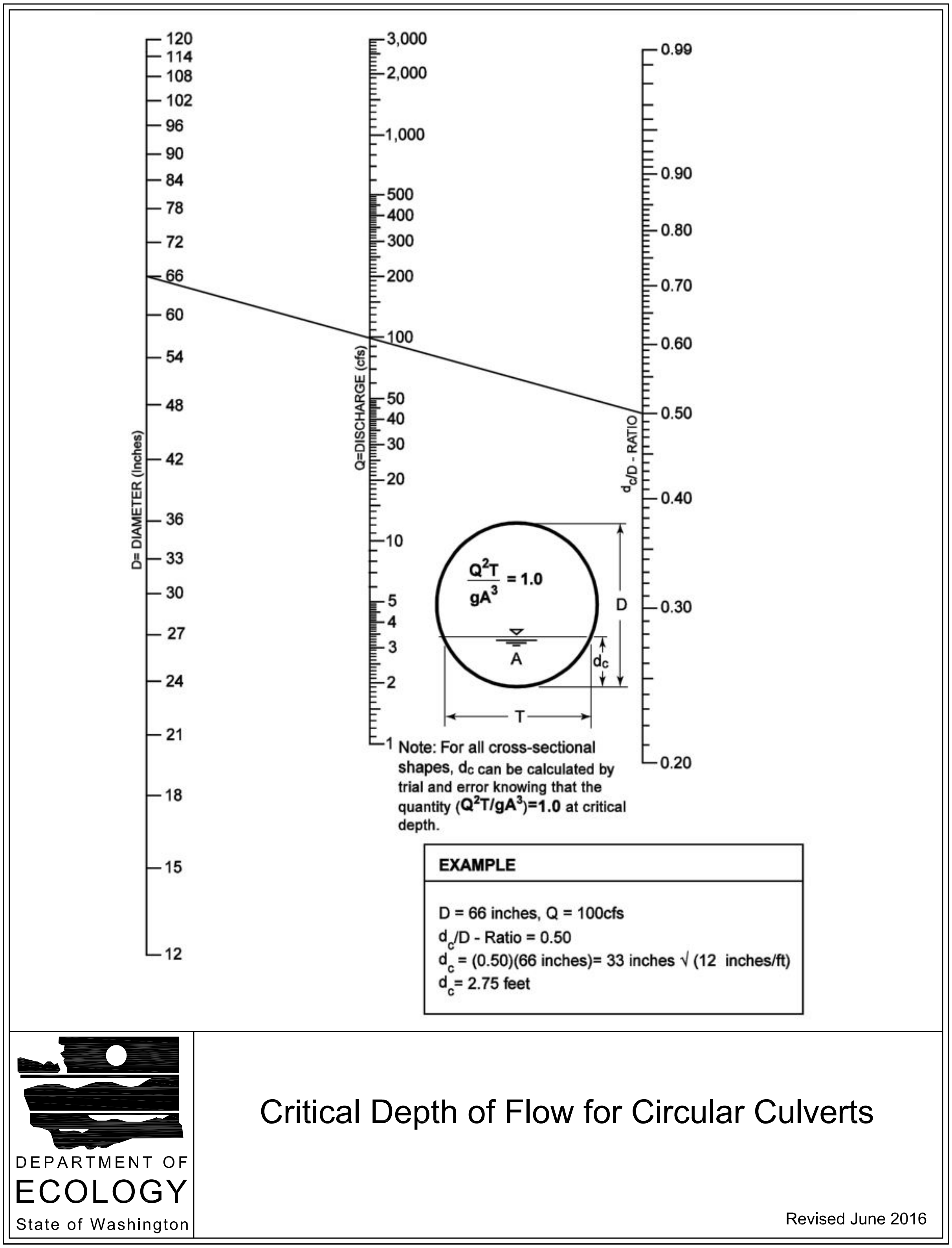
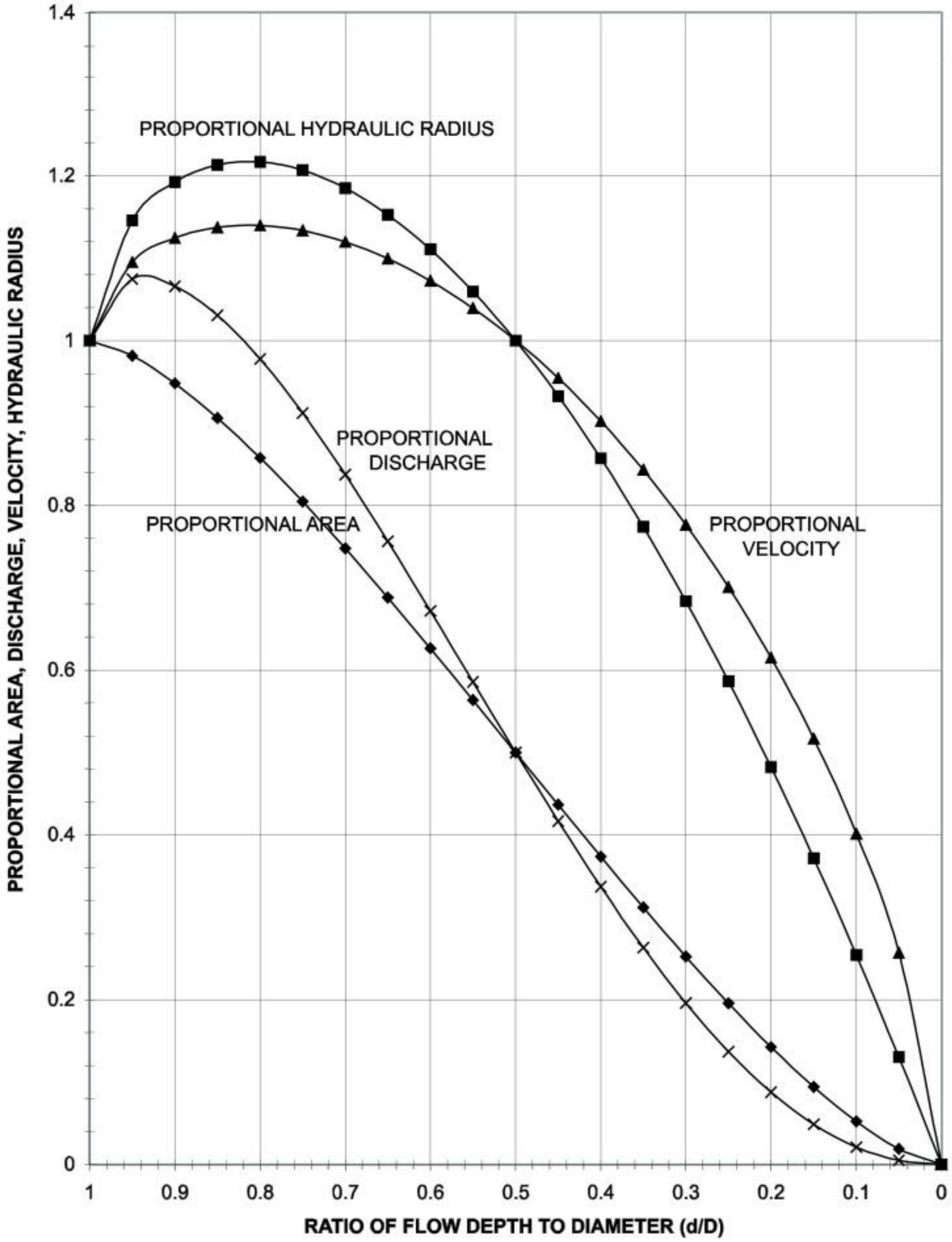


Figure 6.84: Circular Channel Ratios



DEPARTMENT OF ECOLOGY
State of Washington

Circular Channel Ratios

Revised June 2016

BMP T10.40: Combined Detention and Wetpool Facilities

Purpose and Definition

Combined detention and wetpool BMPs have the appearance of a detention BMP, but contain a permanent pool of water as well. The detention BMP is essentially placed on top of the of the wetpool BMP. The wetpool BMP is designed per this chapter, and the detention pond or vault is designed per 6.13 Detention BMPs. The sediment storage area of the detention BMP can be deleted.

The following design procedures, requirements, and recommendations cover differences in the design of the stand-alone wetpool BMP when combined with a detention BMP. The following combined facilities are addressed:

- BMP F6.10: Detention Ponds / BMP T10.10: Wetponds - Basic and Large
- BMP F6.12: Detention Vaults / BMP T5.72: Wetvaults
- BMP F6.10: Detention Ponds / BMP T5.73: Stormwater Treatment Wetlands

There are two sizes of the combined wetpond (basic and large), but only a basic size for the combined wetvault and combined stormwater treatment wetland. The facility sizes (basic and large) are related to the pollutant removal goals. See 6.1.2 Choosing Your Runoff Treatment BMPs for more information about Runoff Treatment performance goals.

Applications and Limitations

Combined detention and wetpool BMPs are very efficient for sites that have both Runoff Treatment and Flow Control requirements. The wetpool BMP may often be placed beneath the detention BMP without increasing the combined facility's surface area. However, the fluctuating water surface of the live storage will create unique challenges for both plant growth and aesthetics.

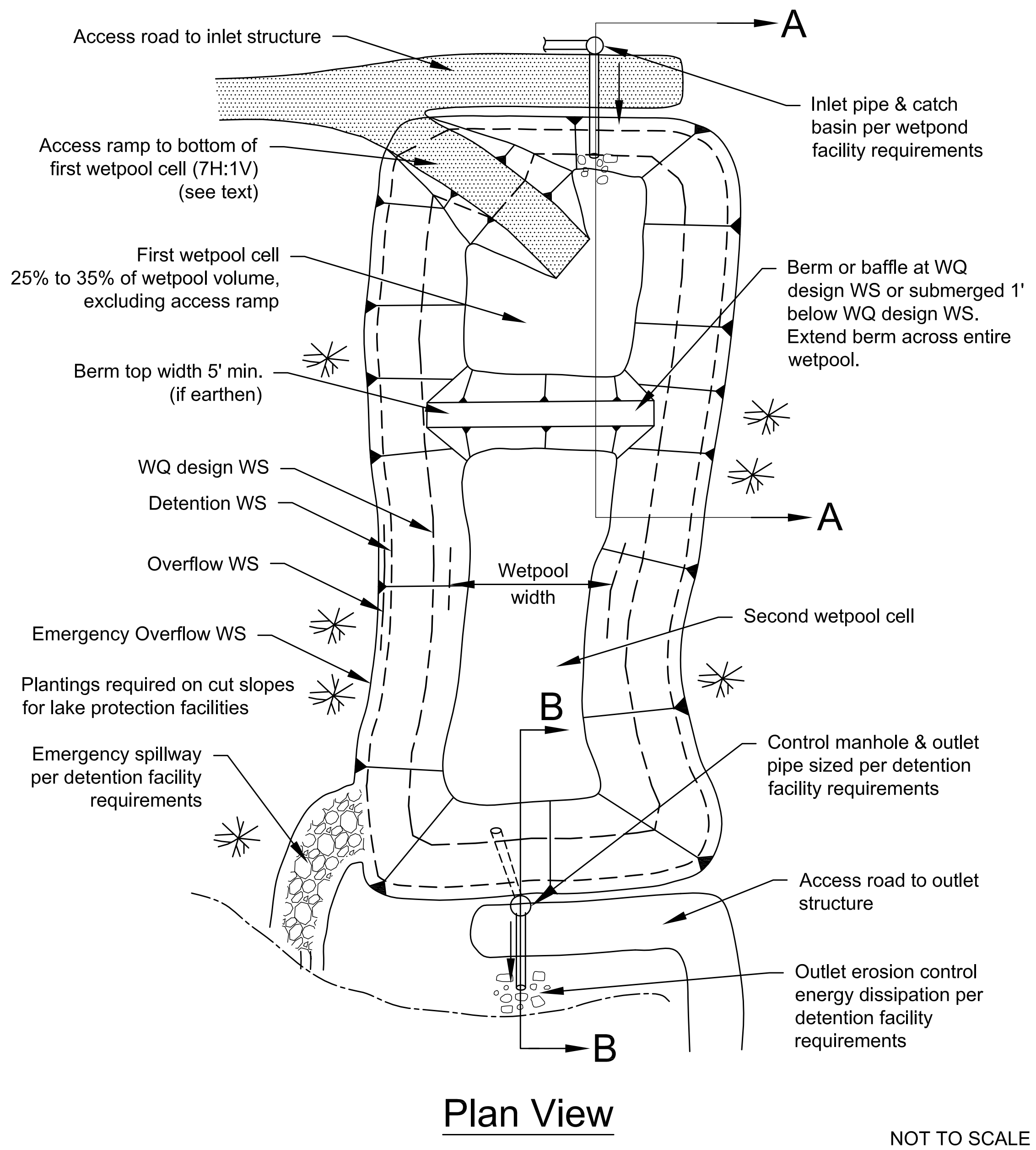
The basis for pollutant removal in combined detention and wetpool facilities is the same as in the stand-alone wetpool BMPs. However, in the combined facility, the detention function creates fluctuating water levels and added turbulence. For simplicity, the positive effect of the extra live storage volume and the negative effect of increased turbulence are assumed to balance, and are thus ignored when sizing the wetpool volume. For a combined detention/stormwater treatment wetland facility, criteria that limit the extent of water level fluctuation are specified to better ensure survival of the wetland plants.

Unlike the wetpool volume, the live storage component of the combined detention and wetpool facility should be provided above the seasonal high water table.

Design Criteria for Combined Detention and Wetpond (Basic and Large)

Typical design details and concepts for a combined detention and wetpond are shown in Figure 6.85: Combined Detention and Wetpond (Plan View) and Figure 6.86: Combined Detention and Wetpond (Section View). The detention portion of the facility shall meet the design criteria and sizing procedures set forth in BMP F6.10: Detention Ponds.

Figure 6.85: Combined Detention and Wetpond (Plan View)

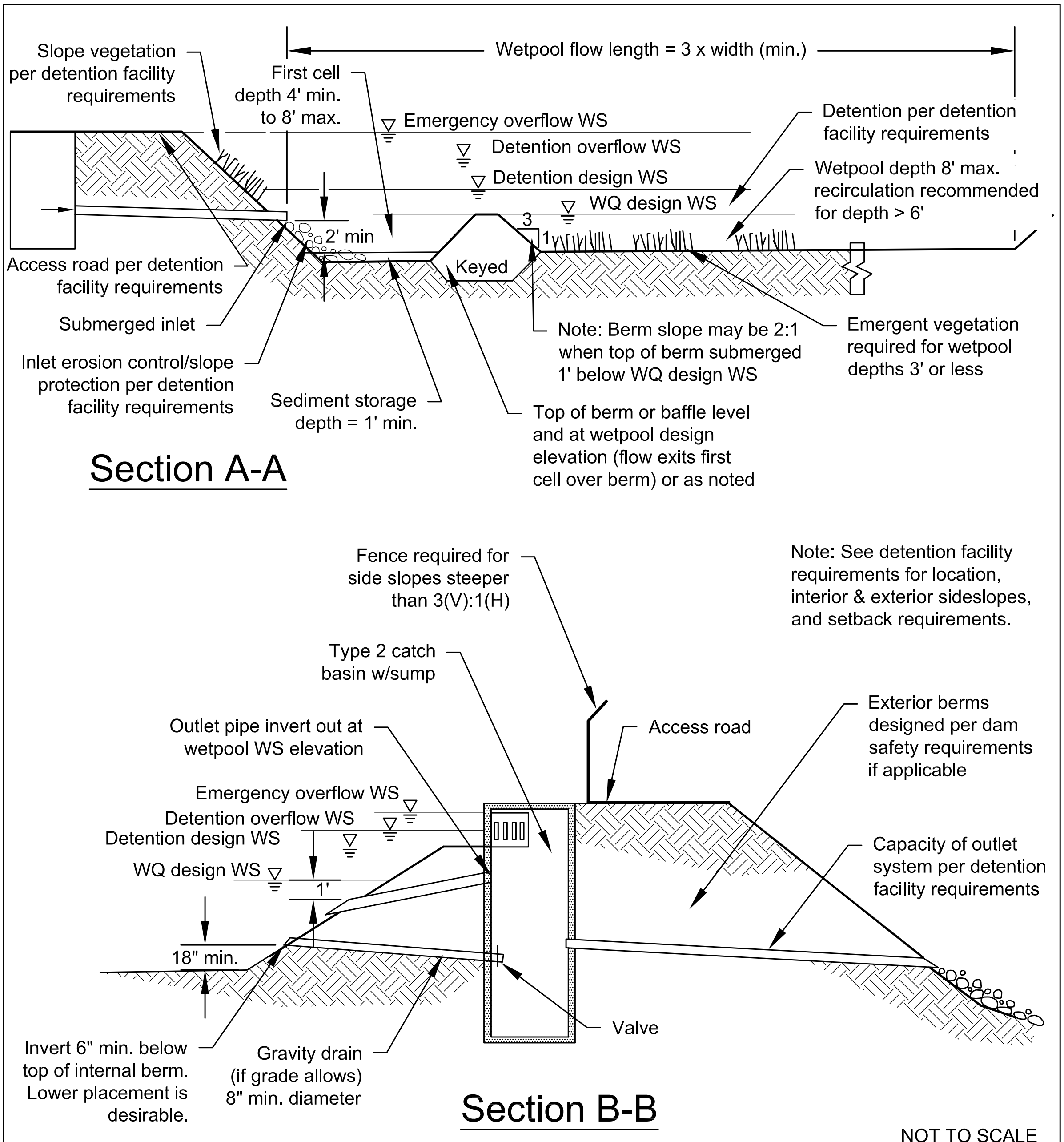


DEPARTMENT OF ECOLOGY
State of Washington

Combined Detention and Wetpond
(Plan View)

Revised June 2016

Figure 6.86: Combined Detention and Wetpond (Section View)

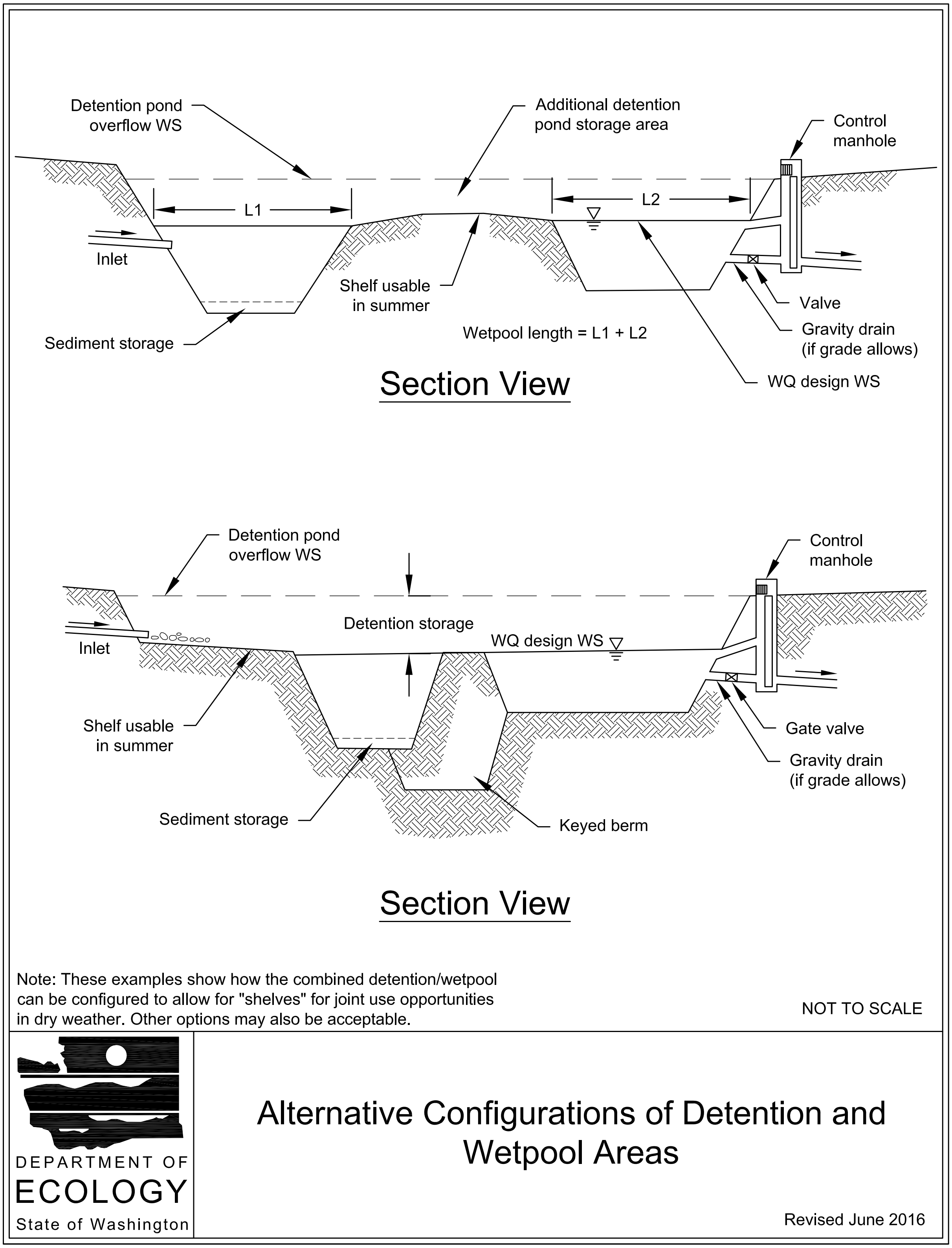


DEPARTMENT OF ECOLOGY State of Washington

Combined Detention and Wetpond (Section View)

Revised June 2016

Figure 6.87: Alternative Configurations of Detention and Wetpool Areas



Sizing Procedure

The sizing procedure for combined detention and wetponds are identical to those outlined for wetponds and for detention facilities. Refer to the guidance in BMP T10.10: Wetponds - Basic and Large to size the wetpool volume (either basic or large) for a combined facility. Refer to the guidance in BMP F6.10: Detention Ponds to size the detention portion of the pond.

Detention and Wetpool Geometry

The wetpool and sediment storage volumes shall not be included in the required detention volume.

The Wetpool Geometry criteria for wetponds (see BMP T10.10: Wetponds - Basic and Large) shall apply with the following modifications/clarifications:

- The wetpool may be made shallower to take up most of the pond bottom, or deeper and positioned to take up only a limited portion of the bottom. Note, however, that having the first wetpool cell at the inlet allows for more efficient sediment management than if the cell is moved away from the inlet. Wetpond criteria governing water depth must still be met. See Figure 6.87: Alternative Configurations of Detention and Wetpool Areas for two possibilities for wetpool cell placement.

  Intent: This flexibility in positioning cells is provided to allow for multiple use options, such as volleyball courts in live storage areas in the drier months.

- The minimum sediment storage depth in the first cell is 1-foot. The 6 inches of sediment storage required for detention ponds does not need to be added to this, but 6 inches of sediment storage must be added to the second cell to comply with the detention sediment storage requirement.

Berms, Baffles, and Slopes

The requirements for berms, baffles, and slopes for combined detention and wetponds are the same as for wetponds (see BMP T10.10: Wetponds - Basic and Large).

Inlet and Outlet

The Inlet and Outlet criteria for wetponds (see BMP T10.10: Wetponds - Basic and Large) shall apply with the following modifications:

- A sump must be provided in the outlet structure of combined detention and wetponds.

- The detention flow restrictor and its outlet pipe shall be designed according to the requirements for detention ponds (see BMP F6.10: Detention Ponds).

Access and Setbacks

The requirements for access and setbacks for combined detention and wetponds are the same as for BMP T10.10: Wetponds - Basic and Large.

Planting Requirements

The planting requirements for combined detention and wetponds are the same as for BMP T10.10: Wetponds - Basic and Large.

Design Criteria for Combined Detention and Wetvault

The sizing procedure for combined detention and wetvaults is identical to those outlined for wetvaults and for detention facilities. Refer to the guidance in BMP T5.72: Wetvaults to size the wetpool volume for a combined facility. Refer to the guidance in BMP F6.12: Detention Vaults to size the detention portion of the vault.

The design criteria for BMP F6.12: Detention Vaults and BMP T5.72: Wetvaults must both be met, except for the following modifications or clarifications:

- The minimum sediment storage depth in the first cell shall average 1-foot. The 6 inches of sediment storage required for detention vaults does not need to be added to this, but 6 inches of sediment storage must be added to the second cell to comply with detention vault sediment storage requirements.
- The oil retaining baffle shall extend a minimum of 2 feet below the WQ design water surface.

  Intent: The greater depth of the baffle in relation to the WQ design water surface compensates for the greater water level fluctuations experienced in the combined vault. The greater depth is deemed prudent to better ensure that separated oils remain within the vault, even during storm events.
- A combined detention and wetvault may not be be combined with BMP T5.100: API (Baffle type) Separator to function as an Oil Control BMP, as is allowed for wetvaults in BMP T5.72: Wetvaults. This is because the added pool fluctuation in the combined detention and wetvault does not allow for the quiescent conditions needed for oil separation.

Design Criteria for Combined Detention and Stormwater Treatment Wetland

The sizing procedure for combined detention and stormwater treatment wetlands is identical to those outlined for stormwater treatment wetlands and for detention facilities. Refer to the guidance in BMP T5.73: Stormwater Treatment Wetlands to size the stormwater treatment wetland. Refer to the guidance in BMP F6.10: Detention Ponds to size the detention portion of the combined detention and wetland facility.

The design criteria for BMP F6.10: Detention Ponds and BMP T5.73: Stormwater Treatment Wetlands must both be met, except for the following modifications or clarifications:

- The Wetland Geometry criteria for BMP T5.73: Stormwater Treatment Wetlands are modified as follows:
  - The minimum sediment storage depth in the first cell is 1-foot. The 6 inches of sediment storage required for detention ponds does not need to be added to this, nor does the 6 inches of sediment storage in the second cell of detention ponds need to

be added.

Intent: Since emergent plants are limited to shallower water depths, the deeper water created before sediments accumulate is considered detrimental to robust emergent growth. Therefore, sediment storage is confined to the first cell which functions as a presettling cell.

- The Inlet and Outlet criteria for BMP T10.10: Wetponds - Basic and Large shall apply with the following modifications:
  - A sump must be provided in the outlet structure of combined detention and stormwater treatment wetlands.
  - The detention flow restrictor and its outlet pipe shall be designed according to the requirements for detention ponds (see BMP F6.10: Detention Ponds).
- A wetland specialist should be consulted to determine if the Planting Requirements per BMP T5.73: Stormwater Treatment Wetlands should be modified for use in the combined facility, based on the expected water level fluctuations due to the live detention storage.
- Water Level Fluctuation Restrictions: The difference between the WQ design water surface and the maximum water surface associated with the 2-year runoff shall not be greater than 3 feet. If this restriction cannot be met, the size of the stormwater treatment wetland must be increased. The additional area may be placed in the first cell, second cell, or both. If placed in the second cell, the additional area need not be planted with wetland vegetation or counted in calculating the average depth.

  Intent: This criterion is designed to dampen the most extreme water level fluctuations expected in combined detention and stormwater treatment wetlands to better ensure that fluctuation-tolerant wetland plants will be able to survive. It is not intended to protect native wetland plant communities and is not to be applied to natural wetlands.

6.10 Pretreatment BMPs

6.10.1 Introduction to Pretreatment BMPs

This chapter presents BMPs that may be used to provide pretreatment prior to other basic, phosphorus, or metals Runoff Treatment BMPs. Pretreatment must be provided in the following applications:

- For sand filters and infiltration BMPs, as directed in 6.7 Filtration BMPs and 6.5 Infiltration BMPs, to protect them from excessive siltation and debris.
- Where the basic, phosphorus, or metals Runoff Treatment BMP or the receiving water may be adversely affected by non-targeted pollutants (e.g. oil), or may by overwhelmed by a heavy load of targeted pollutants (e.g. suspended solids).

BMP T6.10: Presettling Basin is a typical pretreatment BMP used to remove suspended solids. Any Basic Treatment BMP, or detention pond, vault, or tank designed to meet 2.4.6 CE6: Flow Control, can also be used for pretreatment. If an oil/water separator is necessary for oil control, it could also function as the pre-settling basin as long as the influent suspended solids concentrations are not high. However, frequent inspections are necessary to determine when accumulated solids exceed the 6-inch depth at which clean-out is recommended (See Appendix 6-A: BMP Maintenance Tables).

Ecology has approved some emerging technologies for pretreatment through the TAPE process. See 6.11 Manufactured Treatment Devices as BMPs for details.

BMP T6.10: Presettling Basin

Purpose and Definition

A presettling basin provides pretreatment of runoff in order to remove suspended solids, which can impact other Runoff Treatment BMPs.

Application and Limitations

Runoff treated by a presettling basin may not be discharged directly to a receiving water; it must be further treated by a Runoff Treatment BMP to meet the required performance goals for the project (see 6.1.2 Choosing Your Runoff Treatment BMPs).

Design Criteria

1. A presettling basin shall be designed with a wetpool. The treatment volume shall be at least 30 percent of the total volume of runoff from the 6-month, 24-hour storm event. See Chapter 4 - Hydrologic Analysis and Design for guidance on how to calculate this volume.

2. If the runoff in the presettling basin will be in direct contact with the soil, it must be lined per the liner requirement in 6.1.9.1 General Liner Design.

3. The presettling basin shall conform to the following:

    a. The length-to-width ratio shall be at least 3:1. Berms or baffles may be used to lengthen the flowpath through the presettling basin.

    b. The minimum depth shall be 4 feet; the maximum depth shall be 6 feet.

4. Inlets and outlets shall be designed to minimize velocity and reduce turbulence. Inlet and outlet structures should be located at extreme ends of the presettling basin in order to maximize detention time and particle-settling opportunities.

Site Constraints and Setbacks

Site constraints are any manmade restrictions such as property lines, easements, structures, etc. that impose constraints on development. Constraints may also be imposed from natural features such as requirements of the local government's Sensitive Areas Ordinance and Rules. These should also be reviewed for specific application to the proposed development.

- Presettling basins shall be a minimum of 20 feet from any structure, property line, and any vegetative buffer required by the local government.

- Presettling basins shall be 100 feet from any septic tank/drainfield.

- Presettling basins shall be a minimum of 50 feet from any steep slope (greater than 15 percent).
- Embankments that impound water (including presettling basins) must comply with the Washington State Dam Safety Regulations (Chapter 173-175 WAC). If the impoundment has a storage capacity (including both water and sediment storage volumes) greater than 10 acre-feet (435,600 cubic feet or 3.26 million gallons) above natural ground level, then dam safety design and review are required by Ecology. See Dam Safety for Detention BMPs in BMP F6.10: Detention Ponds for more detail.

6.11 Manufactured Treatment Devices as BMPs

6.11.1 Introduction to Manufactured Treatment Devices as BMPs

Traditional best management practices (BMPs) such as wetponds and filtration swales may not be appropriate in many situations due to size and space constraints or their inability to remove target pollutants. Because of this, the stormwater treatment industry emerged to develop new manufactured stormwater treatment devices.

Manufactured treatment devices are emerging technologies that are new to the stormwater treatment marketplace. These devices include both permanent and construction site treatment technologies. Many of these devices have not undergone complete performance testing, so their performance claims cannot be verified.

Ecology has established a program, the Technology Assessment Protocol – Ecology (TAPE), to evaluate the capabilities of manufactured treatment devices. Manufactured treatment devices that have been evaluated by TAPE are approved at some level of use designation under specified conditions. Their use is restricted in accordance with their evaluation as explained in 6.11.3 Approval Process for Manufactured Treatment Devices. The recommendations for use of individual manufactured treatment devices may change as we collect more data on their performance. Updated recommendations on their use are posted to Ecology's TAPE website at the following address:

https://ecology.wa.gov/Regulations-Permits/Guidance-technical-assistance/Stormwater-permittee-guidance-resources/Emerging-stormwater-treatment-technologies

Manufactured treatment devices can also be considered for retrofit situations, where TAPE approval may not be required.

6.11.2 Use Level Designations of Manufactured Treatment Devices

Ecology's Technology Assessment Protocol - Ecology (TAPE) program developed "use level designations" to assess levels of development for manufactured treatment devices. The use level designations are based upon the quantity, quality, and type of performance data. There are three use level designations:

- pilot use level designation (PULD),
- conditional use level designation (CULD), and
- general use level designation (GULD).

Ecology's TAPE website includes a menu for manufactured treatment devices that have a use level designation for the following levels of Runoff Treatment:

- pretreatment,
- oil control,
- phosphorous treatment,
- metals treatment, and
- basic treatment.

For more information, refer to Ecology's TAPE website at the following address:

https://ecology.wa.gov/Regulations-Permits/Guidance-technical-assistance/Stormwater-permittee-guidance-resources/Emerging-stormwater-treatment-technologies

Pilot Use Level Designation (PULD)

For manufactured treatment devices that have limited performance data, the pilot use level designation allows limited use to conduct field-testing. Ecology may give pilot use level designations based solely on laboratory performance data. Pilot use level designations apply for a specified time period only. During this time period, the proponent must complete all field testing and submit a Technology Evaluation Report (TER) to Ecology's TAPE program.

PULD manufactured treatment devices may be installed at sites that are pre-approved by Ecology and the local government with jurisdiction, provided that the vendor and/or developer agree to conduct field testing based on TAPE requirements. Ecology limits the number of installations to five during the pilot use level period and the manufacturer must monitor all five sites. Local governments should not approve manufactured treatment devices that have a PULD for a new or redevelopment project unless Ecology has agreed to the use of the manufactured treatment device at that project site.

Government entities covered by a municipal stormwater NPDES permit must notify Ecology when a PULD device is proposed for installation. The form is available in Ecology's *Technical Guidance Manual for Evaluating Emerging Stormwater Treatment Technologies* (Ecology, 2011b).

Conditional Use Level Designation (CULD)

Ecology established the CULD for manufactured treatment devices that have considerable performance data not collected per the TAPE protocol. Ecology may give a conditional use level designation if a manufacturer collected field data through a protocol reasonably consistent with (but not fully meeting) the TAPE protocol. The field data must meet the statistical goals set out in the *Technical Guidance Manual for Evaluating Emerging Stormwater Treatment Technologies* (Ecology, 2011b). Manufacturers may use laboratory data to supplement field data. Ecology will allow the use of manufactured treatment devices that receive a CULD for a specified time, during which the manufacturer must complete the field testing necessary to obtain a general use level designation (GULD) and must submit a TER to Ecology's TAPE program. Ecology limits the number of installations to ten during the CULD period.

General Use Level Designation (GULD)

The general use level designation (GULD) confers a general acceptance for the specified applications (land uses). Manufactured treatment devices with a GULD may be used for new development, re-development, or retrofit situations anywhere in Washington, subject to conditions that Ecology places within the use designation document. Manufactured treatment devices with a GULD can have an unlimited number of installations.

6.11.3 Approval Process for Manufactured Treatment Devices

Ecology's Role in Evaluating Manufactured Treatment Devices

To aid local governments in selecting manufactured treatment devices, Ecology developed the Technology Assessment Protocol – Ecology (TAPE) and Chemical Technology Assessment Protocol - Ecology (CTAPE) protocols. These protocols provide manufacturers with guidance on stormwater monitoring so that they may verify their performance claims.

As a part of this process, Ecology:

- Posts information on manufactured treatment devices to the TAPE web page, at the following address:

  https://ecology.wa.gov/Regulations-Permits/Guidance-technical-assistance/Stormwater-permittee-guidance-resources/Emerging-stormwater-treatment-technologies

- Created a Board of External Reviewers (BER) to provide expert review services in the review of Quality Assurance Project Plans (QAPPs) and Technical Evaluation Reports (TERs).
- Created a Stakeholder Advisory Group (SAG) of local stakeholders to advise Ecology on the program protocols and develop new guidance.
- Participates in all activities which include reviewing manufacturer performance data and providing recommendations on use level designations (see 6.11.2 Use Level Designations of Manufactured Treatment Devices).
- Grants use level designations based on performance and other pertinent data submitted by the manufacturers and vendors.
- Provides oversight and analysis of all submittals to ensure consistency with this manual.

For full details on the TAPE process for evaluating a manufactured treatment device, refer to *Technical Guidance Manual for Evaluating Emerging Stormwater Treatment Technologies* (Ecology, 2011b).

Local Jurisdiction's Role in Evaluating Manufactured Treatment Devices

Local jurisdictions should consider the following as they make decisions concerning the use of manufactured treatment devices in their jurisdiction:

- Remember the goal:
  - The goal of any stormwater management program or BMP is to treat and release stormwater in a manner that does not harm beneficial uses.
- Exercise reasonable caution:
  - Before allowing the use of a manufactured treatment device, the local jurisdiction should review evaluation information based on the TAPE or CTAPE protocols.
  - A manufactured treatment device cannot be used for new or redevelopment unless it has a use level designation. Having a use level designation means that Ecology and the Technical Review Committee (TRC) or Chemical Technical Review Committee (CTRC) reviewed the system performance data, and believe the device has the ability to provide the level of treatment claimed by the manufacturer.
  - To achieve the goals of the Clean Water Act and the Endangered Species Act, local governments may find it necessary to retrofit stormwater pollutant control systems for many existing stormwater discharges. In retrofit situations, the use of any BMP that makes substantial progress toward these goals is a step forward and is encouraged by Ecology. To the extent practical, the performance of BMPs used in retrofit situations should be evaluated using the TAPE or CTAPE protocols.

TAPE Performance Goals and Water Quality Parameters

In addition to other requirements, Ecology's TAPE program uses the Runoff Treatment Performance Goals detailed in 6.1.2 Choosing Your Runoff Treatment BMPs to evaluate manufactured treatment devices.

Proponents attempting to obtain a GULD for a manufactured treatment device must demonstrate the achievement of applicable performance goals by monitoring the water quality parameters listed in Table 6.39: TAPE Treatment Goals and Water Quality Parameters (continued).

An additional performance goal that is used for TAPE and CTAPE evaluations is the Pretreatment Performance Goal. The Pretreatment Performance Goal is detailed below, and is not included in 6.1.2 Choosing Your Runoff Treatment BMPs.

Pretreatment Performance Goal

- For influent concentrations of 50-100 mg/L of Total Suspended Solids (TSS): effluent must have less than 50 mg/L of TSS.
- For influent concentrations of 100-200 mg/L of TSS: achieve at least 50% removal of total suspended solids.

Table 6.39: TAPE Treatment Goals and Water Quality Parameters

Performance Goal	Influent Range	Criteria	Required Water Quality Parameters
Basic Treatment	20-100 m/L TSS	Effluent goal ≤ 20 mg/L TSS[b]	TSS
	100-200 mg/L TSS	≥ 80 % TSS removal[c]	
	> 200 mg/L TSS	> 80 % TSS removal[c]	
Metals Treatment[d]	Dissolved Copper 0.005-0.02 mg/L[h]	Must meet basic treatment goal and better than basic treatment currently defined as > 30% dissolved copper removal [c,e]	TSS, hardness, total and dissolved Copper and Zinc
	Dissolved Zinc 0.02- 0.3 mg/L[h]	Must meet basic treatment goal and better than basic treatment currently defined as > 60% dissolved zinc removal [c,e]	
Phosphorus Treatment	Total phosphorus (TP) 0.1 to 0.5 mg/L[h]	Must meet basic treatment goal and exhibit ≥ 50% TP removal[b]	TSS, TP, orthophosphate
Oil Contol	Total petroleum hydrocarbons (TPH) >10 mg/L[f]	1) No ongoing or recurring visible sheen in effluent 2) Daily average effluent TPH concentration < 10 mg/L [b,f] 3) Maximum effluent TPH concentration of 15 mg/L [b,f] for a discrete (grab) sample	NWTPH-Dx, visible sheen
Pretreatment[g]	50-100 mg/L TSS	Effluent goal ≤ 50 mg/L TSS[b]	TSS
	100-200 mg/L TSS	> 50% TSS removal [c]	

mg/L - milligrams per liter

Cu - copper

NWTPH-Dx - Northwest Total Petroleum Hydrocarbons-Motor Oil and Diesel fractions

Table 6.39: TAPE Treatment Goals and Water Quality Parameters (continued)

Performance Goal	Influent Range	Criteria	Required Water Quality Parameters
TP - total phosphorus TPH - total petroleum hydrocarbons TSS - total suspended solids Zn - zinc a - Samples with influent concentrations that are greater than the range may be included by artificially setting the value at the upper end of the concentration range prior to completing the pollutant removal efficiency calculations. If the applicant opts to include samples with concentrations that are greater than the influent concentration range, they must include all valid samples that are greater than the range (i.e. applicants cannot “cherry pick” data). b - The upper one-sided 95 percent confidence interval around the mean effluent concentration for the treatment system being evaluated must be lower than this performance goal to meet the performance goal with the required 95 percent confidence. c - The lower one-sided 95 percent confidence interval around the mean removal efficiency for the treatment system being evaluated must be higher than this performance goal to meet the performance goal with the required 95 percent confidence. d - Must meet the removal goal for both dissolved copper and dissolved zinc in order to achieve a Dissolved Metals Treatment GULD. Meeting the removal goal for only one of these dissolved metals is not sufficient. e - This percent removal was determined based on an analysis of the basic treatment BMP dissolved metals removal data from the International Stormwater BMP database to define performance goals for dissolved metals treatment (Washington Stormwater Center and Herrera 2011). Ecology staff reviewed and screened data from the International Stormwater BMP database based on influent concentrations, geographic location, data quality, BMP design, and monitoring problems to develop a subset of data that was representative and suitable for determining BMP performance. f - This performance goal should be evaluated based on the motor oil fraction of TPH-Dx only. g - Pretreatment technologies generally apply to (1) project sites using infiltration treatment and (2) treatment systems where pretreatment is needed to ensure and extend performance of the downstream basic or dissolved metals treatment facilities. h - Dissolved copper, dissolved zinc, and total phosphorus influent concentrations that are less than the specified range may be included. If the proponent opts to include samples with concentrations that are less than the influent concentration range, they must provide detailed information to support a new minimum threshold for their study. They must then use that new threshold across their entire dataset.			

6.11.4 Which Manufactured Treatment Devices Have Ecology Approval?

Ecology's *Emerging Stormwater Treatment Technologies (TAPE)* web page lists manufactured treatment devices that have obtained a use level designation through the Technology Assessment Protocol – Ecology (TAPE) process. Ecology's TAPE web page also provides additional guidance regarding the TAPE process and application forms.

In addition to Ecology certification, local jurisdiction approval is required for installation of manufactured treatment devices with Pilot Use Level Designation (PULD), Conditional Use Level Designation (CULD), or General Use Level Designation (GULD). Local jurisdictions may choose not to accept devices approved through TAPE, or may require additional testing prior to consideration for local approval.

See Ecology's TAPE web page at the following address for details:

https://ecology.wa.gov/Regulations-Permits/Guidance-technical-assistance/Stormwater-permittee-guidance-resources/Emerging-stormwater-treatment-technologies

6.12 Miscellaneous LID BMPs

6.12.1 Introduction to Miscellaneous LID BMPs

BMPs in this section have been grouped because they have the following in common:

- They employ Low Impact Development (LID) Principles
- They cannot be used to meet 2.4.5 CE5: Runoff Treatment
- They typically cannot, by themselves, be used to meet the Flow Control Performance Standard within 2.4.6 CE6: Flow Control
    - Some of the BMPs in this chapter do allow for some amount of Flow Control credit. See the guidance for each individual BMP for details.
- The design methods for each BMP in this section are unique. They do not have strong enough design similarities to other BMPs in this chapter to place them in the other BMP categories identified in thischapter.

Cold Climate Considerations

Grasses or other vegetation used in vegetated roofs may be dormant or ineffective at providing treatment mechanisms (e.g. filtration, pollutant uptake, etc.) during the winter, or may be covered with snow for a substantial amount of time. For vegetated BMPs, plants should be selected to be tolerant of cold and freezing climates. See 6.1.8 Cold Weather Considerations for additional cold weather considerations.

Arid and Semiarid Climate Considerations

In arid/semiarid portions of eastern Washington, grasses and plants used in vegetated roofs should be selected to be drought tolerant and not require watering after establishment (2 to 3 years). In more arid environments, watering may be needed during prolonged dry periods after plants are established.

BMP T5.14: Rain Gardens

Purpose and Definition

Rain gardens are an LID BMP that can provide effective removal of many stormwater pollutants, and provide reductions in stormwater runoff quantity and surface runoff flow rates. Although rain gardens provide these benefits, the amount of benefit is unquantifiable. Therefore, rain gardens cannot be used to meet any of the following:

- 2.4.5 CE5: Runoff Treatment,
- 2.4.6 CE6: Flow Control, or
- 2.4.8 CE8: Wetlands Protection

Rain gardens are non-engineered, shallow, landscaped depressions with amended soils and adapted plants. The depression ponds and temporarily stores stormwater runoff from adjacent areas. A portion of the influent stormwater passes through the amended soil profile and into the native soil beneath. Stormwater that exceeds the storage capacity is designed to overflow to an adjacent drainage system.

Applications and Limitations

Infeasibility criteria for rain gardens are the same as for BMP F6.23: Bioretention.

Although not required, Ecology recommends installation by a landscaping company with experience in rain garden construction.

Rain gardens constructed with imported compost materials should not be used within one-quarter mile of phosphorus-sensitive waterbodies. Preliminary monitoring indicates that new rain gardens can add phosphorus to stormwater. Therefore, they should also not be used with an underdrain when the underdrain water would be routed to a phosphorus-sensitive receiving water.

Design Guidelines

Refer to the *Rain Garden Handbook for Western Washington: A Guide for Design, Installation, and Maintenance* (Hinman et al., 2013) for rain garden specifications and construction guidance.

For amending the native soil within the rain garden, Ecology recommends use of compost that meets the compost specification for BMP F6.23: Bioretention. Compost that includes biosolids or manures shall not be used.

Recommended sizing: Size the rain garden to have a minimum horizontal projected surface area below the overflow which is at least 5% of the area draining to it.

Underdrains

Ecology does not recommend the use of underdrains for rain gardens. Design and construction of an underdrain system likely requires professional expertise.

Where a municipality intends to require or allow underdrained rain gardens in areas with initial infiltration rates between 0.3 and 0.6 inches per hour, the invert of the underdrain shall be 6 inches above the bottom of the aggregate bedding for the underdrain. A larger distance between the underdrain and the bottom of the aggregate bedding is desirable.

Ecology recommends that the municipality establish standard design specifications and drawings.

Infiltration Testing Guidance Specific to Rain Gardens

The site procedures and design guidelines described here are meant to be implemented after a preliminary project layout has been developed, per Chapter 3 - Preparation of Stormwater Site Plans. The designer must perform sufficient infiltration tests to confirm the feasibility of proposed rain garden sites. Testing should occur during the wet season.

The certified soils professional or engineer can exercise discretion concerning the need for and extent of infiltration rate (saturated hydraulic conductivity, K_{sat}) testing. The professional can consider a reduction in the extent of infiltration (K_{sat}) testing if, in their judgment, information exists confirming that the site is unconsolidated outwash material with high infiltration rates, and there is at least 1 foot separation from the bottom of a rain garden to groundwater.

Perform a Small-Scale Pilot Infiltration Test (see 6.5.4 Determining the Design Infiltration Rate of the Native Soils) – or an alternative small scale test specified by the local government – to determine if the minimum measured infiltration rate of 0.3 in/hr is exceeded at the proposed rain garden location. Also determine whether the site has at least one foot separation from the bottom of the rain garden to the seasonal high groundwater or other hydraulic restriction layer.

Legal Documentation to Track Rain Garden Obligations

Where drainage plan submittals include assumptions with regard to size and location of rain gardens, approval of the plat, short-plat, or building permit should identify the rain garden obligation of each lot; and the appropriate lots should have deed requirements for construction and maintenance of the rain gardens.

Runoff Model Representation

Due to the variability in rain garden soils, rain gardens do not provide Flow Control or Runoff Treatment that is quantifiable through modeling.

Maintenance

Refer to the *Rain Garden Handbook for Western Washington: A Guide for Design, Installation, and Maintenance* (Hinman et al., 2013) for tips on mulching, watering, weeding, pruning, and soil management.

Guidance Document: Western Washington Low Impact Development (LID) Operation and Maintenance (O&M) (Herrera and WSC, 2013) may be consulted for more detailed maintenance guidance.

BMP T5.18: Reverse Slope Sidewalks

Purpose and Definition

Reverse slope sidewalks are sloped to drain away from the road and onto adjacent vegetated areas.

Design Criteria

The design must include more than 10 feet of vegetated surface downslope of the reverse slope sidewalk that is not directly connected into the drainage system.

The vegetated surface receiving flow from the reverse slope sidewalk must be native soil or meet the guidelines in BMP F6.61: Post-Construction Soil Quality and Depth.

Runoff Model Representation

When calculating the runoff from post-developed conditions, the sidewalk area may be considered as lawn/landscaped area over the underlying soil type.

BMP F6.13: Rainwater Harvesting

Purpose and Definition

Rainwater harvesting is the capture and storage of rainwater for beneficial use. Roof runoff may be routed to cisterns for storage and nonpotable uses such as irrigation, toilet flushing, and cold water laundry. Rainwater harvesting can help reduce peak stormwater flows, durations, and volumes. The amount of reduction achieved with cistern storage is a function of contributing area, storage volume, season, and rainwater use rate.

Rainwater harvesting has traditionally been used in environments where rainfall or other conditions limit water supply.

The well-documented benefits of rainwater harvesting are that it:

- Reduces domestic water demand (by using the harvested water in place of potable water in appropriate applications);
- Serves as a CSO reduction strategy;
- Can be used as emergency water for fire suppression;
- Provides a sustainable source for irrigation and nonpotable uses;
- Reduces peak runoff and allows sediment to settle; and
- Provides a nonpotable water source when groundwater is unacceptable or unavailable, or it can augment limited groundwater supplies.

Most cisterns are constructed of plastic, steel, or concrete (see Figure 6.88: Polyethylene Cistern and Figure 6.89: Cistern Used to Meet Irrigation Requirements). Plastic is commonly used where the cistern material can be protected from the impacts that excessive sunlight can have on warping and algae growth. Plastic cisterns are lightweight, noncorrosive, and relatively inexpensive. Concrete or steel cisterns are sometimes used for aesthetic values and are often custom-designed to complement the scale and character of the structure. In other instances, a simple plastic or steel cistern may be clad with another material for greater aesthetic appeal.

Figure 6.88: Polyethylene Cistern

Source: Innovative Water Systems, LLC

DEPARTMENT OF ECOLOGY State of Washington

Polyethylene Cistern

Revised June 2013

Figure 6.89: Cistern Used to Meet Irrigation Requirements

Source: Innovative Water Systems, LLC

DEPARTMENT OF ECOLOGY State of Washington

Cistern Used to Meet Irrigation Requirements

Revised June 2013

Applications and Limitations

In order to use the guidance below for runoff model representation, the design must show 100% reuse of the annual average runoff volume.

System designs involving interior uses (such as toilet flushing) must have a monthly water balance that demonstrates adequate capacity for each month and reuse of all stored water annually.

Restrict the use of this BMP to 4 homes/acre housing and lower densities when the captured water is solely for outdoor use.

This manual does not provide guidance for using harvested rainwater as a potable source. Harvested rainwater may be used to replace potable water in certain applications (e.g. water used to flush toilets).

Assessing the feasibility of using a rainwater harvesting system should include both technical and economic considerations. Rainwater harvesting systems are technically feasible for most sites where applicable local setback requirements for structures can be met. In areas with little rainfall, the systems will supplement, rather than replace, other domestic sources of water. Rainwater collection systems may make a project situated in a challenging drainage basin more easily developable because stormwater from roof surfaces can be collected and used for a variety of nonpotable uses.

From a technical design perspective, rainwater harvesting systems should not be used to collect stormwater from roof materials containing contaminants such as zinc, copper, or lead. Depending on the BMPs connected, a rainwater harvesting system could spread these contaminants throughout a site through the irrigation system or bring the contaminants into contact with humans through nonpotable water reuse.

In very rare instances, there may be entitlement challenges associated with constructing a rainwater harvesting system. A rainwater harvesting system would require a water right only if > 5,000 gallons are to be collected daily.

General Design Criteria

The State Building Code Council adopted the 2021 edition of the Uniform Plumbing Code, which governs some aspects of rainwater harvesting (for indoor use only). This code (WAC 51-56) was last updated 11/15/23.

The following general design issues should be considered when designing rainwater harvesting systems:

- Rainwater harvesting systems should be sized according to rainfall data (daily or more frequent [sub-daily] data preferred where available) and proposed indoor and outdoor water needs. The sizing of the collection system should only include non-pollution-generating tributary impervious surfaces.
- Cisterns should be covered to prevent mosquito breeding. The cover will protect the water from sunlight and minimize algae growth.

- Screens on the gutter and intake of the outlet pipe should be included to minimize clogging by leaves and other debris.
- Underground cisterns should have tie-downs per manufacturer's specifications to avoid the floating of the cistern resulting from elevated groundwater levels.
- Flow control structures, overflows, and clean-outs should be readily accessible and alerts for system problems should be easily visible and audible (WSU and PSP, 2012).
- Rainwater harvesting systems should only collect runoff from roof surfaces and not from vehicle or pedestrian areas, or bodies of standing water.
- Depending on its size, an aboveground cistern will be treated as a structure under locally adopted building and zoning codes. As a structure, a cistern would need to be set back from property lines and meet local height, bulk, and dimensional standards. Access to the structure may need to meet confined space requirements (check local requirements). The components of a rainwater harvesting system will depend on the rainfall pattern, physical setting, water needs, and stormwater management goals and are described below.

Catchment or Roof Area

The roof material should not contribute contaminants (such as zinc, copper or lead) to the collection system. The National Sanitation Foundation (NSF) certifies products for rainwater collection systems. Products meeting NSF protocol P151 are certified for drinking water system use and do not contribute contaminants at levels greater than those specified in the U.S. Environmental Protection Agency (U.S. EPA) Drinking Water Regulations (40 CFR Parts 141–143) and health advisories (Stuart, 2001). Guidelines for roofing materials include the following:

- Enameled standing seam metal, ceramic tile, or slate are durable and smooth, and are presumed to not contribute significant contaminants.
- Composition or three-tab roofing should only be used for irrigation catchment systems. Composition roofing is not recommended for irrigation supply if zinc has been applied for moss treatment.
- Lead solder should not be used for roof or gutter construction and existing roofs should be examined for lead content.
- Galvanized surfaces may deliver elevated particulate zinc during initial flushing and elevated dissolved zinc throughout a storm event (Stuart, 2001) and should not be considered for rainwater collection systems.
- Copper should never be considered for roofing or gutters. When used for roofing material, copper can act as an herbicide if rooftop runoff is used for irrigation.
- Treated and untreated wood shingles and shakes should not be considered for rainwater collection systems (WSU and PSP, 2012).

Gutters and Downspouts

Gutters are commonly made from aluminum, galvanized steel, and plastic. Rainwater is slightly acidic; accordingly, collected water entering the cistern should be evaluated for metals or other contaminants associated with the roof and gutters. See the Harvested Rainwater Treatment section (below) for appropriate filters and disinfection techniques. Do not use lead solder for gutter seams. Copper or zinc gutters and downspouts shall not be used; however, if existing gutters and downspouts are already in place, the interior shall be coated with NSF-quality epoxy paint.

Screens should be installed in the top of each downspout. Screens installed on gutters prevent coarse (e.g. leaves and needles), but not fine debris (pollen and dust) from entering the gutter. Gutters will still require cleaning and access should be considered when selecting gutter screens.

First Flush Diverters

First flush diverters collect and route the first flush away from the collection system. The initial flow from a storm can contain higher levels of contaminants from particulates settling on the roof (e.g. bird droppings). A simple diverter consists of a downspout (located upstream of the downspout to the cistern) and a pipe that is fitted and sealed so that water does not back flow into the gutter. Once the pipe is filled, water flows to the cistern downspout. The pipe often extends to the ground and has a clean out and valve (WSU and PSP, 2012).

The *Texas Manual on Rainwater Harvesting* recommends that the first 10 gallons of water be diverted for every 1,000 square feet (sf) of roof (applicable for areas with higher storm intensities) (Texas Water Development Board, 2005). However, local factors such as rainfall frequency, intensity, and pollutants will influence the amount of water diverted. In areas with low precipitation and lower storm intensities, roof washing may divert flows necessary to support system demands.

Roof Strainers and Pre-filters

Roof strainers are placed just before the storage cistern to filter coarse and fine debris. Strainers consist of a tank (typically 30 to 50 gallons), a coarse filter/strainer for leaves and other organic material, and a finer filter (typically ≤ 30 microns). Roof strainers should be cleaned regularly to prevent clogging as well as prevent the development of pathogens (Texas Water Development Board, 2005). It is also possible to use a pre-filter that works in a similar manner instead of the roof strainer.

All rainwater harvesting systems using impervious roof surfaces shall have at least one roof strainer per downspout or prefiltration system. A roof strainer or prefiltration system is not required for pervious roof surfaces such as vegetated roofs. Roof strainers and prefiltration systems shall meet the following design requirements:

- All collected rainwater shall pass through a roof strainer or prefiltration system before the water enters the cistern(s).
- If more than one cistern is used, a roof strainer or prefiltration system shall be provided for each cistern. The exception is a series of cisterns interconnected to supply water to a single system.

- The inlet to the roof strainer shall be provided with a debris screen that protects the roof washer from the intrusion of waste and vermin.
- The roof strainer shall rely on manually operated valves or other devices to do the diversion.

Storage Tank or Cistern

The cistern is the most expensive component of the collection system. Cisterns are commonly constructed of fiberglass, polyethylene, concrete, metal, or wood. Tanks can be installed aboveground (either adjacent to or remote from a structure), under a deck, or in the basement or crawl space.

Aboveground installations are less expensive than belowground applications, all other factors being equal. Aesthetic preferences or space limitations may dictate that the tank be located belowground, or away from the structure.

Multiple tank systems provide redundancy, allowing the system to continue to operate if one of the tanks needs to be shut down for maintenance.

The following criteria apply to storage tanks and cisterns for rainwater harvesting:

- All cisterns shall be listed for use with potable water and shall be capable of being filled from both the rainwater harvesting system and the public or private water system. Note that the water from the cistern should not be considered potable, but it may be used to replace water that is typically drawn from potable sources (e.g. toilet flushing).
- The municipal or on-site well water system shall be protected from cross-contamination in accordance with local jurisdiction requirements.
- Backflow assemblies shall be maintained and tested in accordance with local jurisdiction requirements.
- Cisterns shall have access to allow inspection and cleaning.
- For above grade cisterns, the ratio of the cistern size shall not be > 1:1 height to width. An engineered tank with an engineered foundation may have a height that exceeds the width, subject to approval of the authority having jurisdiction. The ratio for below grade cisterns is not limited.
- Below-grade cisterns shall be provided with manhole risers a minimum of 8 inches above surrounding grade and shall have tie-downs per manufacturer's specifications, or the excavated site must have a daylight drain or some other drainage mechanism to prevent floating of the cistern resulting from elevated groundwater levels.
- Cisterns shall be protected from sunlight to inhibit algae growth and ensure life expectancy of tank.
- All cistern openings shall be protected from unintentional entry by humans or vermin. Manhole covers shall be provided and shall be secured to prevent tampering. Where an opening is provided that could allow the entry of personnel, the opening shall be marked, "DANGER – CONFINED SPACE."

- Cistern outlets shall be located ≥ 4 inches above the bottom of the cistern.
- The cistern shall be equipped with an overflow device. The overflow device shall consist of a pipe equal to or greater than the cistern inlet and a minimum of 4 inches below any makeup device from other sources. The overflow outlet shall be protected with a screen having openings ≤ 0.25 inches or a self-sealing cover.

Pumps and Pressure Tanks

Adequate elevation to deliver water from the storage tank to the filtration and disinfection system and the house at adequate pressure is often not available. Standard residential water pressure is 40 to 60 pounds per square inch (psi). Two methods are used to attain proper pressure: (1) a pump with a pressure tank, pressure switch, and check valve; or (2) an on-demand pump. The first system uses the pressure tank to keep the system pressurized and the pressure switch initiates the pump when pressure falls below a predetermined level. The check valve prevents pressurized water from returning to the tank. The on-demand pump is self-priming and incorporates the pressure switch, pressure tank, and check valve functions in one unit (Texas Water Development Board, 2005).

Where a pump is provided in conjunction with the rainwater harvesting system, the pump shall meet the following criteria:

- The pump and all other pump components shall be listed and approved for use with potable water systems.
- The pump shall be capable of delivering a minimum of 15 psi residual pressure at the highest outlet served. Minimum pump pressure shall allow for friction and other pressure losses. Maximum pressures shall not exceed 80 psi.

Back Flow Prevention

Rainwater is most commonly used to augment an existing potable supply for uses that do not require treatment to be potable. Typically, such systems augment an existing supply because the cistern will likely run dry or near dry in the summer. See local jurisdiction requirements for preventing backflow and subsequent contamination of the potable water supply.

Harvested Rainwater Treatment

The level of treatment required varies, depending on intended use. Treatment is not typically required for non-potable uses such as irrigation and toilet flushing. Treatment may prolong the life of pipe networks for the harvested rainwater. The local jurisdiction may have treatment requirements, depending on the proposed use.

Harvested rainwater treatment falls into three broad categories: filtration, disinfection, and buffering.

Filtration

Filters remove leaves, sediment, and other suspended particles and are placed between the catchment and the tank or in the tank. Filtering begins with screening gutters to exclude leaves and other debris, routing the first flush through first flush diverters, roof washers, and cistern float filters. Cistern float filters are placed in the storage tank and provide filtration as water is pumped from the tank to the disinfection system and the house. The filter is positioned to float 10 to 16 inches below the water surface where the water is cleaner than the bottom or surface of the water column (Texas Water Development Board, 2005).

Types of filters for removing the smaller remaining particles include single cartridges (similar to swimming pool filters) and multicartridge filters. These are typically 5-micron filters and provide final mechanism for removing fine particles before disinfection. Reverse osmosis and nanofiltration are filtration methods that require forcing water through a semipermeable membrane. Membranes provide disinfection by removing/filtering very small particles (molecules) and harmful pathogens. Some water is lost in reverse osmosis and nanofiltration with concentrated contaminants. The amount of water lost is proportional to the purity of the feed water (Texas Water Development Board, 2005).

Disinfection

- Ultraviolet (UV) radiation uses short wave UV light to destroy bacteria, viruses, and other microorganisms. UV disinfection requires prefiltering of fine particles where bacteria and viruses can lodge and elude the UV light. This disinfection strategy should be equipped with a light sensor and a readily visible alert to detect adequate levels of UV light (Texas Water Development Board, 1997).
- Ozone is a form of oxygen produced by passing air through a strong electrical field. Ozone kills microorganisms and oxidizes organic material to carbon dioxide (CO_2) and water. The remaining ozone reverts back to dissolved oxygen (Texas Water Development Board, 1997). Care must be exercised in the choice of materials used in the system using this disinfection technique due to ozone's aggressive properties.
- Activated carbon removes chlorine and heavy metals, objectionable tastes, and most odors.
- Chlorine (commonly in the form of sodium hypochlorite) is a readily available and dependable disinfection technique. Household bleach can be applied in the cistern or feed pumps that release small amounts of solution while the water is pumped (Texas Water Development Board, 1997). There are two significant limitations of this technique: chlorine leaves an objectionable taste (this can be removed with activated charcoal); and prolonged presence of chlorine with organic matter can produce chlorinated organic compounds (e.g. trihalomethanes) that can present health risks (Texas Water Development Board, 1997).
- For potable water systems, the water must be filtered and disinfected after it exits the storage reservoir and immediately before the point of use (Texas Water Development Board, 2005).

Buffering

Rainwater is usually slightly acidic (a pH of approximately 5.6 is typical). Total dissolved salts and minerals are low in precipitation, and buffering with small amounts of a common buffer, such as baking soda, can adjust collected rainwater to near neutral (Texas Water Development Board, 1997). Buffering should be done each fall after tanks have first filled.

Design Procedure

The basic rule for sizing any rainwater harvesting system is that the volume of water that can be captured and stored (the supply) must equal or exceed the volume of water used (the demand) (Texas Water Development Board, 2005). Understanding the water balance will allow the designer to understand whether harvested rainwater will be adequate to meet demands. Only stormwater runoff from roof areas should be directed to rainwater harvesting systems.

The size of the roof, expressed as the catchment area, is equal to the width times the length of the area flowing to a gutter. The slope of the roof is not considered in the catchment area calculation (e.g. the horizontal projection of the area is used for sizing, which is smaller than the actual area for sloped roofs).

General guidelines for sizing the rainwater collection system to the catchment area include the following:

- Rainfall of 1 inch on 1 sf of rooftop will produce 0.6233 gallons of water or approximately 600 gallons per 1,000 sf of roof without inefficiencies in the collection process.
- The system will lose approximately 10 to 25% of the total rainfall due to evaporation, initial wetting of the collection material, and inefficiencies in the collection process (Texas Water Development Board, 2005). Precipitation loss increases with the roughness of the roofing material. Precipitation loss is the least with metal, more with composition, and greatest with wood shake or shingle.

See the *Texas Manual on Rainwater Harvesting* (Texas Water Development Board, 2005) for a detailed discussion on water balance modeling for sizing of rainwater harvesting systems. Where daily or sub-daily rainfall data are available, daily or sub-daily water balance modeling is recommended over monthly water balance modeling. The finer time scale will allow the designer to evaluate the timing and magnitude of system overflows, thereby allowing for more accurate sizing of downstream conveyance and Flow Control BMPs where needed.

Estimating Indoor Water Demand

Harvested rainwater should not be used as a potable source. Harvested rainwater may be used to replace potable water in certain applications (e.g. water used to flush toilets). Use the following paragraph to help calculate water demand. The calculations will depend on the proposed uses of the harvested water.

Indoor water demand is largely unaffected by changes in weather, although changes in household occupancy rates depending on the season and very minor changes in consumption of water due to increases in temperature may be worth considering in some instances. The results of a study of 1,200 single-family homes indicated that the average water-conserving household used approximately 49.6 gallons per person per day (AWWA, 1999b). Many households use less than this average. Overall demand for showers, baths, and faucet uses is a function of both time of use and rate of flow. Many people do not open the flow rate as high as it could be, finding low or moderate flow rates more comfortable (WSU and PSP, 2012). In estimating demand, measuring flow rates and consumption in the household may be worth the effort to get more accurate estimates but should be verified with the records of historical use from a municipal water bill if available.

Estimating Outdoor Water Demand

Outdoor water demand peaks during the summer months. The water demands of a large turf grass area often exceed the volume of harvested rainwater for irrigation. For planning purposes, historical evapotranspiration and evaporation should be used to project potential water demand.

Construction Criteria

The technology for rainwater harvesting is well developed and the components are commercially available. Placing a cistern underground may result in a considerable amount of excavation and grading. Where rainwater harvesting systems are used for nonpotable uses, the sophistication of the design will benefit from an experienced contractor. Contractors should confirm the occurrence of the following:

- A cistern should be located where the surrounding area can be graded to provide good drainage of stormwater runoff away from the cistern. Avoid placing cisterns in low areas subject to flooding. This will reduce the chance of untreated runoff contaminating the stored cistern water.
- Cisterns should always be located upslope from any sewage disposal facilities.
- Underground cisterns should be provided with manhole risers extending a minimum of 8 inches above surrounding grade and should have tie-downs per manufacturer's specifications. If tie-down systems are not provided, the excavated site should have a daylight drain or some other drainage mechanism to prevent floating of the cistern resulting from elevated groundwater levels.
- Manhole openings should have a watertight curb with edges projecting several inches above the level of the surrounding surface. The edges of the manhole cover should overlap the curb and project downward a minimum of 2 inches. Manhole covers should be provided with locks to further reduce the danger of contamination and accidents.
- Place the manhole opening near a corner or an edge of the structure so that a ladder can be lowered into the cistern and braced securely against a wall.
- All cistern openings should be protected from unintentional entry by humans or vermin. Manhole covers should be provided and secured to prevent tampering. Where an opening is provided that could allow the entry of personnel, the opening shall be marked "DANGER – CONFINED SPACE."
- Cisterns should be protected from sunlight to inhibit algae growth to ensure the life expectancy of the tank.
- The floor of the cistern should be constructed to slope slightly toward the drain to facilitate cleaning. The valve and drain line should be insulated by a sufficient depth of earth to prevent freezing during even the most severe winter weather.
- Cisterns should be vented to allow fresh air to circulate into the storage compartment. The openings, located several feet above ground level, should be oriented to face the direction of the prevailing winds, west in most cases, to maximize ventilation. For the vents, 4- or 6-inch-diameter plastic pipe is adequate. The contractor should confirm that each vent pipe

has a watertight seal through the top of the cistern.

- Cisterns should be located as close as possible to the structure benefitting from the water reuse or landscape planned for irrigation.
- Cisterns should be installed in accordance with the manufacturer's installation instructions. Where the installation requires a foundation, the foundation shall be flat and be capable of supporting the cistern weight when the cistern is full.

Runoff Model Representation

If the water balance model used to size the rainwater harvesting system shows that there is no overflow (e.g. all of the stored water is used or evaporated), subtract the contributing roof area from the runoff model used to size Flow Control BMPs.

Operation and Maintenance Criteria

- Maintenance criteria for rainwater collection systems include typical household and system specific procedures. All controls, overflows, and clean-outs should be readily accessible and alerts for system problems should be easily visible and audible.
- Debris should be removed from the roof as it accumulates.
- Gutters should be cleaned as necessary (for example in September, November, January, and April). The most critical cleaning is in mid- to late-spring to flush pollen deposits from surrounding trees.
- Screens at the top of the downspout should be maintained in good condition.
- Prefilters should be cleaned monthly.
- Filters should be changed every 6 months or as a drop in pressure is noticed.
- Storage tanks should be chlorinated quarterly at 0.2 to 0.5 parts per million (ppm) or a rate of 0.25 cup of household bleach (5.25% solution) to 1,000 gallons of stored water.
- Storage tanks should be inspected and debris removed periodically as needed.
- When storage tanks are cleaned, the inside surface should be rinsed with a chlorine solution of 1 cup bleach to 10 gallons water.
- Roof washers should be readily accessible for regular maintenance.
- Prefiltration screens or filters should be maintained consistent with manufacturer's specific-ations.

See Appendix 6-A: BMP Maintenance Tables for additional recommendations for maintenance of rainwater harvesting systems.

BMP F6.61: Post-Construction Soil Quality and Depth

Purpose and Definition

Naturally occurring (undisturbed) soil and vegetation provide important stormwater functions including: infiltration; nutrient, sediment, and pollutant adsorption; sediment and pollutant biofiltration; water interflow storage and transmission; and pollutant decomposition. These functions are largely lost when development strips away native soil and vegetation and replaces it with minimal topsoil and sod. Not only are these important stormwater functions lost, but such landscapes themselves can become pollution generating pervious surfaces due to increased use of pesticides, fertilizers and other landscaping and household/industrial chemicals, the concentration of pet wastes, and pollutants that accompany roadside litter.

Establishing soil quality and depth can obtain greater stormwater functions in the post-development landscape and help preserve the plant and soil system more effectively. This type of approach provides a soil/landscape system with adequate depth, permeability, and organic matter to sustain itself and to continue working as an effective stormwater infiltration system.

Applications and Limitations

Amending soils to establish a minimum soil quality and depth is not the same as preservation of naturally occurring soil and vegetation. However, establishing a minimum soil quality and depth will provide improved on-site management of stormwater flow and water quality.

This BMP can be considered infeasible on till soil slopes greater than 33 percent.

In addition to providing some amount of Flow Control benefit, this BMP also offers the following benefits:

- Amended soils can be included in designs for dispersion BMPs (see 6.3 Dispersion BMPs) to improve dispersal and absorption of stormwater flows.
- This BMP creates a medium for healthy plant growth, reducing the need for fertilizers and pesticides and peak summer irrigation needs (Chollak, n.d.).
- This BMP can improve overall site water quality performance by promoting infiltration; increasing cation exchange capacity, pollutant adsorption, and filtration; and buffering soil pH (USDA and USCC, 2005).

Design Guidelines

Organic Matter

Soil organic matter can be attained through numerous materials such as compost, composted woody material, biosolids, forest product residuals, or other locally available materials deemed suitable for this application. The materials used must be appropriate and beneficial to the plant cover to be established and must not have an excessive percentage of clay fines.

Soil Retention

Retain, in an undisturbed state, the duff layer and native topsoil to the maximum extent practicable. In any areas requiring grading, remove and stockpile the duff layer and topsoil on site in a designated, controlled area, not adjacent to public resources and critical areas, to be reapplied to other portions of the site where feasible.

Soil Quality

All areas subject to clearing and grading that have not been covered by impervious surface, incorporated into a drainage facility, or engineered as structural fill or slope shall, at project completion, demonstrate the following:

1. A topsoil layer comprised as follows:
   - **Planting Beds:** 8-10 percent organic content using 3 inches of compost incorporated to an 8-inch depth or a topsoil mix containing 35-40 percent compost by volume.
   - **Turf areas:** 3-5 percent organic content using 1.75 inches of compost incorporated to an 8-inch depth or a topsoil mix containing 20-25 percent compost by volume.
   - pH between 6.0 and 8.0 or a pH appropriate for installed plants.
2. The topsoil layer shall have a minimum depth of eight inches except where tree roots limit the depth of incorporation of amendments needed to meet the criteria. Subsoils below the topsoil layer should be scarified at least 4 inches with some incorporation of the upper material to avoid stratified layers, where feasible.
3. Mulch planting beds with 2 inches of organic material.
4. Use compost and other materials that meet the following organic content requirements:
   - The organic content must be met using the compost specification for BMP F6.23: Bioretention, with the exception that the compost may have up to 35% biosolids or manure.
   - The compost must also have an organic matter content of 40% to 65%, and a carbon to nitrogen ratio below 25:1.

The resulting soil should be conducive to the type of vegetation to be established.

Implementation Options

The soil quality design guidelines listed above can be met by using one of the methods listed below:

1. Leave undisturbed native vegetation and soil, and protect from compaction during construction.
2. Amend existing site topsoil or subsoil with organic content at the rates given above.

3. Stockpile existing topsoil during grading, and replace it prior to planting. Stockpiled topsoil must also be amended if needed to meet the organic matter or depth requirements as given above.
4. Import topsoil mix of sufficient organic content and depth to meet the requirements.

More than one method may be used on different portions of the same site. Soil that already meets the depth and organic matter quality standards, and is not compacted, does not need to be amended.

Construction Criteria

Protecting and enhancing site soils requires planning and sequencing of construction activities to reduce impacts. The following recommended steps are adapted from the *Low Impact Development Technical Guidance Manual for Puget Sound* (WSU and PSP, 2012) and the Building Soil – A Foundation for Success website (http://www.buildingsoil.org/). These steps begin with land clearing and grading and continue through end of construction (prior to planting) and after planting is complete:

Land Clearing and Grading Phase

- Fence all vegetation and soil protection areas prior to first disturbance, and communicate those areas to clearing and grading operators. The root zones of trees that may extend into the grading zone should be protected or cut rather than ripped during grading.
- Chip land-clearing debris on-site and reuse as erosion-control cover or stockpile for reuse as mulch at end of project.
- Stockpile topsoil to be reused with a breathable cover, such as wood chips or landscape fabric.
- If amended, topsoils will be placed at end of project. Grade 8 to 12 inches below finish grade to allow for placing the topsoil.

Construction Phase

- Ensure erosion and sediment control BMPs are in place before and modified after grading to protect construction activities. Compost-based BMPs (compost “blankets” for surface, and compost berms or socks for perimeter controls) give a “two-for-one” benefit because the compost can be reused as soil amendment at the end of the project.
- Lay out roads and driveways immediately after grading and place rock bases for them as soon as possible. Keep as much construction traffic as possible on the road base, and off open soils. This will improve erosion compliance, reduce soil compaction, and increase site safety by keeping rolling equipment on a firm base.
- Protect amended/restored soils from equipment-caused compaction by using steel plates or other BMPs if equipment access is unavoidable across amended soils.
- Maintain vegetation and soil protection area barriers and temporary tree root zone

protection BMPs throughout construction and ensure that all contractors understand their importance.

End of Construction, Soil Preparation Before Planting

- Ensure vegetation and soil protection barriers are maintained through the end of construction.
- Disturbed or graded soil areas that have received vehicle traffic will need to be decompacted to a minimum 12-inch depth. This can be done with a cat-mounted ripper or with bucket-mounted ripping teeth.
- Amend all disturbed areas with compost or other specified amendments ≥ 8 inches deep by tilling, ripping, or mixing with a bucket loader. Alternatively, place amended stockpiled topsoil or import an amended topsoil. It is good practice to scarify or mix amended soils several inches into the underlying subsoil to enhance infiltration and root penetration. Compost from erosion BMPs (compost blankets, berms, or socks) can be reused as appropriate if immediately followed by planting and mulching so there is no lapse in erosion control.
- Amended topsoil can be placed as soon as building exterior work is complete. During this step, vehicles should stay on roads and driveway pads. Compost, soil blends provide good ongoing erosion protection.
- Avoid tilling through tree roots – instead use shallow amendment and mulching.
- Final preparation for turf areas should include raking rocks, rolling, and possibly placing 1 to 2 inches of sandy loam topsoil before seeding or sodding.
- Plan for amended soil to settle by placing amended soil slightly higher than desired final grade, or retain or import a smaller amount of amended topsoil to meet final grades adjacent to hardscape such as sidewalks.
- Keep compost, topsoil, and mulch delivery tickets so inspector can verify that quantities and products used match those intended per the design.

After Planting and End of Project Phase

- Remove protection area barriers, including sediment fences, filter socks, and curb and storm drain barriers. Evaluate trees for stress and need for treatment, such as pruning, root-feeding, mulching etc. Plan to have an arborist on-site, as appropriate.
- Mulch all planting beds where soil has been amended and replanted with 2 to 3 inches of arborist wood chip or other specified mulch.
- Communicate a landscape management plan to property owners that includes: on-site reuse of organics (e.g. mulch leaves, mulch-mow grass clippings) to maintain soil health; avoiding pesticide use; and minimal organic-based fertilization.

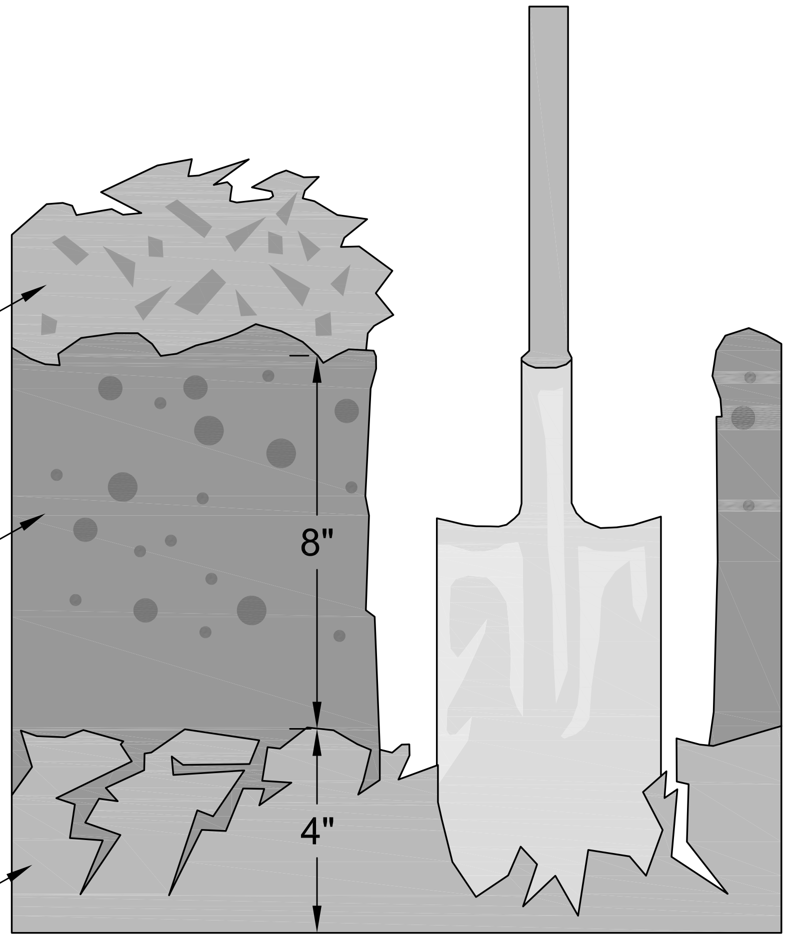
Operation and Maintenance Criteria

- Establish soil quality and depth toward the end of construction and once established, protect from compaction, such as from large machinery use, and from erosion.
- Plant and mulch areas immediately after amending and settling the soil to stabilize the site as soon as possible.
- Leave plant debris or its equivalent on the soil surface to replenish organic matter.
- Landscape management plans should continually renew organic levels through mulch-mowing on turf areas, allowing fallen leaves to remain on beds, and/or replenishing mulch layers every 1 to 2 years.
- Minimize or eliminate use of irrigation, herbicides, pesticides and fertilizers. Landscape management personnel should be trained to minimize chemical inputs, use nontoxic alternatives, and manage the landscape areas to minimize erosion, recognize soil and plant health problems, and optimize water storage and soil permeability.
- Remove weeds as necessary or appropriate through manual removal, tilling and/or remulching.
- Protect amended areas from excessive foot traffic and equipment to prevent compaction and erosion.

Runoff Model Representation

All areas meeting the soil quality and depth design criteria may be entered into approved runoff models as “Pasture” rather than “Lawn/Landscaping”.

Figure 6.90: Planting Bed Cross-Section



Reprinted from *Guidelines and Resources For Implementing Soil Quality and Depth BMP T5.13 in WDOE Stormwater Management Manual for Western Washington*, 2010, Washington Organic Recycling Council

NOT TO SCALE

DEPARTMENT OF ECOLOGY State of Washington

Planting Bed Cross-Section

Revised June 2016

BMP F6.62: Tree Retention and Tree Planting

Purpose and Definition

Trees provide multiple environmental benefits including energy conservation, air quality improvement, carbon sequestration, increased property values, and stormwater management.

Mature, healthy trees can play a significant role in reducing stormwater runoff by intercepting and storing precipitation, promoting evapotranspiration, and slowly releasing intercepted precipitation from foliage and branches to the surrounding soil. The root systems of trees also serve to penetrate soil, build soil structure, and provide conduits for infiltration. The degree of stormwater management provided by a tree depends on the tree type (i.e. evergreen or deciduous), canopy area, and whether or not the tree canopy overhangs impervious surfaces.

Properly planted new and retained trees can intercept precipitation and reduce associated surface flow on impervious surfaces (see Figure 6.91: Illustration of How a Tree Can Intercept and Infiltrate Stormwater). When a development project retains and/or plants trees in accordance with the criteria outlined below, the project receives "Flow Control Credits". The credits can be applied toward meeting Flow Control based performance standards.

Many hydrologic models capture the hydrologic benefits of trees (e.g. as evapotranspiration and interception storage) when the project retains or increases forest or pasture cover area. The "Flow Control Credit" (per this BMP) accounts for the benefits of a tree canopy overhanging impervious surfaces, by allowing a reduction in the impervious surface in the model. Development using the "Flow Control Credits" with tree retention and planting results in a reduced runoff volume to mitigate for compared to development without them. Because evergreen trees provide more hydrologic benefits throughout the year ((Herrera, 2008) and (Jayakaran et al., 2022b)), Ecology gives higher "Flow Control Credits" to evergreen trees than deciduous trees.

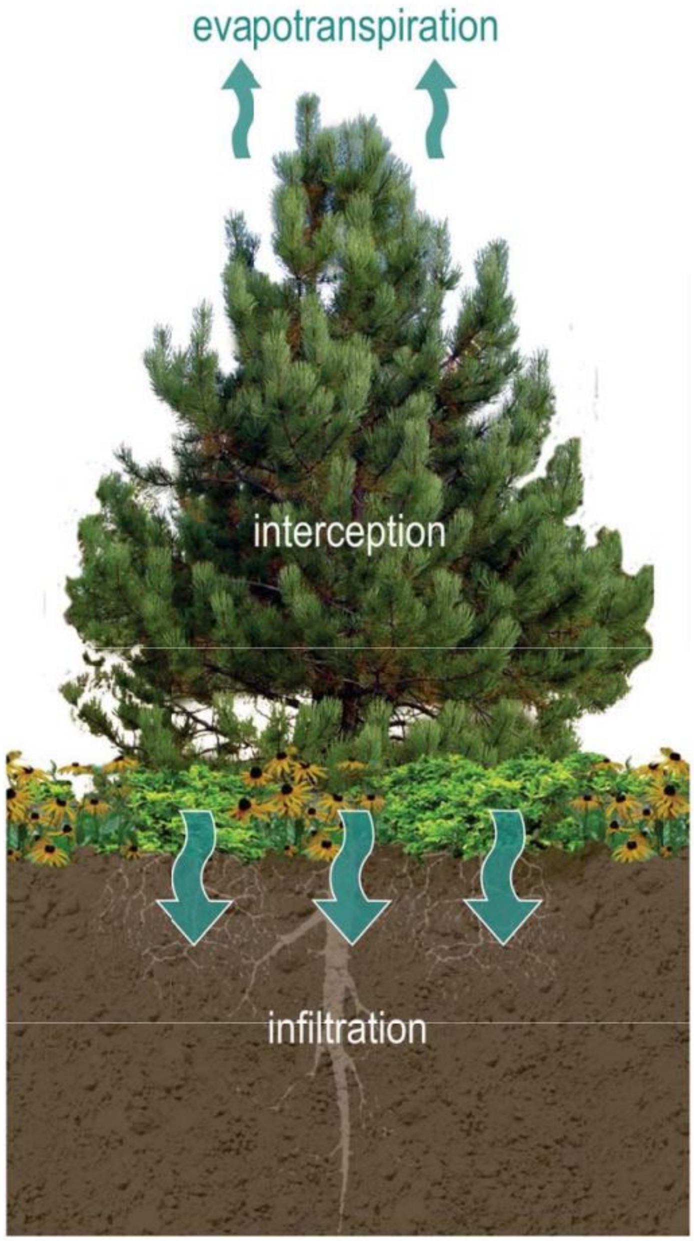
Flow Control credits may be applied to project sites of all sizes.

Applications and Limitations

Applications and limitations for individual existing retained or newly planted trees on new or redevelopment projects include the following:

- Tree crown growth can be restricted by adjacent structure or overhead utilities.
- Inadequate underground rooting space can impair growth and cause premature mortality (Lindsay and Bussuk, 1992), (Grabosky and Gilman, 2004).
- Adequate soil volume and quality are needed for trees to reach a healthy mature size.
- Trees surrounded by or located near impervious surfaces can experience limited soil moisture, nutrients, and gas exchange.
- Larger mature trees provide more stormwater (and other) benefits than small trees.
- Appropriate drainage is needed to ensure the growth of healthy trees (Urban, 2008).
- Trees should be protected when located near plowed snow storage areas.

Figure 6.91: Illustration of How a Tree Can Intercept and Infiltrate Stormwater



Source: AHBL, Inc.

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Illustration of How a Tree Can Intercept and Infiltrate Stormwater

Revised June 2013

General Design Criteria

Retention and Protection of Tree(s) as a Flow Control BMP

Trees used to gain Flow Control credits shall be retained, maintained, and protected on the site as a Flow Control BMP after construction and for the life of the development or until any approved redevelopment occurs in the future. Trees that are removed or die shall be replaced with like species during the next planting season. Trees shall be pruned according to industry standards (ANSI A 300 standards).

Site Assessment and Planning for Tree Retention and/or Planting

Planting and retaining healthy trees requires space and investment. The designer/engineer should be engaged from planning through construction phases, whether new construction or a retrofit, to conduct site assessment to inform soil strategies and species selection for healthy tree growth. The initial site assessment for location and type of tree should include the following:

- Available aboveground growing space
- Available belowground root space and ground-level planting area relative to existing or planned pavement, buildings, and utilities
- Type of soil and availability of water, including subgrade soils, groundwater levels, and site drainage patterns
- Overhead obstructions
- Vehicle and pedestrian sight lines
- Proximity to paved areas and underground structures
- Proximity to property lines, buildings, and other vegetation
- Prevailing wind direction and sun exposure
- Maintenance
- Slope and topographic features
- Proximity to snow storage areas
- Lists of required and prohibited local trees

Soil analysis for trees should include: understanding historical uses, extent and result of disturbances, soil texture, compaction, permeability, barriers and interfaces in the soil profile, and chemical characteristics (Urban, 2008). Urban soils are often degraded from construction activities. If the existing soil or structural soils are used as the planting material, particular attention should be given to soil pH, which is often high due to concrete/construction debris and can cause nutrient deficiency and other problems. The ideal soil pH for most trees is 5 to 6.5 (Day and Dickinson, 2008).

Water availability and the site drainage pattern are also important. In general, the tree planting pit or reservoir in the tree rooting zone (18 to 24 inches) and above the underdrain (if installed) should drain down within 48 hours to encourage aerobic conditions and good root distribution through planting pit for many tree species (Bartens et al., 2009). If there is potential for extended ponding, consult a qualified professional for appropriate drainage strategies and a landscape architect or arborist for appropriate tree species for more saturated conditions.

Additional environmental, economic, and aesthetic functions, such as shade (reduced heat island effect), windbreak, privacy screening, air quality, and increased property value can also be considered when determining the use, type, and placement of trees.

Tree Retention Design Criteria

General

Setbacks of proposed infrastructure from existing trees are critical considerations. Tree protection requirements limit grading and other disturbances in proximity to the tree.

Existing tree species and location must be clearly shown on submittal drawings.

Trees must be viable for long-term retention (i.e. in good health and compatible with proposed construction).

Tree Size

To receive Flow Control credit, retained trees shall have a minimum 6 inches diameter at breast height (DBH). DBH is defined as the outside bark diameter at 4.5 feet above the ground on the uphill side of a tree. For existing trees smaller than this, the newly planted tree credit may be applied.

The retained tree canopy area shall be measured as the area within the tree drip line. A drip line is the line encircling the base of a tree, which is delineated by a vertical line extending from the outer limit of a tree's branch tips down to the ground. If trees are clustered, overlapping canopies are not double counted.

Tree Location

Flow Control credit for retained trees depends upon proximity to ground level impervious or other hard surfaces. To receive a credit, the existing tree must be on the development site and within 20 feet of new and/or replaced ground level impervious or other hard surfaces (e.g. driveway or patio) on the development site. Distance from impervious or other hard surfaces is measured from the tree trunk center.

A mature tree’s trunk flare should not be paved to ensure healthy tree retention. The trunk flare is the transition area between the base of the trunk and root crown and is often 2 to 3 times the trunk diameter (trunk diameter measured at 4 feet aboveground). An arborist report may be required if impervious surface is proposed within the critical root zone of the existing tree. The critical root zone is defined as the line encircling the base of the tree with half the diameter of the dripline. If the arborist report concludes that impervious surface should not be placed within 20 feet of the tree, and canopy overlap with impervious surface is still anticipated given a longer setback, a higher tree Flow Control credit may be approved.

Protection During Construction

The existing tree roots, trunk, and canopy shall be fenced and protected during construction activities. See (TCIA, 2019) for more guidance.

Tree Retention Flow Control Credit

Flow Control credits for retained trees are provided in Table 6.40: Flow Control Credits for Retained Trees by tree type. These credits can be applied to reduce impervious or other hard surface area requiring Flow Control. Credits are given as a percentage of the existing tree canopy area. The minimum credit for existing trees ranges from 50 to 100 square feet.

Flow Control credits are not applicable to trees in native vegetation areas used for dispersion BMPs or other Flow Control credit. Credits are also not applicable to trees in planter boxes. The total tree credit for retained trees shall not exceed 25% of the impervious or other hard surface area requiring mitigation.

Table 6.40: Flow Control Credits for Retained Trees

Tree Type	Credit
Evergreen	20% of canopy area (minimum credit of 100 SF/tree)
Deciduous	10% of canopy area (minimum credit of 50 SF/tree)

Impervious/Hard Surface Area Mitigated =

$$(\Sigma \text{ Evergreen Canopy Area} \times 0.2) + (\Sigma \text{ Deciduous Canopy Area} \times 0.1)$$

Note that the minimum credits are 50 SF/tree and 100 SF/tree (for evergreen and deciduous, respectively). The minimum tree size is determined by DBH (described above). This means that if the DBH of the retained tree is acceptable, but the canopy is less than 500 SF, then the project will still get credit as if the canopy is 500 SF.

Newly Planted Tree Design Criteria

Tree Species

There are numerous tree species appropriate for eastern Washington with conditions ranging from sustained temperatures over 100 degrees in the summer to severe winter winds and cold weather. Successful planning where extreme growing conditions occur is essential. Absolute cold is not so much the problem as are drying winds that dehydrate plants growing in frozen soils. Wind protection, mulching, appropriate soil structure and careful late-autumn watering helps facilitate healthy tree growth in areas of extreme weather.

Each jurisdiction should adopt a list of approved tree species for Flow Control credit.

Tree Size

To receive Flow Control credit, new deciduous trees at the time of planting shall be at least 1.5 inches in diameter measured 6 inches above the ground. New evergreen trees shall be at least 4 feet tall.

Tree Location and Planting Criteria

Trees shall be sited according to sun, soil, and moisture requirements. Planting locations shall be selected to ensure that sight distances and appropriate setbacks are maintained given mature height, size, and rooting depths. Similar to retained trees, Flow Control credit for newly planted trees depends upon proximity to ground level impervious surfaces.

To receive a credit, the tree must be planted on the development site and within 20 feet of new and/or replaced ground level impervious surfaces (e.g. driveway, patio, or parking lot). Distance from impervious surfaces is measured from the edge of the surface to the center of the tree at ground level. To help ensure tree survival and canopy coverage, the minimum tree spacing for newly planted trees shall accommodate mature tree spread.

Plant in appropriate areas characterized by quality soils and adequate soil volume for the appropriate tree species. (Urban, 2008) recommends a minimum depth for planting soil of 30 to 48 inches. This depth should extend for a 10-foot radius around the tree in lawn areas. Adequate soil volume depends on soil type, water availability and tree size (crown projection or trunk diameter), at a rate of 1 to 3 cf of soil per 1 sf of tree crown area. For trees without irrigation, soil volume should be high.

Planting beds should be of an adequate size for the tree selected and special attention should be given to increasing soil and rooting volume. Where significant snow storage is anticipated, trees should be protected and planted away from significant snow accumulations. Plowed snow is denser and can be heavily laden with deicing chemicals and salts - either of which can be detrimental to healthy plant and tree growth. In parking areas where snow accumulation can be significant, parking and drive lanes should be arranged to allow ease of snow plowing and to facilitate the protection of planting areas.

Multiple strategies for increasing the soil depth and volume to promote healthy trees are described below.

Irrigation

Provisions shall be made for supplemental irrigation during the first three growing seasons after installation to help ensure tree survival.

Newly Planted Tree Flow Control Credit

Flow Control credits for newly planted trees are provided in Table 6.41: Flow Control Credits for Newly Planted Trees by tree type. These credits can be applied to reduce the impervious or other hard surface area requiring Flow Control. Credits range from 20 to 50 square feet (SF) per tree.

Table 6.41: Flow Control Credits for Newly Planted Trees

Tree Type	Credit
Evergreen	50 SF per tree
Deciduous	20 SF per tree

Impervious/Hard Surface Area Mitigated =

Σ Number of Trees x Credit (sq. ft.)

Flow Control credits are not applicable to trees in native vegetation areas used for dispersion BMPs or other Flow Control credit. Credits are also not applicable to trees in planter boxes. The total tree credit for newly planted trees shall not exceed 25% of the impervious or other hard surface area requiring mitigation.

Strategies for Increasing the Soil Depth and Volume to Promote Healthy Trees

Use of Soil Amendment for Trees

If possible, stockpile and reuse existing soils for tree planting. For adequate drainage and tree health, (Urban, 2008) recommends avoiding topsoil that has more than 35% clay, 45% silt, or 25% fine sand. Loam, sandy loam, and sandy clay loam provide good textural classifications for supporting healthy tree growth.

If stormwater is directed to the tree planting area, a designed soil mix may be necessary to achieve adequate infiltration and drain-down characteristics.

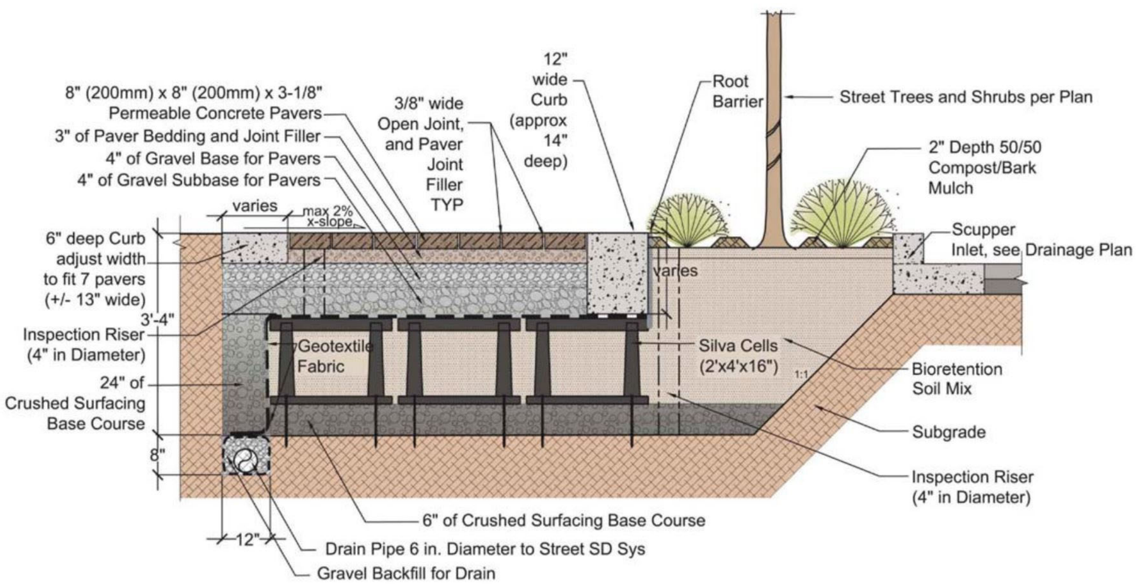
A variety of materials are available to amend existing soils or design a specific soil mix. Mineral soil amendments alter soil texture and improve infiltration and water holding characteristics. Common materials used in tree planters and planting areas include sand, expanded shale, clay and slate, and diatomaceous earth (see (Urban, 2008) for detailed descriptions for using mineral amendments).

Where the native soils are low in organic matter, biologic and organic amendments should be used to improve organic matter content, infiltration capability, nutrient availability, soil biota, and cation exchange capacity, as appropriate. Biologic amendments include mycorrhizal fungi spores, kelp extracts, humic acids, organic fertilizers, and compost tea. If tree planting soil is poor quality, biologic amendments generally only offer a temporary improvement for tree growth.

Increasing Soil and Rooting Volume: Soil Cell Systems

Soil cell systems are modular frames (base and pillar) with a deck that supports the pavement above and creates large spaces for uncompacted soil and tree roots. DeepRoot Green Infrastructure developed the Silva Cell, which is a common type of rigid load-bearing soil cell for trees. The decks are often designed for AASHTO H-20 loading (see Figure 6.92: Silva Cell Filled With Bioretention Soil Mix and Topped With Permeable Pavers). Many utilities can be installed within and through the cells; however, utilities require planning and careful consideration. Many types of soil can be used to fill the cells for a rooting medium, including imported soils designed for the specific tree or excavated soils (including heavier dense soils with higher clay content) amended with compost if necessary (ASLA, 2010). An advantage with soil cells is that > 90% of the volume created by the cell is available for soil.

Figure 6.92: Silva Cell Filled With Bioretention Soil Mix and Topped With Permeable Pavers



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Silva Cell Filled With Bioretention Soil Mix and Topped With Permeable Pavers

Revised June 2013

Increasing Soil and Rooting Volume: Structural Soils

Structural soils provide a porous growth medium and structural support for sidewalks and street edges. Structural soils are a mix of mineral soil (typically a loam or clay loam with ≥ 20% clay for adequate water and nutrient holding capacity) and coarse aggregate (typically uniformly graded ¾-inch to 1½-inch angular crushed rock) that, after compaction, maintains porosity (typically 25% to 30%) and infiltration capacity (typically > 20 inches per hour [in/hr]). Current research and installation experience has resulted in guidelines for designing with structural soil including the following:

- Structural soil can be used under all or part of the paved surfaces adjacent to trees to provide the necessary soil volume. Where structural soil is placed adjacent to open graded base aggregate, geotextile should be used to prevent migration of the fine aggregate in the structural soil to the more open graded material (Bassuk et al., 2005).
- **Soil depth:** 24 inches (minimum) to 36 inches (recommended) (Bassuk et al., 2005).
- **Compaction:** 95% Proctor (Bassuk et al., 2005).
- **Tree pit opening:** If the tree pit opening is at least 5 feet x 5 feet, a well-drained top soil can be used in the planting area. If the opening is smaller, structural soil can be used immediately under and up to the root ball (Bassuk et al., 2005).
- **Available soil:** The structural aggregate uses approximately 80% of the available space; therefore, approximately 20% of the total planting volume is available soil to support tree growth.
- **Soil volume:** 2 cf for each 1 sf of crown projection (mature tree) is a well-accepted industry standard. Because the structural aggregate uses approximately 80% of the available space, 10 cf of structural soil for each 1 sf of crown projection (mature tree) may be needed.
- **Planters with impervious walls:** Openings filled with uncompacted soil can be used to allow roots to access surrounding structural soil (Bassuk et al., 2005).
- **Tree species:** Use species that are tolerant of well-drained soil and periodic flooding.
- **Drain-down:** Structural soil reservoir should drain down within 48 hours to encourage good root distribution through planting pit (Bartens et al., 2009).

Many structural soils are proprietary mixes distributed through licensed providers. Sand-based structural soil (SBSS) is an urban tree planting system that is not proprietary. SBSS consists of a uniform gradation of medium to coarse sand (typically 30 inches deep) mixed with compost (2% to 3% by volume) and loam to achieve approximately 8% to 10% silt by volume.

In general, the saturated hydraulic conductivity should be approximately 4 to 6 in/hr. The uniformly graded sand maintains porosity and infiltration capacity when compacted; however, the load-bearing capacity of the mix is reduced due to the uniform particle size. Accordingly, crushed rock is used between the sand and surface wearing course.

Structural soils can be used in conjunction with permeable pavement (Haffner et al., 2007).

Contact authorized distributors and see (Day and Dickinson, 2008) for guidelines on specific structural soil products.

Increasing Soil and Rooting Volume: Creating Root Paths

Root paths are a technique to connect planting areas, interconnect tree roots, or guide roots out of confined areas to soil under pavement or adjacent to paved area that has the capability to support root growth (e.g. uncompacted, adequately drained loams). The actual root paths add only small amounts of rooting volume. The path trenches are typically 4 inches wide by 12 inches deep and filled with a strip drain board and topsoil. Root paths are excavated with a standard trenching machine, placed approximately 4 feet on center, and compacted with a vibrating plate compactor to retain subgrade structural integrity for pavement. The trenches should be extended into the tree planting pit a minimum of 1 foot and preferably within a few inches of the tree root ball (Urban, 2008).

Increasing Soil and Rooting Volume: Connecting to Adjacent Soil Volume

Soil trenches are used to increase soil and root volume, connect to other tree planting areas, and importantly, connect to larger areas with soil that have the capability to support root growth (e.g. uncompacted, adequately drained loams). The trenches are typically 5 feet wide with sloped sides for structural integrity and filled with topsoil or a designed soil mix. The installed soil is lightly compacted (e.g. 80% Proctor) with a gravel base placed on top of the soil to increase support for the sidewalk. The sidewalk is reinforced with rebar and thickened to span the soil trench. The thickened portion should extend a minimum 18 inches onto the adjacent compacted subgrade. An underdrain may be necessary depending on subgrade soil with low infiltration rates and if stormwater is directed to the tree planting area. Consult with a licensed professional for drainage requirements. Provide subsurface irrigation conduit preferably from stormwater or harvested water in areas with < 30 inches of annual precipitation (Urban, 2008).

Construction Criteria

Protecting new and existing trees and minimizing soil compaction during construction is essential to maintain infiltration and adequate growing characteristics in the built environment. This is particularly true in urban areas. The designer should pay close attention to construction sequencing and material staging from the planning through construction phases as well as tree protection measures after the project is completed. It is also important to protect construction site soils from compaction and contamination in tree planting areas.

See the construction criteria in BMP F6.61: Post-Construction Soil Quality and Depth for additional guidelines.

Operation and Maintenance Criteria

If a tree is dead, damaged, or declining, the tree should be replaced per the planting plan (either with the same type of tree or a substitute that is acceptable to the local jurisdiction).

There are a vast number of resources associated with proper tree maintenance practices, including:

- Washington State University staff have prepared guidance for general tree maintenance that can be found on Washington State University's website:

http://www.wsu.edu/

- Additional sources of species-specific maintenance guidance can be found in The New Sunset Western Garden Book (Sunset Magazine, 2012).
- The American National Standards Institute (ANSI) ANSI A300 Tree Care Standards.

Runoff Model Representation

If the design criteria for this BMP are followed, the total impervious/hard surface areas entered into the runoff model may be reduced by the amount indicated in the design criteria above.

BMP F6.63: Vegetated Roofs

Purpose and Definition

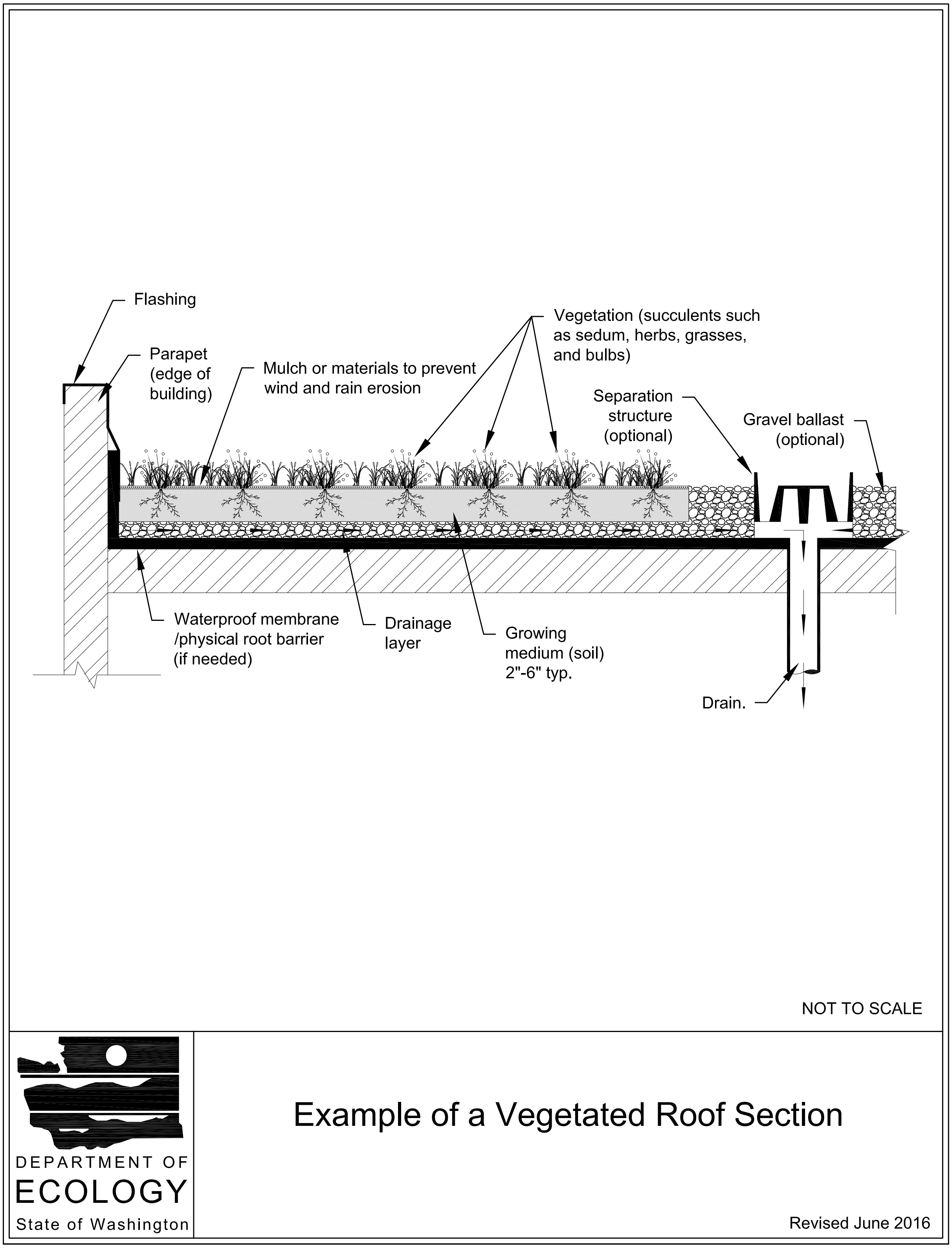
Vegetated roofs (also known as ecoroofs and green roofs) are thin layers of engineered soil and vegetation constructed on top of conventional flat or sloped roofs. Vegetated roofs can provide multiple benefits, including stormwater volume reduction and flow attenuation, resulting in some amount of Flow Control. Air quality and habitat are also enhanced through the use of vegetated roofs. The range of benefits for a vegetated roof depends on a number of design factors such as plant selection, depth and composition of soil mix, location of the roof, orientation and slope, weather patterns, and the maintenance plan.

Perhaps the two most compelling benefits of vegetated roofs that are unassociated with stormwater are those associated with energy savings and service life. The planting system of a vegetated roof creates a buffer between ambient air temperature and the roof insulation. The result is a minimization in fluctuation between high and low temperatures. These benefits can reduce the load on the building’s mechanical heating and cooling systems, resulting in considerable energy savings.

Properly constructed vegetated roofs also last longer than most conventional roofing membranes. Vegetated roofs last longer because the waterproof membrane is protected from ultraviolet rays. The vegetation and substrate cover the membrane and protect it from thermal shock stresses that can result in excessive wear and cracking.

Vegetated roofs have become increasingly popular on office, industrial, and warehouse structures where large, flat roofs are typical of design. The use of vegetated roofs on residential structures in the United States is less common. Many single-family residential roof structures were never designed to accommodate the wet soil loads associated with a vegetated roof. Consequently, the retrofit of residential structures for a vegetated roof often requires significant structural buttressing. Residential structures may also have steeply pitched roofs that make vegetated roofs either technically or economically infeasible.

Figure 6.93: Example of a Vegetated Roof Section



Applications and Limitations

How to use this BMP to Help Meet New and Redevelopment Requirements

Vegetated roofs may be used to reduce the post project impervious surfaces represented in runoff modeling calculations. This may help meet the Flow Control performance goals for 2.4.6 CE6: Flow Control, and/or 2.4.8 CE8: Wetlands Protection.

Weight and Slope Considerations for Retrofit Applications

For retrofit applications, the designer must ensure that the existing roof has both an appropriate slope and adequate structural integrity to support the weight of a vegetated roof. See the design criteria below for slope and weight considerations for vegetated roofs.

Economic Considerations

The economic feasibility of a vegetated roof should be reviewed in the larger context of the cost to operate and maintain the building. The vegetated roof will contribute stormwater values that should be considered when feasibility analyses are performed. Other inputs to the economic feasibility analysis for a vegetated roof should include its longer service life over most conventional roofing materials and the savings in heating and cooling costs.

Types of Vegetated Roofs

Application Types

Vegetated roofs are typically divided into three categories:

- "extensive" (1.5-6 inches deep),
- "intensive" (anything deeper than 6 inches), and
- "semi-intensive" (some combination of intensive and extensive depth ranges).

Extensive vegetated roofs have a shallow (< 6 inches depth) growing medium. These roof designs are typically light-weight structures (approximately 10 to 35 pounds per square foot when wet) that cover large expanses of rooftop and require minimal maintenance. Extensive vegetated roofs do not typically accommodate human use, except for maintenance access (Dunnett and Kingsbury, 2008). Their intent is to maximize the total vegetated area. These are particularly good for roof retrofits, in which the structural capacity of the roof cannot necessarily be improved.

Intensive vegetated roofs typically accommodate human recreational use in that they are used much like a typical garden (Dunnett and Kingsbury, 2008). Intensive vegetated roofs use a deeper growing medium (> 6 inches) and can include small trees and shrubs. They tend to be more expensive and their heavier weight on the roof (approximately 50 to 300 pounds per square foot when wet) must be considered during the design of the roof structure (University of Florida, 2008). They are often built in highly visible areas, such as outdoor roof terraces. Intensive designs are more likely to succeed in new construction where the load bearing capacity of the roof is designed concurrently with the vegetated roof.

The classification of extensive versus intensive roofs is used here to present the well-accepted vernacular of vegetated roof design. These typologies have been helpful in the past at indicating the kinds of plants and functions the vegetated roof could provide. The fact is, if done correctly, elements of one can be incorporated in the other.

Vegetation Assembly Types

There are two types of vegetated roof assemblies: modular and loose laid. Modular assemblies are either containers or pre-vegetated mats. The containers are from 3-6 inches deep and are approximately 3-4 feet wide. Pre-vegetated mats are usually high-density polypropylene filament mesh approximately ¾ inch thick that are planted with vegetation whose roots intertwine with the filaments. Loose laid assemblies are mats that have each element independently installed. There are advantages and disadvantages to each approach and modular and loose laid assemblies can be incorporated into one installation.

Vegetated Roof Components

General design criteria for the major components of vegetated roofs are provided below. See Figure 6.94: Basic Vegetated Roof Components for an illustration of each component of a vegetated roof.

Roof Deck

There are three common roof deck assemblies that influence vegetated roof design:

- Inverted roof membrane assembly
- Conventional roof membrane assembly
- Cold roof assembly

Each is defined by the relationship among the roof insulation, the roof deck, and the waterproof membrane. In an inverted roof membrane assembly, the insulation is placed above the membrane with the geotextiles, growth media, and plants placed above. In a conventional roof membrane assembly, the membrane is on top of the insulation, which, in turn, rests on the roof deck. A cold roof assembly has the membrane on top of the roof deck and the insulation placed under the deck and separated from the underside of the deck by a ventilation space.

The roof deck can be made of steel, concrete, plywood, or any other material sufficiently strong to support the load of the vegetated roof between framing members and provide an acceptable substrate for the membrane. Its drainage planes must be slightly more aggressive than those designed for a typical flat roof because minor ponding will not evaporate as quickly under a vegetated roof assembly. The deck may also be supplemented by other materials, such as fiber cement board, used to provide a bondable surface for certain membrane types.

Roof Structural Support

Ensure that the additional weight of the vegetated roof is distributed evenly across the roof deck and support structure below. Working closely with a licensed engineer in the state of Washington with structural expertise throughout the design of the vegetated roof is essential. Consider the weight of saturated soils, weight of snow in the winter, as well as a maintenance regime to mechanically remove snow buildup to prevent roof damage and collapse.

Fire Protection

Flammable materials in the construction of the vegetated roof should be avoided. Designers should maintain a clear rock or gravel border around parapet walls, rooftop windows, chimneys, and other openings where fire may spread. Specifying fire-resistant vegetation can also minimize the total amount available fire fuel. Factory Mutual's knowledge center, at the following web address, provides fire ratings, research, and testing related to reducing property-related hazards:

http://www.fmglobal.com/

Protective Layer – Root Penetration Layer

Maintaining a continuous separation between the roof membrane and vegetative root zone will reduce the potential for root damage. The material should be raised above the substrate at the edges and around vertical projections, like vents.

Waterproof Membrane

Waterproof membranes used for vegetated roofs are generally slightly thicker than those used for standalone applications. Built-up roofing is still used in some instances; however, most of the current waterproof membranes fall under the following categories:

- Single-ply membranes such as:
  - EPDM (Ethylene propylene diene monomer), a rubber that comes in either reinforced or non-reinforced varieties.
  - TPO (Thermoplastic polyolefin) or PVC (Polyvinyl chloride). Both of these are thermo-plastics.
- Multi-ply membrane applications such as:
  - SBS (styrene butadiene styrene)
  - APP (Attactic polypropylene)
- Fluid or spray applied membranes of various chemical compositions, such as resins, Urethanes, EPDM, butyl-modified bitumen, among others.

Different manufacturers of the same type of membrane may produce different qualities of product. So all TPO's, for instance, are not identical. Asphaltic membranes contain a carbon that is attractive to plant roots. Most asphaltic membranes, therefore, require a root barrier to be installed if they are used in a vegetated roof assembly. Different membranes may have more recycled content, may be more readily recyclable, have less embodied energy, or have less impact on the environment in general, making them "greener" than the alternatives. In a retrofit scenario, some membranes may be chemically incompatible with materials in the previous application. For example, asphaltic materials are chemically incompatible with materials such as TPO and PVC.

Membranes can be mechanically fastened or adhered to the roof deck; however, it is generally recommended they be fully adhered. In conjunction with the field membrane (the membrane that covers the large areas of the roof), there is also the flashing membrane. Flashing membrane is generally thinner, more flexible, and not reinforced in order for it to fit around various shapes like corners and roof deck penetrations. Like the field membrane. it is waterproof. When leaks occur, the vast majority of them are in areas around flashing. Membrane manufacturers have developed pre-molded flashing elements to reduce chance of leakage in these areas.

Each of the membrane types mentioned has its own process to bond waterproof seams. EPDM use solvents and adhesives, like a tire patch kit. TPO and PVC use hot air to melt plies into each other. SBS uses open flame torches. Many membrane applications can involve several different types of adhesion or bonding. For example, TPO and PVC can use both hot air and adhesives to bond in different situations. In addition to membrane applications like field membrane and flashing membrane, there is also count-flashing that is not waterproof and is designed to shed water away from vulnerable areas, such as membrane terminations. Details for membrane roofing are readily available from membrane manufacturers and organizations like the Sheet Metal and Air Conditioning Contractors' National Association and the National Roofing Contractors Association. Membrane manufacturers have warranty details that must be used in their assemblies in order to qualify for warranty coverage.

Drainage Layer

All vegetated roofs should have a drainage component. Usually this takes the form of a drain mat or granular drainage media. Drain mats come in many configurations, from polyethylene dimpled sheets with cups that hold water to polypropylene filament. They rest on the waterproof membrane and in some situations serve as a membrane protection. Granular drainage material is free from organics and usually rests on a protection fabric placed on the membrane.

Drainage elements serve two functions:

1. Remove excess water from saturated growth media (soil mix).
2. Help provide aeration to the bottom layer of growth media.

Drain mats are designed to resist the compressive forces of the growth media and vegetation above. Drain mats are also frequently used under non-vegetated areas, such as inert border areas to protect the membrane, as well as to ensure good drainage on the entire roof.

Many drain mats come with an adhered filter fabric. The role of filter fabric is to contain the fines and organics within the planted area. Filter fabric is non-woven polyethylene, polystyrene or other inert material. In time, roots will penetrate the fabric; however, the critical time for its proper functioning is within the first 5-10 years of the roof's soil and plant development. Filter fabric must be placed between the growth media and any other element, horizontal or vertical. If the vegetation is not bounded by a parapet, some other kind of border or soil restraint is placed on top of the drainage and filtration layers and around the perimeter of the planted area. Frequently, this is an aluminum angle to the height of the soil depth. This restraint must be inert and sturdy enough to withstand the overturning forces of the adjacent soil mix. Placing the perimeter restraint on the drain mat/layer allows drainage water to freely flow below it.

Substrate / Growth Media

Vegetated roof soil, or substrate, must support the chemical, biological, and physical requirements of the plants, which is especially challenging due to the system's disconnection from the ground. Substrate varies in depth and composition for structural, planting, and stormwater management purposes. Depending on the soil composition and weight, additional roof support may be required. Weight, water storage, and nutrient-holding capacity are the primary factors to be considered when selecting substrate and drainage material (WSU and PSP, 2012).

The substrates of vegetated roofs perform the majority of water retention. The amount of water retained is primarily a factor of substrate depth, although studies suggest that substrates deeper than 6 inches do not necessarily provide more retention capability (Retzlaff, 2006).

Substrate depths of 2 to 3 inches support a wider range of succulent species, grasses, and herbaceous plants. Depths of 4 to 8 inches will enable a wide range of drought-tolerant perennials and grasses and some tough small shrubs. Substrate depths of 12 to 20 inches will allow the growth of many perennials and shrubs, whereas trees require 32 to 52 inches.

Vegetation

The plants on vegetated roofs are typically succulents, grass, herbs, and/or wildflowers adapted to the harsh conditions (minimal soils, seasonal drought, high winds, and strong sun exposure - i.e. alpine conditions) prevalent on rooftops . Plants should have a proven capacity to tolerate rooftop growing conditions, such as extreme temperatures and drought. Some examples of plant species are sempervivum, sedum, creeping thyme, allium, phloxes, and anntenaria. (Scholtz-Barth, 2001).

Vegetated roofs are not native environments. As a result, many native plants that do well at grade do very poorly on adjacent vegetated roofs. Two identical vegetated roofs very close to one another may develop differently due to subtle differences in their microclimates. The designer should identify the different zones of exposure and moisture on the roof prior to developing the planting scheme. Rooftops have many microclimates to consider. Vertical surfaces, such as walls and parapets, may shade or reflect light and heat onto plantings depending on their orientation. The parts of the roof near the top of a slope are frequently drier and more prone to drought conditions than the areas at the toe of a slope and around roof drains, where moisture tends to collect.

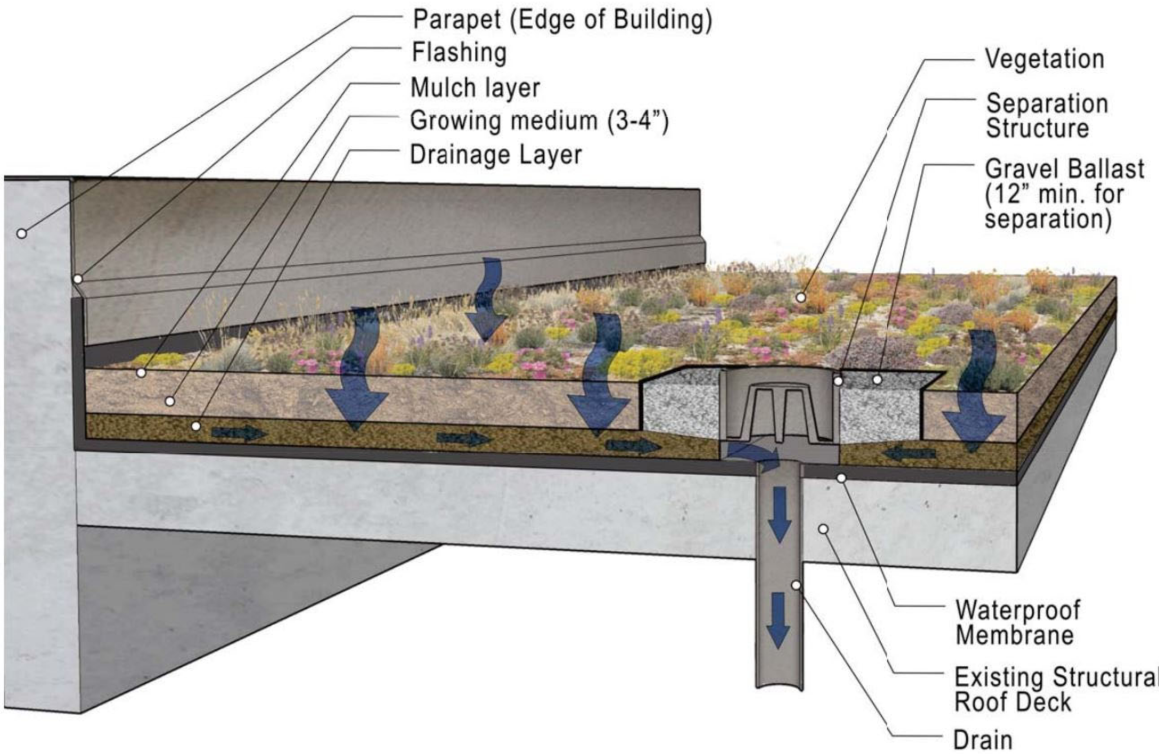
As growth media becomes deeper, a wider variety of plants can be used. At 2-3 inches mosses, sedums, and some grasses are possible. At 3-5 inches a wider array of sedums and grasses are possible, with the addition of some herbaceous perennials. And at 6-8 inches a relatively wide variety of the genera is possible. The varieties of plants can start to approximate the plants at grade when the growth media is deeper than 8 inches.

Plants can be installed as vegetated mats, individual plugs, spread as cuttings, or by seeding. Vegetated mats and plugs provide the most rapid establishment for sedums. Cuttings spread over the substrate are slower to establish and will likely have a high mortality rate; however, this is a good method for increasing plant coverage on a roof that is in the process of establishing a plant community (Scholtz-Barth, 2001). During the plant establishment period, soil erosion can be reduced by using a biodegradable mesh blanket or a hydro-mulch paper emulsion.

Leak Detection Layer (Optional)

Electronic leak detection systems are an optional technology designed to precisely locate a leak if one occurs after construction. Using a leak detection system reduces the likelihood that the significant portions of the vegetated roof materials will have to be removed in the event of a leak (WSU and PSP, 2012).

Figure 6.94: Basic Vegetated Roof Components



Source: Low Impact Development Approaches Handbook (CleanWater Services, 2009)

DEPARTMENT OF ECOLOGY
State of Washington

Basic Vegetated Roof Components

Revised June 2013

Design Criteria

General Design Criteria

Vegetated roofs should be designed on a site-by-site, building-by-building basis so that all opportunities and constraints are comprehensively evaluated and used to guide the vegetated roof design.

Sizing requirements for vegetated roofs will vary considerably depending on the type of roof (e.g. extensive or intensive), structural loading requirements, roof size and drainage needs, etc. Consult a licensed engineer in the state of Washington with structural expertise for sizing the system for structural capacity, a licensed professional for sizing drainage system components, a landscape architect for determining plant type, sizes, and spacing, and other licensed professionals as needed based on the site-specific application.

The waterproof membrane must be protected once installed and should be tested in accordance with the manufacturer's recommendations prior to placement of the growth medium and other subsequent vegetated roof materials (WSU and PSP, 2012).

Making the roofing contractor responsible for the vegetated roof installation, either directly or by means of subcontracted services, can help ensure that the integrity of the waterproof membrane is maintained during construction.

Off-the-shelf vegetated roof products have become popular as roofing companies seek to fill the growing demand for vegetated roofs. Off-the-shelf products are typically installed by roofing contractors that are licensed by the company that furnished or grew the vegetation mats or trays. Where off-the-shelf roof systems are selected, the product design will be provided by the company that grew the vegetation mats or trays based on the microclimatic conditions provided by a licensed professional and the building design provided by the architect and licensed engineer in the state of Washington with structural expertise.

Planning

Vegetated roofs can be an effective low impact development (LID) BMP. However, local climate considerations like freezing temperatures, heavy snowfall, strong winds, and hot, arid summers need to be considered when analyzing the use of a vegetated roof.

During the initial planning stages, the designer should consider the following questions:

- What is the appropriate type and design of vegetated roof based on its intended function?
- Is the load bearing capacity of the building able to support the intended vegetated roof? What is that capacity? Is the size of the roof sufficient?
- Can the vegetated roof be maintained easily and affordably?
- What stormwater benefits will accrue from the design?

Because of their location, vegetated roofs typically require more planning and coordination to implement than ground-level landscaping. For new construction, a critical path approach is highly recommended to establish the sequence of tasks to be carried out during construction of the system. New construction involves many trades, each with its particular role and potential conflicts during installation of the vegetated roof. For example, construction may require coordination among a general contractor, landscape contractor, roofing contractor, leak detection specialist, irrigation specialist, HVAC contractor, and construction inspectors, all of whom require access to the roof areas at various times during the process.

Weight Considerations

One of the first steps in the design is to establish the allowable weight of the vegetated roof system. For existing buildings, the building structure should be evaluated by a structural engineer to determine the available capacity to bear the additional weight of the vegetated roof. For new buildings, structural design calculations should account for the weight of the proposed roof system.

Slope Considerations

While vegetated roofs can be installed on slopes up to 40 degrees, slopes between 5 and 20 degrees are most suitable and can provide natural drainage by gravity. Roofs with slopes greater than 10 degrees require an analysis of engineered slope stability, and those greater than 20 degrees require a structural reinforcement system and additional assemblies to hold the soil substrate and drainage aggregate in place (WSU and PSP, 2012).

Runoff Model Representation

Conduct the following steps to size vegetated roofs for Flow Control credit:

1. Determine the depth of the vegetated roof growing medium (D). The following assumptions may be used:
    - Succulent species, grasses, and herbaceous plants = 2 to 3 inches
    - Drought-tolerant perennials and grasses and some tough small shrubs = 4 to 8 inches
    - Perennials and shrubs = 12 to 20 inches
    - Trees = 32 to 52 inches
2. Select an appropriate land use type for input into the hydrologic model (see Chapter 4 - Hydrologic Analysis and Design for hydrologic modeling methods).
    - For vegetated roof surfaces with 3 to 8 inches of growing medium depth, model the roof surface as 50% lawns, heavy soil (open space, fair condition) area and 50% impervious area.
    - For vegetated roof surfaces with greater than 8 inches of growing medium depth, model the roof surface as 50% lawns, sandy soil (open space, good condition) and 50% impervious area.

Operation and Maintenance Criteria

Proper maintenance and operation are essential to ensure the designed performance and benefits continue over the full life cycle of the installation. Each vegetated roof installation will have specific design, operation, and maintenance guidelines provided by the manufacturer and installer.

The following guidelines provide a general set of standards for prolonged vegetated roof performance. Note that some maintenance recommendations are different for extensive versus intensive vegetated roof systems. The procedures outlined below focus on extensive roof systems, and different procedures for intensive roofs are noted.

See Appendix 6-A: BMP Maintenance Tables for additional maintenance guidelines.

Schedule

- All facility components, including structural components, waterproofing, drainage layers, soil substrate, vegetation, and drains, should be inspected for proper operation throughout the life of the system.
- The manufacturer or designer should provide the maintenance and operation plan and inspection schedule.
- All elements should be inspected no less than two times per year for extensive installations and four times annually for intensive installations. Some manufacturers suggest monthly inspections.
- The facility owner should keep a maintenance log recording inspection dates, observations, and activities.
- Inspections should be scheduled to coincide with maintenance operations and with important horticultural cycles (e.g. before major weed varieties disperse seeds).

Structural and drainage components

- Structural and drainage components should be maintained according to manufacturer's requirements and accepted engineering practices.
- Drain inlets should provide unrestricted stormwater flow from the drainage layer to the roof drain system unless the assembly is specifically designed to impound water as part of an irrigation or stormwater management program.
    - Clear the inlet pipe of soil substrate, vegetation, or other debris that may obstruct free drainage of the pipe. Sources of sediment or debris should be identified and corrected.
    - Inspect the drain pipe inlet for cracks, settling, and proper alignment, and correct and re-compact soils or fill material surrounding the pipe if necessary.
- If part of the roof design, inspect fire ventilation points for proper operation.

Vegetation management

- The vegetation management program should establish and maintain a minimum of 90 percent plant coverage on the soil substrate.
- During regularly scheduled inspections and maintenance, bare areas should be filled in with manufacturer-recommended plant species to maintain the required plant coverage.
- Normally, dead plant material will be recycled on the roof; however, specific plants or aesthetic considerations may warrant removing and replacing dead material (see manufacturer's recommendations).
- Invasive or nuisance plants should be removed regularly and not allowed to accumulate and exclude planted species. At a minimum, schedule weeding with inspections to coincide with important horticultural cycles (e.g. before weed varieties disperse seeds).
- Weeding should be performed manually and without herbicide applications when possible.
- Extensive roof gardens should be designed to require minimal fertilization after plant establishment. If fertilization is necessary during plant establishment or for plant health and survivability after establishment, use an encapsulated, organic slow release fertilizer (excessive fertilization can contribute to increased nutrient loads in the stormwater system and receiving waters). If possible, test the growth medium prior to fertilization. Some membranes are resistant to fertilizers and others are not; check with the membrane manufacturer prior to fertilizer application.
- Intensive vegetated roofs typically require more fertilization than extensive roofs. Follow manufacturer's and installer's recommendations.
- Avoid application of mulch on extensive roofs. Mulch should be used only during plant establishment or in unusual situations, and according to the roof manufacturer's guidelines. In conventional landscaping, mulch enhances moisture retention; however, moisture on a vegetated roof should be controlled by means of proper growth media design. Mulch can also increase the establishment of weeds.

Irrigation

- Plant selection directly affects water requirements for the vegetated roof.
- Surface irrigation systems on extensive roof gardens can promote weed establishment and root development near the drier surface layer of the soil substrate, and increase plant dependence on irrigation. Accordingly, subsurface irrigation methods are preferred. If surface irrigation is the only method available, use drip irrigation to deliver water to the base of the plant.
- Extensive roofs should be watered only when absolutely necessary for plant survival. When watering is necessary (i.e. during early plant establishment and drought periods), saturate to the base of the soil substrate (typically 30-50 gallons per 100 square feet) and allow soil to dry completely.

Operation and maintenance agreements

- Written guidance and/or training for operating and maintaining the vegetated roof should be provided along with the operation and maintenance agreement to all property owners and tenants.

Contaminants

- Measures should be taken to prevent the possible release of pollutants to the roof garden from mechanical systems or maintenance activities on mechanical systems.
- Any cause of pollutant release should be corrected as soon as identified and the pollutant removed. Contact the membrane manufacturer regarding potential damage to the membrane due to contaminants.

Insects

- Properly designed vegetated roofs will provide drainage rates that do not allow pooling of water for periods that are long enough to promote development of insect larvae. If standing water is present for extended periods, inspect the drainage elements and correct the drainage problem.
- Chemical sprays should not be used.

Access and safety

- Egress and ingress routes should be clear of obstructions and maintained to design standards.
- Safety procedures appropriate for maintaining the roof should be clearly identified and should include training of workers, fall prevention systems, and safety harnesses.

BMP F6.64: Minimal Excavation Foundations

Purpose and Definition

Grading and excavation during construction can degrade the infiltration and storage capacity of native soils. A minimal excavation foundation is a building best management practice (BMP) that minimizes mass grading and site disturbance by distributing a building's structural load onto piles or limited excavation perimeter walls.

As noted in the *Low Impact Development Technical Guidance Manual for Puget Sound* (WSU and PSP, 2012), "[m]inimal excavation foundation systems take many forms, but in essence are a combination of driven piles and a connecting component at, or above, grade. The piles allow the foundation system to reach or engage deeper load-bearing soils without having to dig out and disrupt upper soil layers, which convey, infiltrate, store, and filter stormwater flows."

Piles are a less disruptive approach to site development. The piles may be vertical, screw-augured, or angled pairs that can be made of corrosion-protected steel, wood, or concrete. The connection component handles the transfer of loads from the above structure to the piles and is most often made of concrete. Cement connection components may be precast or poured on-site in continuous perimeter wall or isolated pier configurations.

Although not as widely used as other low impact development (LID) BMPs, minimal excavation foundations hold an important place within LID guidance. Minimal excavation foundations can make sites developable that would be otherwise undevelopable. Sites with shallow depth to bedrock, high water tables, or challenging soils such as the lithosols and caliche soils can be made buildable through the use of minimal excavation foundations.

Applications and Limitations

Consult with a licensed engineer in the state of Washington with geotechnical and structural expertise to determine the feasibility of using limited excavation foundations. Designers should consider the following guidance:

- Minimal excavation foundations generally are not suitable for structures greater than three stories high.
- Perimeter walls with pins generally should not be used on sites with slopes > 10%.
- Piers generally should not be used on sites with slopes > 30%
- Minimal excavation foundations should not be used on sites with high organic content or low bearing capacity unless the depth to bearing soils is limited (use is subject to review and evaluation by a licensed engineer in the state of Washington with geotechnical expertise).
- Minimal excavation foundations should not be used on fill soils unless the pilings can reach the bearing soils (use is subject to review and evaluation by a licensed engineer in the state of Washington with geotechnical expertise).
- To minimize soil compaction, heavy equipment, including pile driving equipment that would degrade the natural soil profile's ability to retain, drain and/or filter stormwater cannot be used within or immediately surrounding the building. Tracked equipment weighing 650 psf or less is acceptable.

General Design Criteria

Minimal excavation foundations in both pier and perimeter wall configurations are suitable for residential or commercial structures up to three stories high. Accessory structures such as decks, porches, and walkways can also be supported, and the technology is particularly useful for elevated paths and foot-bridges in open spaces and other environmentally sensitive areas. Wall configurations are typically used on flat to sloping sites up to 10%, and pier configurations flat to 30%.

The minimal excavation foundation approach can be installed on all soils, provided the material is penetrable and will support the intended type of piles. Soils typically considered problematic due to high organic content (e.g. topsoils or peats) or overall bearing characteristics may often remain in place provided their depth is limited and the pins have adequate penetration into suitable underlying soils.

These systems may be used on fill soils if the depth of the fill does not exceed the reaction range of the intended piles. Fill compaction requirements for support of such foundations may be below those of conventional development practice in some applications. In all cases, for both custom and preengineered systems, a qualified professional should determine the appropriate pile and connection components and define criteria for specific soil conditions and construction requirements.

Based on the type of structure to be supported and the specific site or lot topography, a pier-type foundation or perimeter-wall-type foundation must first be selected (see Figure 6.95: Pier-Type Minimal Excavation Foundation and Figure 6.96: Wall-Type Minimal Excavation Foundation). Soil conditions are determined by a limited geotechnical analysis identifying soil type, water content at saturation, strength and density characteristics, and in-place weight. However, depending on the pile system type, the size or scale of the supported structure, and the nature of the site and soils, a more complete soils report including slope stability and liquefaction analysis may be required.

Piers using pin piles can be used for various structure types, including residential and light commercial buildings. When designing with piers, the licensed professional or vendor supplies the structural requirements (pile length and diameter and pier size) for the pier system. A licensed engineer in the state of Washington with structural expertise then determines the number and location of piers given the structure size, loads, and load bearing location.

Roof runoff and surrounding storm flows may be allowed to infiltrate without using constructed conveyance when selection of the foundation type and grading strategy results in retention of the top layers of soil without significant reduction in soil permeability and storage capability.

Where possible, roof runoff should be infiltrated uphill of the structure and across the broadest possible area. Infiltrating upslope more closely mimics natural (preconstruction) conditions by directing subsurface flows through minimally impacted soils surrounding, and in some cases, under the structure. This provides infiltration and subsurface storage area that would otherwise be lost in the construction and placement of a conventional “dug-in” foundation system. Passive gravity systems for dispersing roof runoff are preferred; however, active systems can be used if backup power sources are incorporated and a consistent and manageable maintenance program is ensured.

Garage slabs, monolithic-poured patios, or driveways can block dispersed flows from the minimal excavation foundation perimeter and dispersing roof runoff uphill of these areas is not recommended (or must be handled with other stormwater management practices). Some soils and site conditions may not warrant intentionally directing subsurface flows directly beneath the structure, and in these cases, only the preserved soils surrounding the structure and across the site may be relied on to mimic natural flow pathways.

Figure 6.95: Pier-Type Minimal Excavation Foundation

Source: AHBL, Inc.

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Pier-Type Minimal Excavation Foundation

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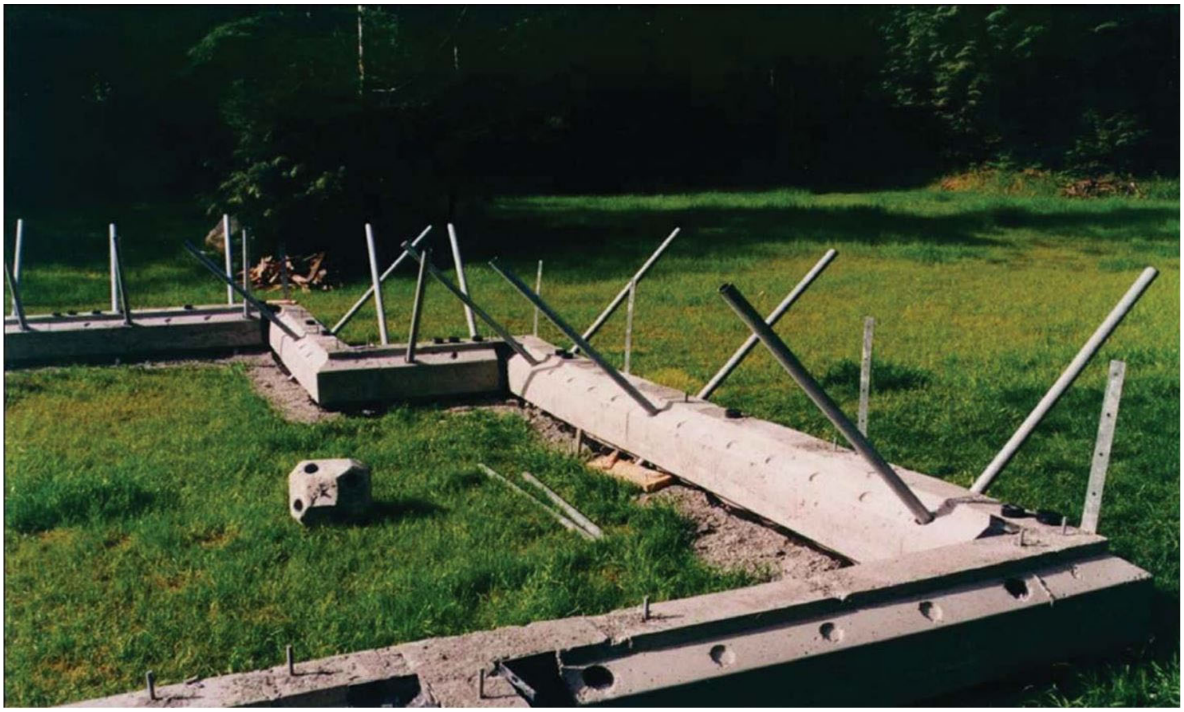
Figure 6.96: Wall-Type Minimal Excavation Foundation



Source: Pin Foundations, Inc.

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Wall-Type Minimal Excavation Foundation

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Design Procedure

Determine the size and quantity of pin piles based on the size of the structure, number of stories, and weights of materials used. Pin piles should be sized to resist both gravity (dead, live, and snow) and lateral loads (wind and seismic). Additional design considerations include uplift resistance for seismic overturning forces. Sizing of minimal excavation foundations is performed by a licensed engineer in the state of Washington with structural and geotechnical expertise on a site-by-site basis.

Construction Criteria

Piers

Pier applications require grubbing, and in some cases, blading to prepare the site. The permeability of some soil types can be significantly reduced even with minimal equipment activity; accordingly, the lightest possible tracked equipment should be used for preparing or grading the site. Consult a qualified professional with soils experience for site specific recommendations.

On relatively flat sites, blading should be limited to shaping the site for the best possible drainage and infiltration. Removing the organic topsoil layer is not typically necessary. On sloped sites, the soils may be bladed smooth at their existing grade to receive pier systems, again with the goal of achieving the best possible drainage and infiltration. This will result in the least disturbance to the upper permeable soil layers on sloped sites.

Minimal excavation systems may be installed “pile first” or “post pile.” The pile first approach involves driving or installing all required piles in specified locations to support the structure, and then installing a connecting component (such as a formed and poured concrete grade beam) to engage the piles. Post pile methods require the setting of precast or site poured components first, through which the piles are then driven. Pile first methods are typically used for deep or problematic soils where final pile depth and embedded obstructions are unpredictable. Post pile methods are typically shallower using shorter, smaller diameter piles—and used where the soils and bearing capacities are well defined. In either case, the piles are placed at specified intervals correlated with their capacity in the soil, the size and location of the loads to be supported, and the carrying capacity of the connection component.

The piles are driven with a machine mounted, frame mounted, or handheld automatic hammer. The choice of driving equipment should be considered based on the size of pile and intended driving depth, the potential for equipment site impacts, and the limits of movement around the structure.

Walls

Piling combined with precast walls with sloped bases, or slope cut forms for pouring continuous walls, may be used on sites with limited topography changes similar to the pier applications. Rectilinear wall systems (flat bottom sections), combined with piles, may also be used, but require more site preparation and soil disturbance.

While creating more soil disturbance, sloped sites should be terraced to receive conventional flat-bottomed forms or precast walls. The height difference between terraces will be a result of the slope percentage and the width of the terrace itself. The least impacts on soil will be achieved by limiting the width of each terrace to the width of the equipment blade and cutting as many terraces as possible. Some footprint designs will be more conducive to limiting these cuts and should be considered by the designer.

The terracing technique removes more of the upper permeable soil layer and this loss should be figured into any analysis of storm flows through the site. As with the pier systems, consult a qualified professional with soils experience for specific recommendations.

With wall systems, a free draining, compressible buffer material (pea gravel, corrugated vinyl or foam product) should be placed on surface soils to prepare the site for placement of wall components. This buffer material separates the base of the grade beam from surface of the soil to prevent impacts due to expansion or frost heave and, in some cases, is used to allow movement of saturated flows beneath the wall.

Additional soil may remain from foundation construction depending on grading strategy and site conditions. The material may be used to backfill the perimeter of the structure if the impacts of the additional material and equipment used to place the backfill are considered when evaluating runoff conditions.

Operation and Maintenance Criteria

Corrosion rates for buried galvanized or coated steel piling, or degradation rates for buried concrete piling, are typically very low to nonexistent, and piling for these types of foundations are usually considered to last the life of the structure. Special conditions such as exposure to salt air or highly caustic soils in unique built environments, such as industrial zones, should be considered. Wood piling typically has a more limited lifetime. Some foundation systems also allow for the removal and replacement of pilings, which can extend the life of the support indefinitely.

Runoff Model Representation

- Where residential roof runoff is dispersed on the up-gradient side of a structure in accordance with the design criteria and guidelines in BMP T5.10B: Downspout Dispersion Systems, the tributary roof area may be modeled as pasture underlain by the native soil type, provided the dispersed runoff is not cut off by an embedded grade beam, wall, or skirt structure from reaching the preserved permeable soils below the building.
- If roof runoff is dispersed down gradient of the structure in accordance with the design criteria and guidelines in BMP T5.10B: Downspout Dispersion Systems, AND there is at least 50 feet of vegetated flow path through native material or lawn/landscape area that meets the guidelines in BMP F6.61: Post-Construction Soil Quality and Depth, the tributary roof areas may be modeled as lawn/landscaped area.
- Where terracing on a slope below the building or vegetated flow path, as defined above, is necessary for construction, the square footage of roof that can be modeled as pasture or lawn/landscaped area must be reduced to account for lost permeable soils. The roof area modeled as pasture or lawn/landscape shall be reduced by the same percentage as that of the intact permeable soils in the slope below the structure or within the down gradient flow path that are removed by the terracing.

6.13 Detention BMPs

6.13.1 Introduction to Detention BMPs

This section presents guidance for design and analysis of detention BMPs. These BMPs provide Flow Control by providing temporary storage of the increased surface water runoff that results from development. The amount of Flow Control required for a project varies depending on the project type and location (e.g. retrofit projects vs. new or redevelopment projects required to meet standards per 2.4 Core Elements (CEs)).

For project sites at which infiltration or dispersion is feasible, infiltration BMPs (6.5 Infiltration BMPs) or dispersion BMPs (6.3 Dispersion BMPs) may be preferred over detention BMPs because they better mimic predeveloped hydrologic conditions and are often smaller and easier to maintain.

The concept of detention is to collect runoff from a developed area and, using a control structure, release it at a slower rate as it enters the collection system (see 6.13.2 Control Structure Design). The reduced release rate requires temporary storage of the excess runoff in a pond, tank, or vault, with the release occurring over a few hours or days. The volume of temporary storage needed is dependent on:

1. The size of the drainage area,
2. The extent of disturbance of the natural vegetation, topography, and soils and creation of effective impervious surfaces (i.e. surfaces that drain to a stormwater collection system), and
3. How rapidly the water is allowed to leave the detention BMP (i.e. the target release rates).

If runoff from surfaces that require Flow Control is not separated from runoff from other existing surfaces (whether on-site or off-site), refer to the guidance in 4.2.4 Flow Bypass and Additional Area Inflow for additional guidance when sizing the detention BMPs.

Cold Climate Considerations

Cold climates can present additional challenges to the selection, design, and maintenance of Detention BMPs due to the potential for pipe freezing, lose of infiltration capability, ice clogging of orifice or other control structures, short growing season (for landscaped BMPs), and the need to manage snowfall. Designers of Detention BMPs in cold climates should be aware of these challenges and make provisions for them in their final designs.

Regions which have an average daily maximum temperature of 35°F or less during January, and which have a growing season < 120 days, are especially vulnerable to the effects of cold weather. These cold weather conditions exist in many parts of eastern Washington and are therefore an important design concern. See 6.1.8 Cold Weather Considerations for additional information on cold weather challenges to BMP design.

Arid and Semiarid Climate Considerations

For vegetated detention pond BMPs in arid/semiarid portions of eastern Washington, plants should be selected to be drought tolerant and not require watering after establishment (2 to

3 years). In more arid environments, watering may be needed during prolonged dry periods after plants are established.

BMP F6.13: Rainwater Harvesting can be used in environments where rainfall or other conditions limit water supply. Many areas of eastern Washington are situated in climate zones where rainwater collection systems, in the form of cisterns, may provide beneficial use.

A challenge in eastern Washington is that the majority of the rainfall occurs during the winter and spring. Summer water demand for irrigation typically exceeds the amount of rainwater harvested on the site. Consequently, rainwater harvesting systems that are used as the sole supply for irrigation will need to be connected with a water supply so that the tanks do not go dry in the summer.

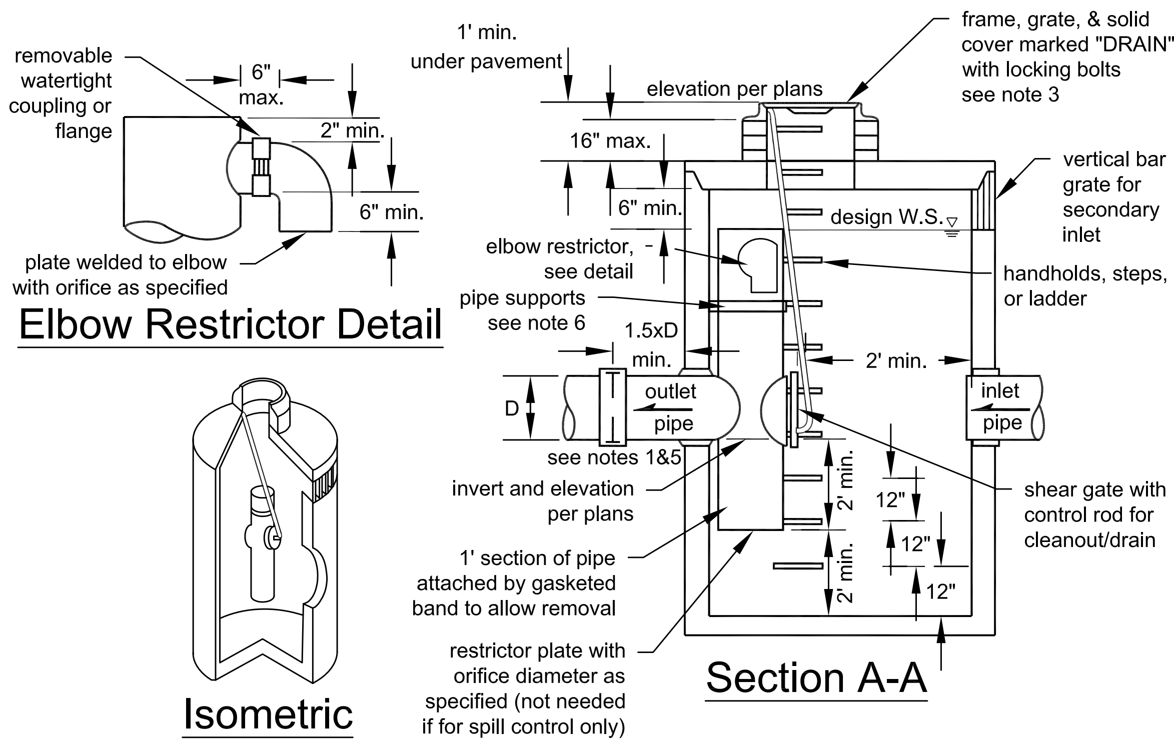
6.13.2 Control Structure Design

Control structures are catch basins or manholes with a restrictor device for controlling outflow from a detention BMP to meet the desired performance standard. Riser type restrictor devices (“tees”) or flow restrictor oil pollution control tees (“FROP-Ts”) also provide some incidental oil and water separation to temporarily detain oil or other floatable pollutants in runoff due to accidental spill or illegal dumping.

The restrictor device usually consists of two or more orifices and/or a weir section sized to meet performance requirements.

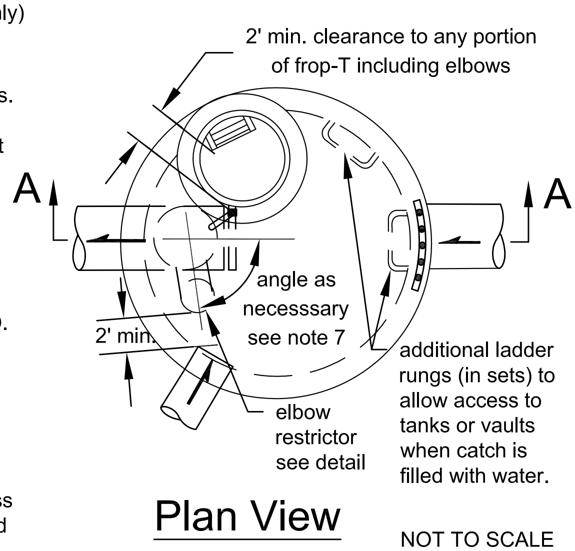
Standard control structure details are shown in Figure 6.97: Flow Restrictor (TEE), Figure 6.98: Flow Restrictor (Baffle), and Figure 6.99: Flow Restrictor (Weir).

Figure 6.97: Flow Restrictor (TEE)



Notes:

1. Use a minimum of a 54" diameter type 2 catch basin.
2. See BMP design guidance for outlet capacity requirements.
3. Metal Parts: Corrosion resistant. Non-Galvanized parts preferred. Galvanized pipe parts to have asphalt treatment 1.
4. Frame and ladder or steps offset so:
   A. Cleanout gate is visible from top.
   B. Climb-down space is clear of riser and cleanout gate.
   C. Frame is clear of curb.
5. If metal outlet pipe connects to cement concrete pipe: outlet pipe to have smooth O.D. equal to concrete pipe I.D. less ¼".
6. Provide at least one 3" x 0.90 inches support bracket anchored to concrete wall. (maximum 3'-0" vertical spacing)
7. Locate elbow restrictor(s) as necessary to provide minimum clearance as shown.
8. Locate additional ladder rungs in structures used as access to tanks or vaults to allow access when catch basin is filled with water.



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Flow Restrictor (TEE)

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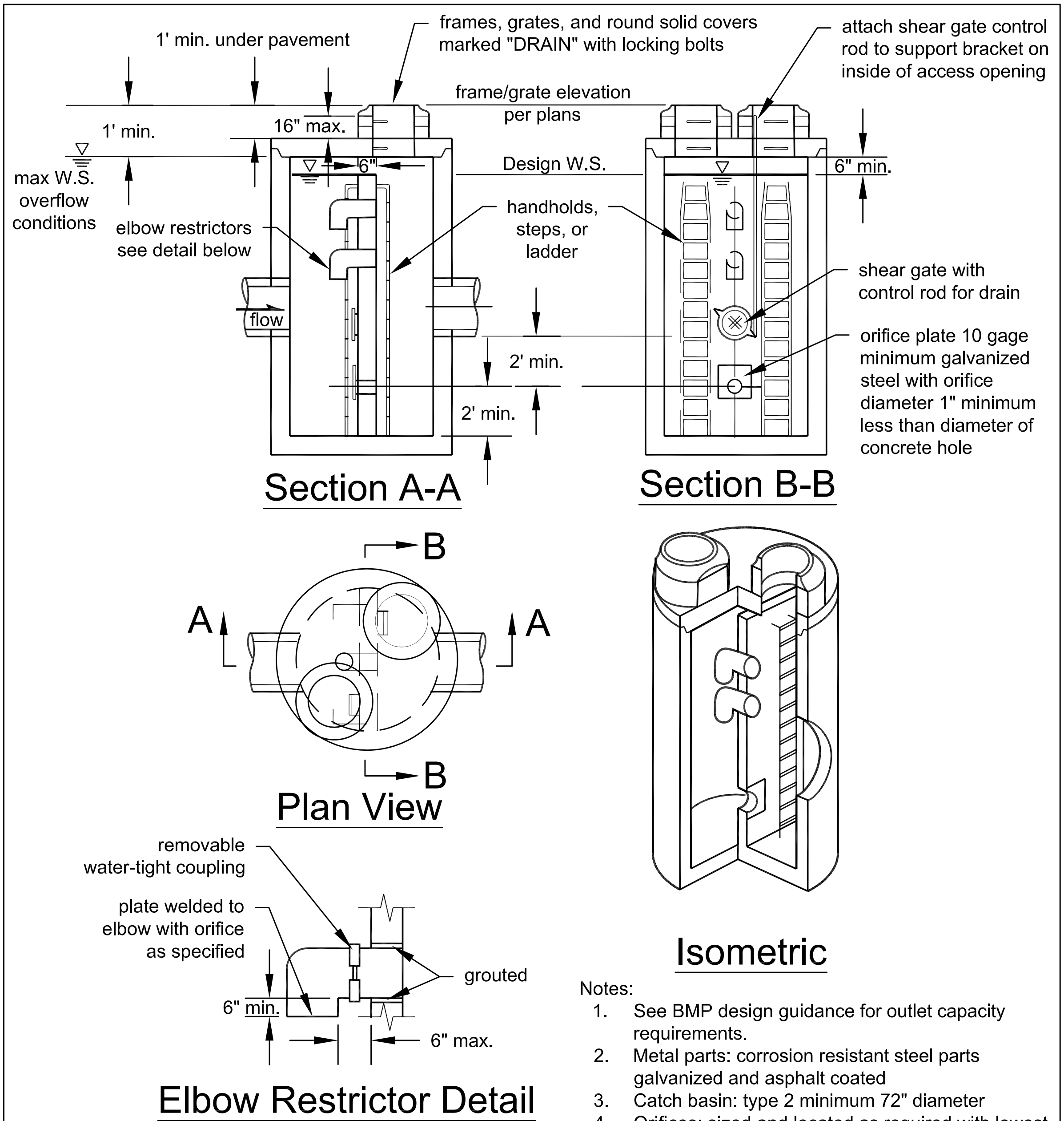
Figure 6.98: Flow Restrictor (Baffle)



Notes:

1. See BMP design guidance for outlet capacity requirements.
2. Metal parts: corrosion resistant steel parts galvanized and asphalt coated
3. Catch basin: type 2 minimum 72" diameter
4. Orifices: sized and located as required with lowest orifice a minimum of 2' from base

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Flow Restrictor (Baffle)

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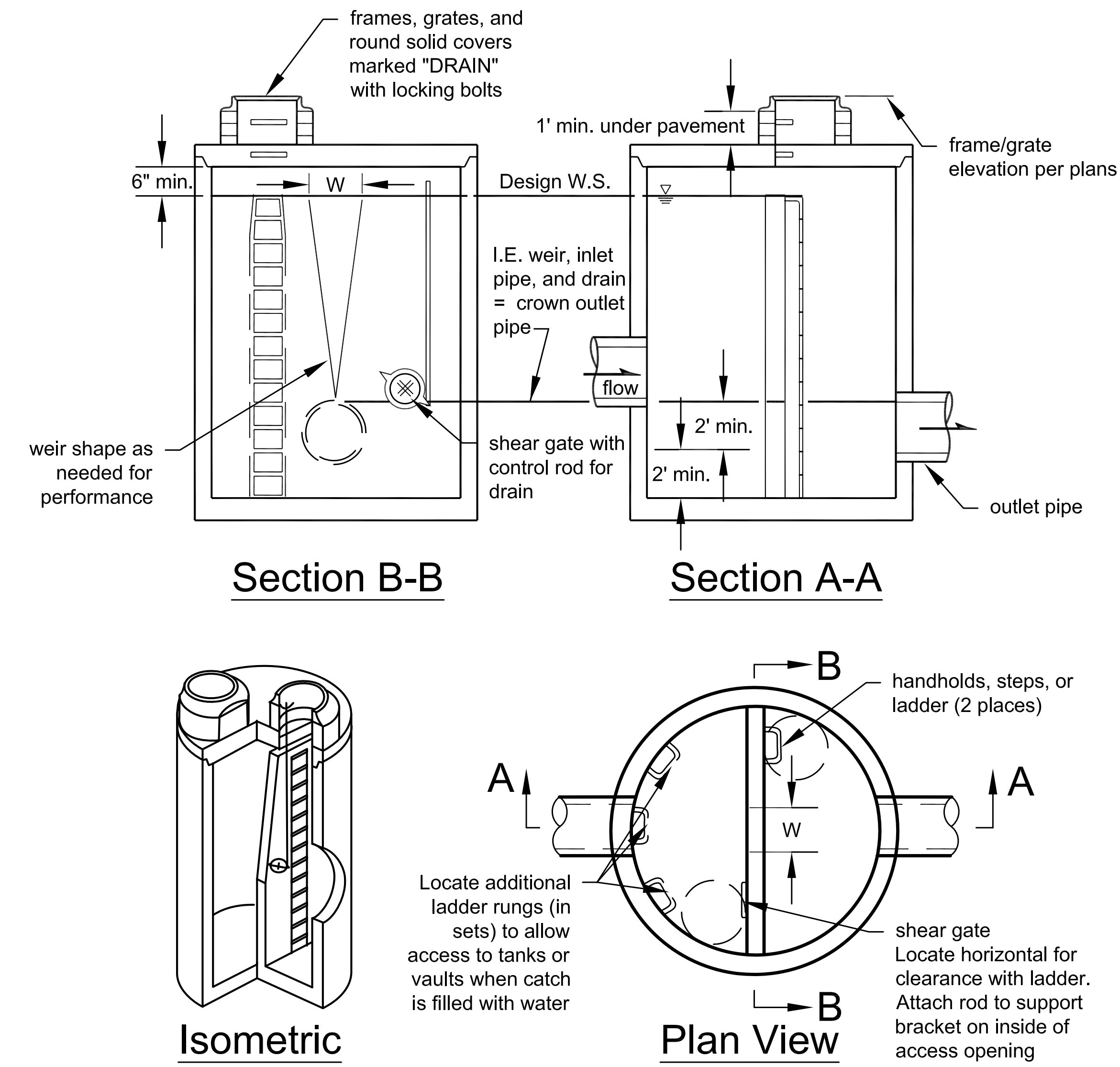
Figure 6.99: Flow Restrictor (Weir)



Notes:

1. See BMP design guidance for outlet capacity requirements.
2. Metal Parts: corrosion resistant steel parts galvanized and asphalt coated.
3. Catch Basin: type 2 min. 72" diameter.
4. Baffle Wall: to be designed with concrete reinforcing as required.
5. Spill containment must be provided to temporarily detain oil or floatable pollutants in runoff due to accidental spill or illegal dumping.

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Flow Restrictor (Weir)

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Design Criteria

Multiple Orifice Restrictor

In most cases, control structures need only two orifices: one at the bottom and one near the top of the riser, although additional orifices may best utilize the detention storage volume. Several orifices may be located at the same elevation if necessary to meet performance requirements.

The following criteria apply to the design of multiple orifice restrictors:

1. The minimum orifice diameter is 0.5 inches. The intent of this requirement is to minimize clogging and maintenance of the orifice.

   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, under such circumstances, flow-throttling devices may be a feasible option. These devices will throttle flows while maintaining a plug-resistant opening.

2. Orifices may be constructed on a tee section as shown in Figure 6.97: Flow Restrictor (TEE) or on a baffle as shown in Figure 6.98: Flow Restrictor (Baffle).

3. 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 (see Figure 6.101: Rectangular, Sharp Crested Weir).

4. Consider the backwater effect of water surface elevations in the downstream conveyance system. High tailwater elevations may affect performance of the restrictor system and reduce live storage volumes.

Riser and Weir Restrictor

1. Weirs may be used as flow restrictors (see Figure 6.99: Flow Restrictor (Weir), Figure 6.101: Rectangular, Sharp Crested Weir, Figure 6.102: V-Notch, Sharp-Crested Weir, and Figure 6.103: Sutro Weir). However, they must be assumed as plugged when designing the primary overflow from the detention BMP.

2. Combined flows from the orifice(s), weir(s), and riser top may be used to meet performance requirements; however, the riser must be designed to provide for primary overflow from the detention BMP (i.e. the riser must pass the 25 year developed peak flow, with all other orifices plugged). See Riser Overflow for a description of how to calculate the head in feet above a riser of given diameter and flow.

Access

1. Provide an access road to the control structure for inspection and maintenance. Design and construct the access road as specified in BMP F6.10: Detention Ponds.

2. Manhole and catch basin lids for control structures must be locking, and rim elevations must match proposed finish grade.

3. Manholes and catch basins must meet the Occupational Safety and Health Administration (OSHA) and Washington Industrial Safety and Health Act (WISHA) confined space requirements, which include clearly marking entrances to confined space areas. This may be accomplished by hanging a removable sign in the access riser, just under the access lid.

Information Plate

It is recommended that a brass or stainless steel plate be permanently attached inside each control structure with the following information engraved on the plate:

- Name and file number of the project
- Name and organization of (1) project proponent, (2) design engineer, and (3) contractor
- Date constructed
- Name and date of manual used for design
- Outflow performance criteria
- Release mechanism size, type, and invert elevation
- List of stage, discharge, and volume at one foot increments
- Elevation of overflow
- Recommended frequency of maintenance.

Maintenance Criteria

Control structures have a history of maintenance-related problems and it is imperative to establish a good maintenance program for them to function properly. A typical problem is that sediment builds up inside the structure, which blocks or restricts flow to the inlet. Similarly, ice buildup during the winter may also block or restrict flows.

To prevent this problem, routinely clean out control structures (i.e. at least twice per year). Conduct regular inspections of control structures to detect the need for non-routine cleanout, especially if construction or land-disturbing activities occur in the contributing drainage area.

A 15-foot-wide access road to the control structure should be installed for inspection and maintenance.

Also see Appendix 6-A: BMP Maintenance Tables.

Methods of Analysis

This section presents the methods and equations for design of control structure restrictor devices. Included are details for the design of orifices, rectangular sharp crested weirs, v-notch weirs, sutro weirs, and overflow risers.

Orifices

Flow through orifice plates in the standard tee section or turned down elbow may be approximated by the general equation:

$$Q = CA\sqrt{2gh}$$

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 6.100: Simple Orifice 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:

$$d = \sqrt{\frac{36.88Q}{\sqrt{h}}}$$

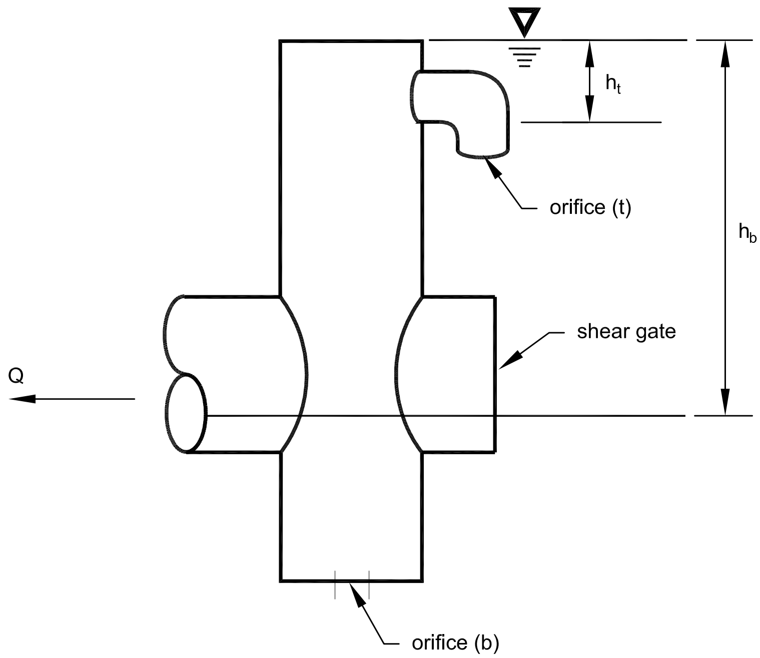
where

d = orifice diameter (inches)

Q = flow (cfs)

h = hydraulic head (ft)

Figure 6.100: Simple Orifice



$$Q = CA_b\sqrt{2gh_b} + CA_t\sqrt{2gh_t}$$
$$= C\sqrt{2g}(A_b\sqrt{h_b} + A_t\sqrt{h_t})$$

h_b = distance from hydraulic grade line at the 2 – year flow of the outflow pipe to the overflow elevation

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Simple Orifice

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Rectangular Sharp Crested Weir

The rectangular sharp crested weir design shown in Figure 6.101: Rectangular, Sharp Crested Weir may be analyzed using standard weir equations for the fully contracted condition.

$$Q=C * (L - 0.2H) * H^{3/2}$$

where:

Q = flow (cfs)

C = 3.27 + 0.40 * H/P (ft)

H = head (ft) as shown in Figure 6.101: Rectangular, Sharp Crested Weir

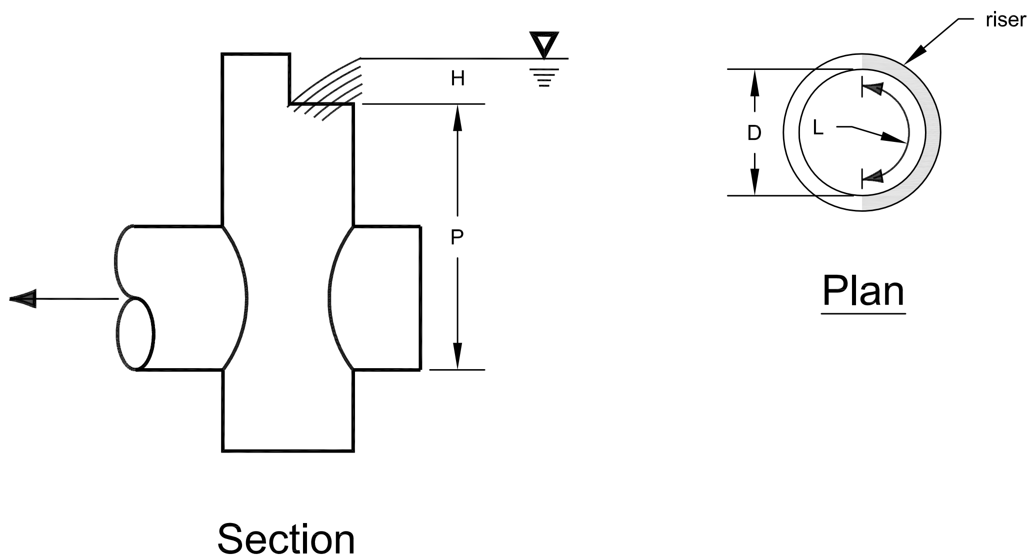
P = height above the pipe invert (ft) as shown in Figure 6.101: Rectangular, Sharp Crested Weir

L = length (ft) of the portion of the riser circumference as necessary, not to exceed 50 percent of the circumference

D = inside riser diameter (ft)

Note that this equation accounts for side contractions by subtracting 0.1H from L for each side of the notch weir.

Figure 6.101: Rectangular, Sharp Crested Weir



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Rectangular, Sharp-Crested Weir

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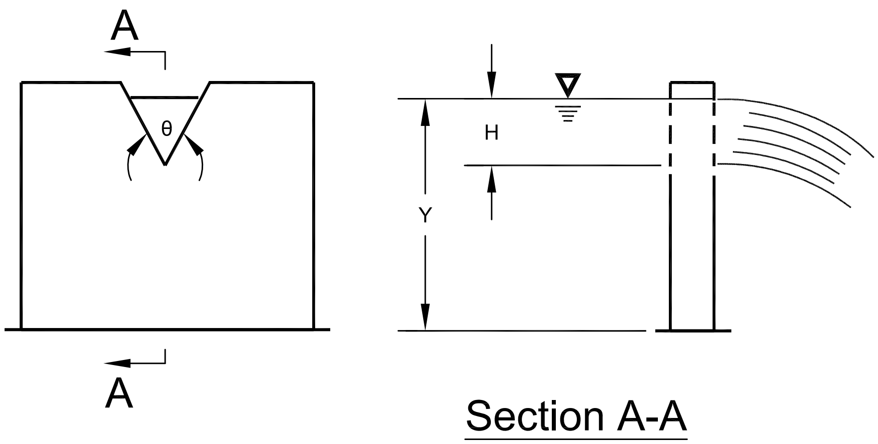
V-Notch Sharp-Crested Weir

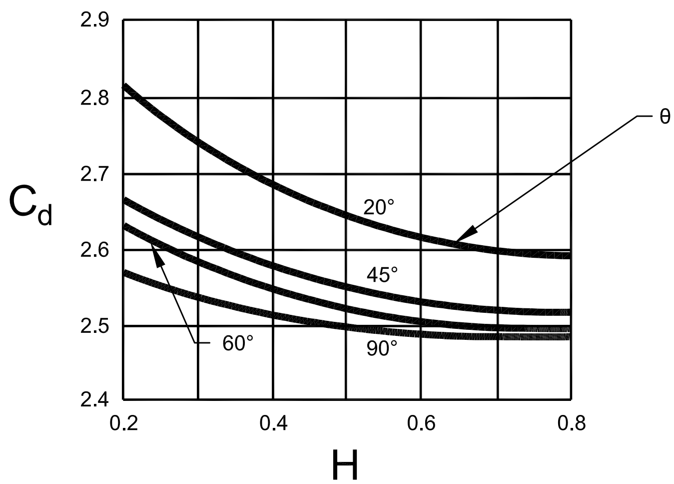
V-notch weirs may be analyzed using the standard equations provided on Figure 6.102: V-Notch, Sharp-Crested Weir.

Figure 6.102: V-Notch, Sharp-Crested Weir



$$Q = C_d\left(\tan\frac{\theta}{2}\right)H^{\frac{5}{2}} \text{ in cfs}$$

Where values of C_d may be taken from the following chart:



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V-Notch, Sharp Crested Weir

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Proportional or Sutro Weir

Sutro weirs are designed so that the discharge is proportional to the total head. This design may be useful in some cases to meet performance requirements.

The sutro weir consists of a rectangular section joined to a curved portion that provides proportionality for all heads above the line A-B (see Figure 6.103: Sutro Weir). The weir may be symmetrical or non-symmetrical.

For this type of weir, the curved portion is defined by the following equation (calculated in radians):

$$\frac{x}{b} = 1 - \frac{2}{\pi} Tan^{-1} \sqrt{\frac{Z}{a}}$$

where a, b, x and Z are as shown in Figure 6.103: Sutro Weir.

The head discharge relationship is:

$$Q = \left(C_d\right)\left(b\right)\left(\sqrt{2ga}\right)\left(h_1 - \frac{a}{3}\right)$$

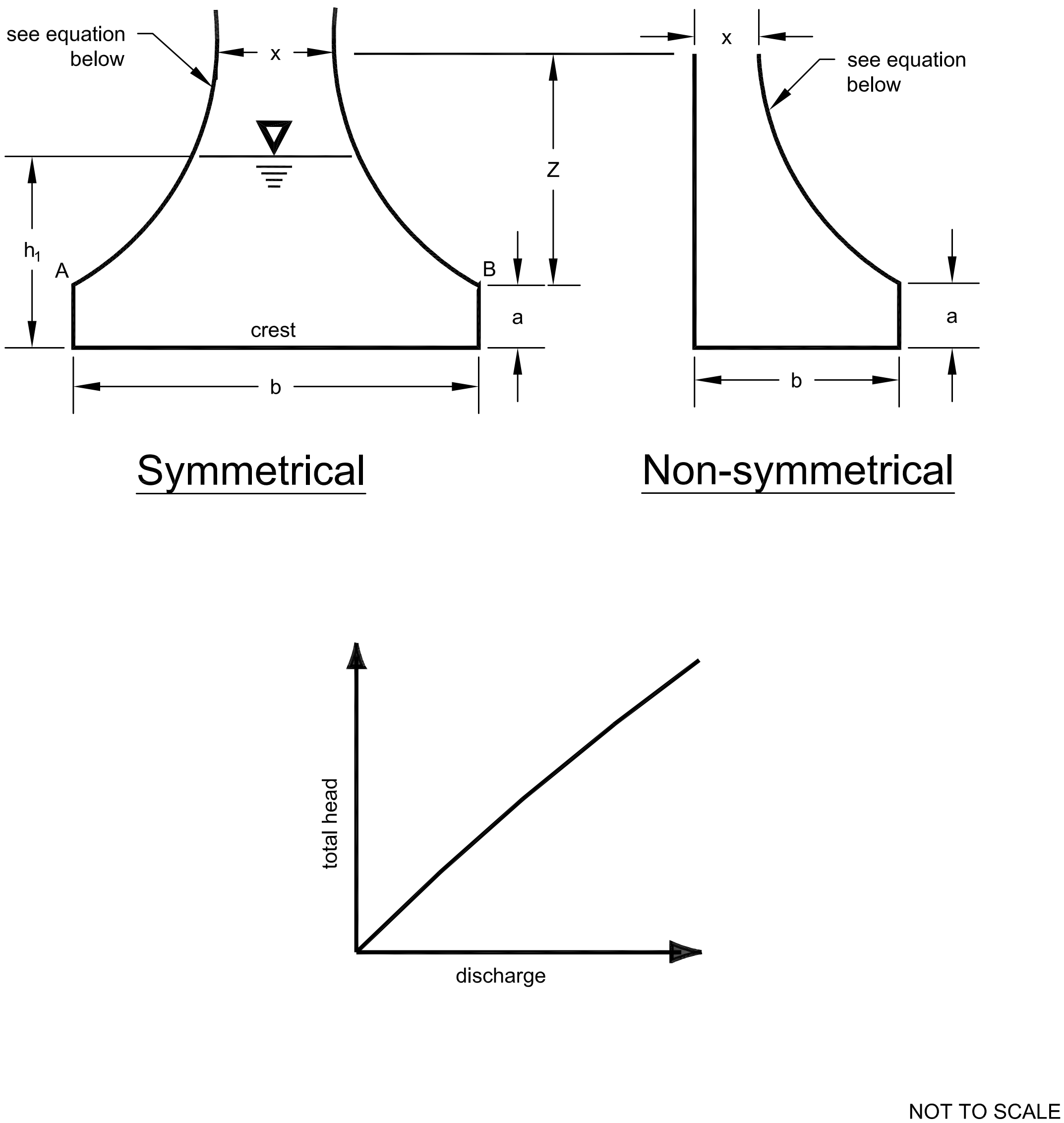
Values of C_d for both symmetrical and non symmetrical sutro weirs are summarized in Table 6.42: Values of Cd for Sutro Weirs.

Note: When b > 1.50 or a > 0.30, use C_d=0.6.

Table 6.42: Values of C_d for Sutro Weirs

C_d Values, Symmetrical							C_d Values, Non-Symmetrical					
b (ft)							b (ft)					
a (ft)	0.50	0.75	1.00	1.25	1.50		a (ft)	0.50	0.75	1.00	1.25	1.50
0.02	0.608	0.613	0.617	0.6185	0.619		0.02	0.614	0.619	0.623	0.6245	0.625
0.05	0.606	0.611	0.615	0.617	0.6175		0.05	0.612	0.617	0.621	0.623	0.6235
0.10	0.603	0.608	0.612	0.6135	0.614		0.10	0.609	0.614	0.618	0.6195	0.620
0.15	0.601	0.6055	0.610	0.6115	0.612		0.15	0.607	0.6115	0.616	0.6175	0.618
0.20	0.599	0.604	0.608	0.6095	0.610		0.20	0.605	0.610	0.614	0.6155	0.616
0.25	0.598	0.6025	0.6065	0.608	0.6085		0.25	0.604	0.6085	0.6125	0.614	0.6145
0.30	0.597	0.602	0.606	0.6075	0.608		0.30	0.603	0.608	0.612	0.6135	0.614

Figure 6.103: Sutro Weir



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Sutro Weir

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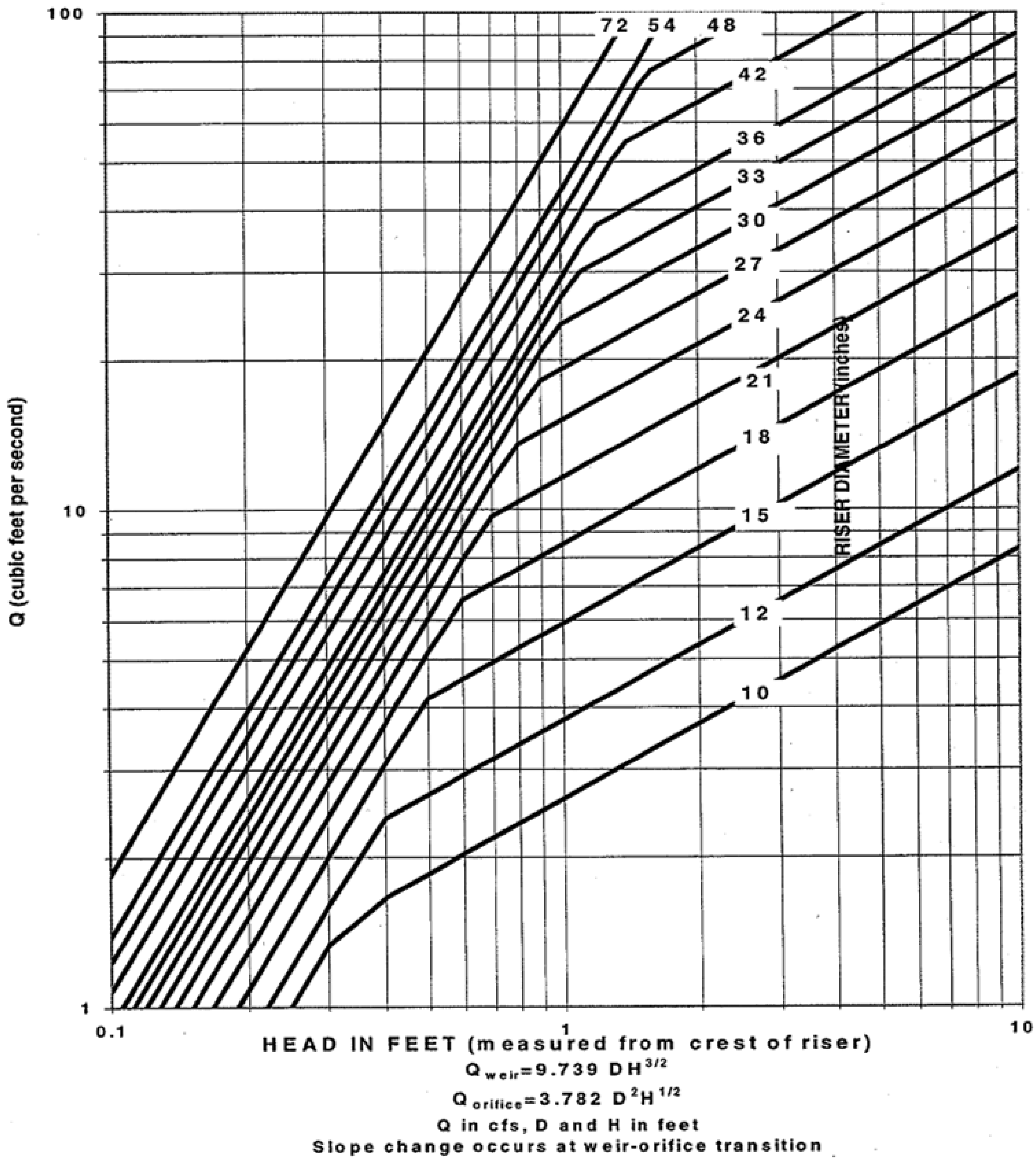
Riser Overflow

The nomograph in Figure 6.104: Riser Inflow Curves can be used to determine the head (in feet) above a riser of given diameter and for a given flow (usually the 25- to 100-year peak flow for developed conditions).

Figure 6.104: Riser Inflow Curves



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Riser Inflow Curves

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6.13.3 Other Detention Design Options

This section presents options beyond the BMPs provided in this manual that the designer may want to consider incorporating into the project design for detaining flows to meet Flow Control requirements.

Use of Parking Lots for Additional Detention

Parking lots may be used to provide additional detention volume, provided that all of the following criteria are met:

1. The depth of water detained does not exceed 1 foot (or other depth established by the permitting authority or local jurisdiction) at any location in the parking lot for runoff events up to and including the 100 year event.
2. The gradient of the parking lot area subject to ponding is 1 percent or greater.
3. The emergency overflow path is identified and noted on the engineering plan(s). The overflow must not create a significant adverse impact to downstream properties or drainage system(s).
4. Fire lanes used for emergency equipment must be free of ponding water for all runoff events up to and including the 100 year event.
5. A downstream Runoff Treatment BMP with sorptive oil removal is needed prior to discharge to surface or groundwater.

Use of Roofs for Detention

Detention ponding on roofs of structures may be used to meet Flow Control requirements provided all of the following are met:

1. The roof support structure is analyzed by a structural engineer to address the weight of ponded water (including an appropriate safety factor).
2. The roof area subject to ponding is sufficiently waterproofed to achieve a minimum service life of 30 years.
3. The minimum pitch of the roof area subject to ponding is 1/4 inch per foot.
4. An overflow system is included in the design to safely convey the 100 year peak flow from the roof.
5. A mechanism is included in the design to allow the ponding area to be drained for maintenance purposes or in the event the restrictor device is plugged.

BMP F6.10: Detention Ponds

The design criteria in this section are for detention ponds (this BMP). However, many of the criteria also apply to BMP F6.21: Infiltration Ponds, BMP T10.10: Wetponds - Basic and Large, and BMP T10.40: Combined Detention and Wetpool Facilities.

Dam Safety for Detention BMPs

Stormwater detention BMPs that can impound 10 acre-feet (435,600 cubic feet; 3.26 million gallons) or more with the water level measured at the embankment crest are subject to the state's dam safety requirements, even if water storage is intermittent and infrequent (WAC 173-175-020 (1)). The principal safety concern is for the downstream population at risk if the dam should breach and allow an uncontrolled release of the pond contents. Peak flows from dam failures are typically much larger than the 100-year flows which detention BMPs are typically designed to accommodate.

Dam safety considerations generally apply only to the volume of water stored above natural ground level. Per the definition of dam height in WAC 173-175-030, natural ground elevation is measured from the downstream toe of the dam. If a trench is cut through natural ground to install an outlet pipe for a spillway or low-level drain, the natural ground elevation is measured from the base of the trench where the natural ground remains undisturbed.

With regard to the engineering design of stormwater detention BMPs, the primary effect of the state's dam safety requirements is in sizing the emergency spillway to accommodate the runoff from the dam safety design storm without overtopping the dam. The hydrologic computation procedures are the same as for the original pond design, except that the computations must use more extreme precipitation values and the appropriate dam safety design storm hyetographs. This information is described in detail within guidance documents developed by and available from Ecology's Dam Safety Office. In addition to the other design requirements for stormwater detention BMPs, dam safety requirements should be an integral part of planning and design for stormwater detention ponds. It is most cost-effective to consider these requirements from the beginning of the project.

In addition to the hydrologic and hydraulic issues related to precipitation and runoff, other dam safety requirements include geotechnical issues, construction inspection and documentation, dam breach analysis, inundation mapping, emergency action planning, and periodic inspections by project owners and by Dam Safety engineers. All of these requirements, plus procedural requirements for plan review and approval and payment of construction permit fees are described in detail in guidance documents developed by and available from the Dam Safety Office.

In addition to the written guidance documents, Dam Safety engineers are available to provide technical assistance to project owners and designers in understanding and addressing the dam safety requirements for their specific project. In the interest of providing a smooth integration of dam safety requirements into the stormwater detention project and streamlining Dam Safety's engineering review and issuance of the construction permit, it is recommended and requested that Dam Safety be contacted early in the project's planning process. The Dam Safety Office is located in the Ecology headquarters building in Lacey.

For more information about dam safety, please refer to Ecology's Dam Safety Office's Website at:

https://www.ecology.wa.gov/Water-Shorelines/Water-supply/Dams

Design Criteria

Standard details for detention ponds are shown in Figure 6.105: Typical Detention Pond, Figure 6.106: Typical Detention Pond Sections, and Figure 6.107: Overflow Structure. Control structure details and design guidance are provided in 6.13.2 Control Structure Design.

General

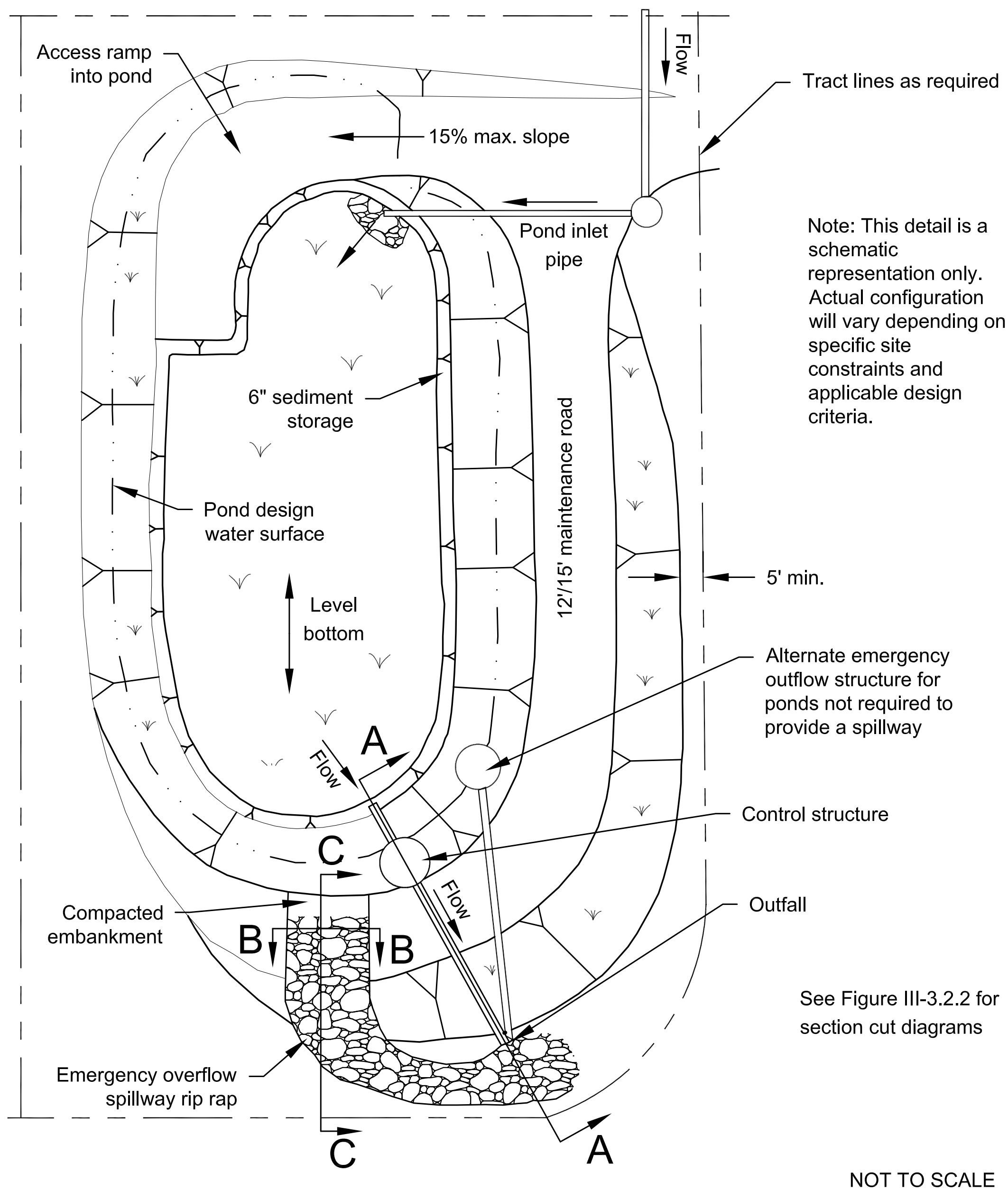
1. Detention ponds must be designed as flow through systems (however, parking lot storage may be utilized through a back up system; see 6.13.3 Other Detention Design Options). Developed flows must enter through a conveyance system separate from the control structure and outflow conveyance system. Maximizing distance between the inlet and outlet is encouraged to promote sedimentation.

2. Detention pond bottoms should be level and be located a minimum of 0.5 foot (preferably 1 foot) below the inlet and outlet to provide sediment storage.

3. Design guidelines for outflow control structures are specified in 6.13.2 Control Structure Design.

4. A geotechnical analysis and report must be prepared for slopes over 15%, or if located within 200 feet of the top of a slope steeper than 40%, or landslide hazard area. The scope of the geotechnical report should include the assessment of impoundment seepage on the stability of the natural slope where the pond will be located within the setback limits set forth in this section.

Figure 6.105: Typical Detention Pond



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Typical Detention Pond

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Figure 6.106: Typical Detention Pond Sections

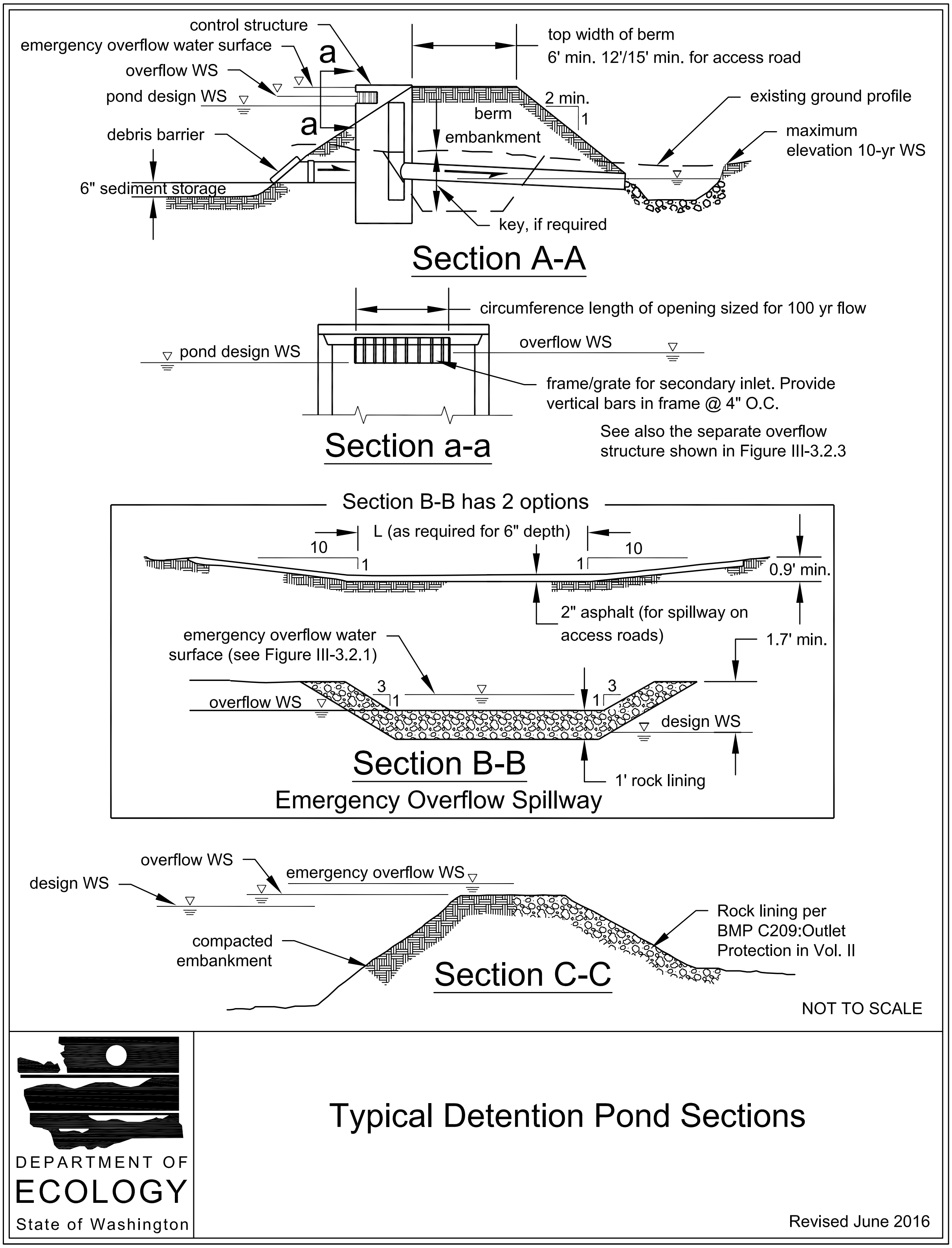
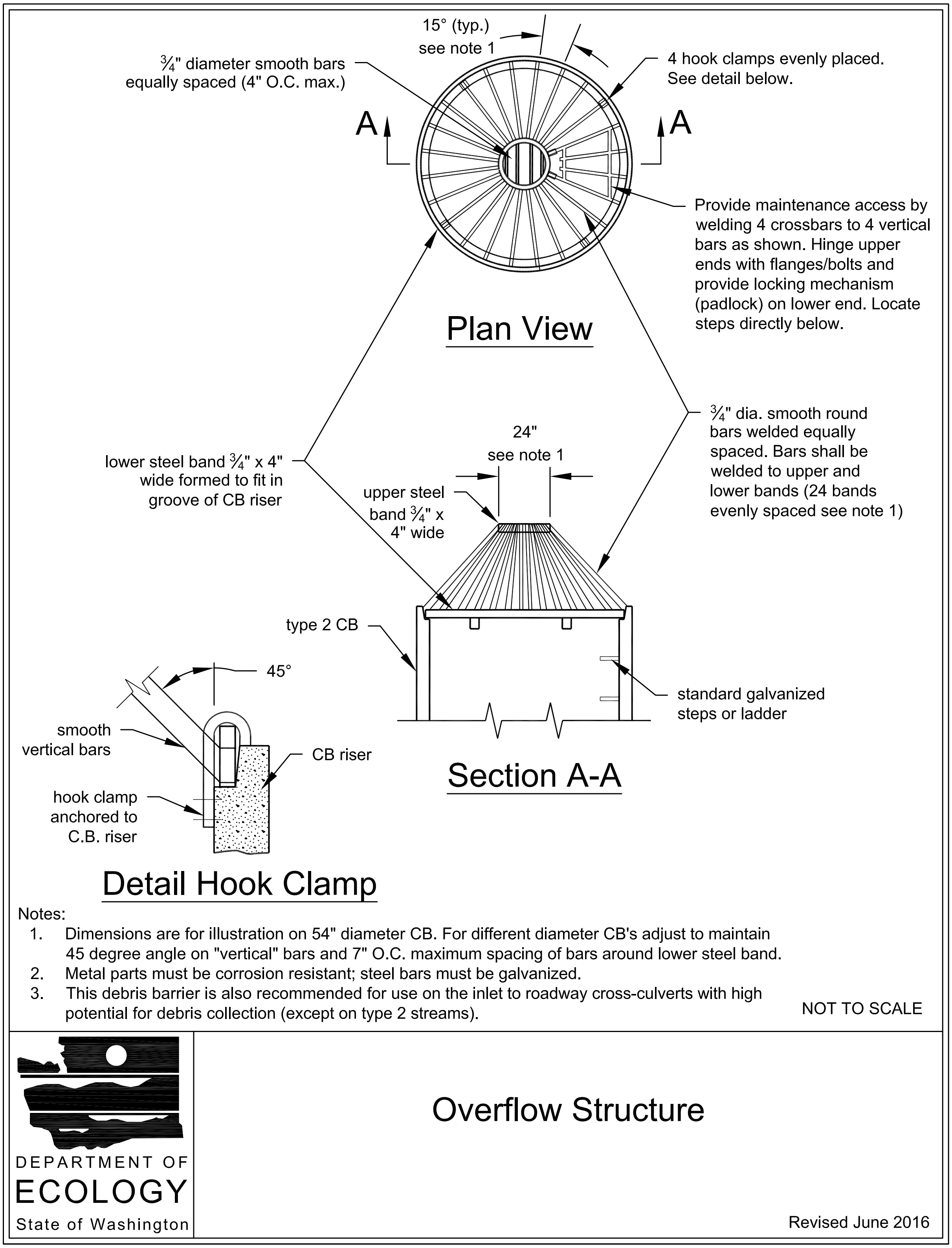


Figure 6.107: Overflow Structure



Side Slopes

1. Interior side slopes up to the emergency overflow water surface should not be steeper than 3H:1V unless a fence is provided (see Fencing below).
2. Exterior side slopes must not be steeper than 2H:1V, unless analyzed for stability by a geotechnical engineer.
3. Detention pond walls may be vertical retaining walls, provided:
   - They are constructed of reinforced concrete per BMP F6.12: Detention Vaults.
   - A fence is provided along the top of the wall.
   - The entire detention pond perimeter may be retaining walls, however, it is recommended that at least 25 percent of the pond perimeter be a vegetated soil slope not steeper than 3H:1V. If the entire pond perimeter is to be retaining walls, provide ladders on the walls for safety reasons.
   - The design is stamped by a licensed engineer in the state of Washington with structural expertise.

   Other retaining walls such as rockeries, concrete, masonry unit walls, and keystone type walls may be used if designed by a geotechnical engineer or a civil engineer with structural expertise.

Inlet

Reduce flow velocities of the discharge to the pond from the inlet pipe by using the methods described in 6.1.10.3 Outfall Systems.

Embankments

1. Pond berm embankments higher than 6 feet must be designed by a licensed engineer in the state of Washington with geotechnical expertise
2. For berm embankments 6 feet or less, the minimum top width should be 6 feet, or as recommended by a geotechnical engineer.
3. Construct pond berm embankments on native consolidated soil (or adequately compacted and stable fill soils analyzed by a geotechnical engineer) free of loose surface soil materials, roots, and other organic debris.
4. Construct pond berm embankments greater than 4 feet in height by excavating a key equal to 50 percent of the berm embankment cross sectional height and width, unless specified otherwise by a geotechnical engineer.
5. Embankment compaction should be accomplished in such a manner as to produce a dense, low permeability engineered fill that can tolerate post-construction settlements with a minimum of cracking. Place the embankment fill on a stable subgrade and compact to a minimum of 95% of the Standard Proctor Maximum Density (ASTM Procedure D698) or

95% of the Modified Proctor Maximum Density (ASTM Procedure D1557). Placement moisture content should lie within 1% dry to 3% wet of the optimum moisture content. The referenced compaction standard may have to be increased to comply with local regulations.

Construct the berm embankment of soils with the following characteristics: a minimum of 20% silt and clay, a maximum of 60% sand, a maximum of 60% silt, with nominal gravel and cobble content. Soils outside this specified range can be used, provided the design satisfactorily addresses the engineering concerns posed by these soils. The paramount concerns with these soils are their susceptibility to internal erosion or piping, and to surface erosion from wave action and runoff on the upstream and downstream slopes, respectively. Note: In general, excavated glacial till is well suited for berm embankment material.

6. Place anti seepage filter-drain diaphragms on outflow pipes in berm embankments impounding water with depths greater than 8 feet at the design water surface. See *Dam Safety Guidelines Part IV: Dam Design and Construction*, (Ecology, 1993) Section 3.3.B on pages 3-27 to 3-30.

Primary Overflow

1. Provide a primary overflow (usually a riser pipe within the control structure; see 6.13.2 Control Structure Design) in all detention ponds, tanks, and vaults to bypass the 25 year developed peak flow over or around the restrictor system. This assumes the facility will be full due to plugged orifices or high inflows. The primary overflow is intended to protect against breaching of a pond embankment (or overflows of the upstream conveyance system in the case of a detention tank or vault). The design must provide controlled discharge directly into the downstream conveyance system or another acceptable discharge point.
2. Provide a secondary inlet to the control structure in ponds as additional protection against overtopping should the inlet pipe to the control structure become plugged. A grated opening ("jailhouse window") in the control structure manhole functions as a weir (see Figure 6.106: Typical Detention Pond Sections) when used as a secondary inlet.

   Note: The maximum circumferential length of this opening must not exceed one half the control structure circumference. The "birdcage" overflow structure as shown in Figure 6.107: Overflow Structure may also be used as a secondary inlet.

Emergency Overflow Spillway

- In addition to the primary overflow (described above), ponds, tanks, and vaults must have an emergency overflow spillway. Emergency overflow spillways are intended to control the location of overtopping in the event of total control structure failure (e.g. blockage of the control structure outlet pipe) or extreme inflows, and direct overflows back into the downstream conveyance system or other acceptable discharge point.
- For impoundments of 10 acre-feet or greater, the emergency overflow spillway must meet the state's dam safety requirements (see Dam Safety for Detention BMPs above).
- For impoundments under 10 acre-feet, ponds must have an emergency overflow spillway that is sized to pass the 100 year developed peak flow in the event of total control structure

failure (e.g. blockage of the control structure outlet pipe) or extreme inflows.

- As an option for ponds with berms less than 2 feet in height and located at grades less than 5 percent, emergency overflow may be provided by an emergency overflow structure, such as a Type II manhole fitted with a birdcage as shown in Figure 6.107: Overflow Structure. The emergency overflow structure must be designed to pass the 100 year developed peak flow, with a minimum 6 inches of freeboard, directly to the downstream conveyance system or another acceptable discharge point. Where an emergency overflow spillway would discharge to a slope steeper than 15%, consideration should be given to providing an emergency overflow structure in addition to the spillway.
- Armor the emergency overflow spillway with riprap in conformance with BMP C209: Outlet Protection. The spillway must be armored full width, beginning at a point midway across the berm embankment and extending downstream to where emergency overflows reenter the conveyance system (see Figure 6.106: Typical Detention Pond Sections).
- Emergency overflow spillway designs must be analyzed as broad crested trapezoidal weirs as described in Methods of Analysis (below). Either one of the weir sections shown in Figure 6.106: Typical Detention Pond Sections may be used.
- Design the emergency overflow spillway to allow a minimum of 1 foot of freeboard above the maximum design storm (100-year, 24-hour storm) water surface level.

Access

1. Provide maintenance access road(s) to the control structure and other drainage structures associated with the pond (e.g. inlet or bypass structures). It is recommended that manhole and catch basin lids be in or at the edge of the access road and at least 3 feet from a property line.
2. An access ramp is needed for removal of sediment with a trackhoe and truck. Extend the ramp to the pond bottom if the pond bottom is greater than 1,500 square feet (measured without the ramp). If the pond bottom is less than 1,500 square feet (measured without the ramp), the ramp may end at an elevation 4 feet above the pond bottom.

   On large, deep ponds, provide truck access to the pond bottom via an access ramp so loading can be done in the pond bottom. On small deep ponds, the truck can remain on the ramp for loading. On small shallow ponds, a ramp to the bottom may not be required if the trackhoe can load a truck parked at the pond edge or on the internal berm of a wetpond or combined pond (trackhoes can negotiate interior pond side slopes).
3. The internal berm of BMP T10.10: Wetponds - Basic and Large or BMP T10.40: Combined Detention and Wetpool Facilities may be used for access if all of the following apply:
   - The internal berm is no more than 4 feet above the first wetpool cell.
   - The first wetpool cell is less than 1,500 square feet (measured without the ramp).
   - The internal berm is designed to support a loaded truck, considering the berm is normally submerged and saturated.

4. If a fence is required, access should be limited by a double posted gate or by bollards – two fixed bollards on each side of the access road and two removable bollards equally located between the fixed bollards.
5. The design guidelines for access roads and ramps:
   - A maximum grade of 15%.
   - A minimum of 40 feet outside turning radius.
   - Locate fence gates only on straight sections of road.
   - 15 feet in width on curves and 12 feet on straight sections.
   - The drivable surface should have a 20-year design life to carry the load of a 24-ton truck; assume three trips per year.
   - Provide a paved apron where access roads connect to paved public roadways.
   - A truck turnaround is required at the terminus of the road.
6. Construct access roads and ramps with asphalt pavement, permeable pavement, gravel surface, or modular grid pavement. All surfaces must conform to the jurisdictional standards and manufacturer's specifications.

Fencing

1. A fence is needed at the emergency overflow water surface elevation, or higher, where a pond interior side slope is steeper than 3H:1V, or where the impoundment is a wall greater than 24 inches in height. The fence need only be constructed for those slopes steeper than 3H:1V. Other regulations such as the International Building Code or Uniform Building Code may require fencing of vertical walls. If more than 10 percent of slopes are steeper 3H:1V, it is recommended that the entire pond be fenced.

   Fences discourage access to portions of a pond where steep side slopes (steeper than 3:1) increase the potential for slipping into the pond. Fences also serve to guide those who have fallen into a pond to side slopes that are flat enough (flatter than 3:1 and unfenced) to allow for easy escape.
2. It is recommended that fences be 6 feet in height. For example designs, see WSDOT Standard Plan L-2, Type 1 or Type 3 chain link fence. The fence may be a minimum of 4 feet in height if the depth of the impoundment (measured from the lowest elevation in the bottom of the impoundment, directly adjacent to the bottom of the fenced slope, up to the emergency overflow water surface) is 5 feet or less. For example designs, see WSDOT Standard Plan L-2, Type 4 or Type 6 chain link fence.
3. Access road gates may be 16 feet in width consisting of two swinging sections 8 feet in width. Provide additional vehicular access gates as needed to facilitate maintenance access.
4. Pedestrian access gates (if needed) should be 4 feet in width.

5. Vertical metal balusters or 9 gauge galvanized steel fabric with bonded vinyl coating can be used as fence material. For steel fabric fences, consider the following aesthetic features:
   a. Vinyl coating that is compatible with the surrounding environment (e.g. green in open, grassy areas and black or brown in wooded areas). All posts, cross bars, and gates may be painted or coated the same color as the vinyl clad fence fabric.
   b. Fence posts and rails that conform to WSDOT Standard Plan L 2 for Types 1, 3, or 4 chain link fence.
6. For metal baluster fences, Uniform Building Code standards apply.
7. Wood fences may be used in subdivisions where the fence will be maintained by homeowners associations or adjacent lot owners.
8. Wood fences should have pressure treated posts (ground contact rated) either set in 24 inch deep concrete footings or attached to footings by galvanized brackets. Rails and fence boards may be cedar, pressure treated fir, or hemlock.
9. Where only short stretches of the pond perimeter (< 10 percent) have side slopes steeper than 3:1, use split rail fences (3 foot minimum height) or densely planted thorned hedges (e.g., barberry, holly) in place of a standard fence.

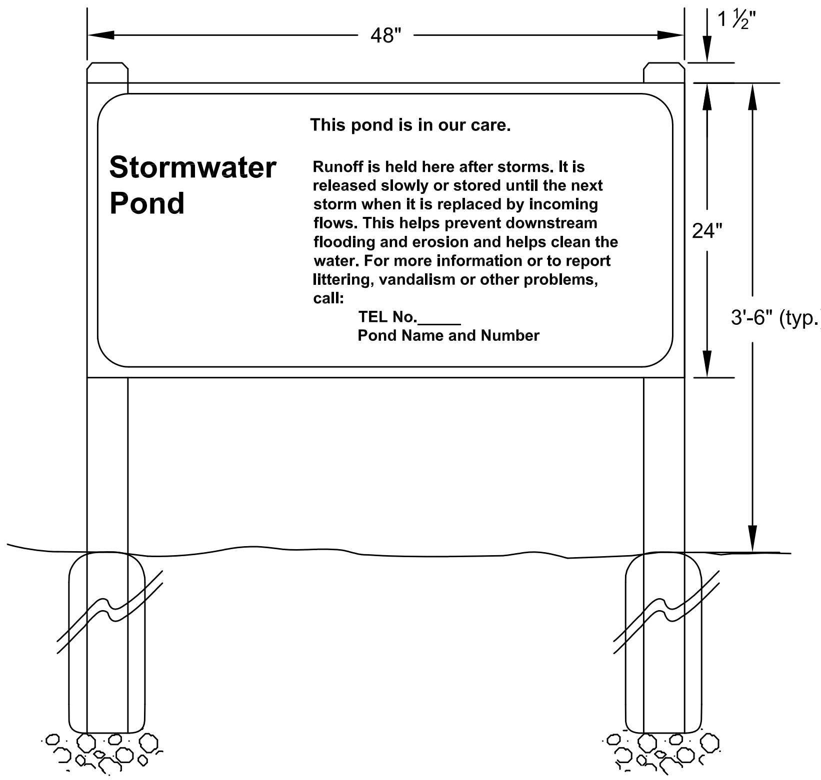
Sediment Depth Marker

Consider providing a fixed vertical sediment depth marker installed in the BMP to measure sediment deposition over time.

Signage

Detention ponds (this BMP), BMP F6.21: Infiltration Ponds, BMP T10.10: Wetponds - Basic and Large, and BMP T10.40: Combined Detention and Wetpool Facilities should have a sign placed for maximum visibility from adjacent streets, sidewalks, and paths. An example of sign specifications for a permanent surface water control pond is illustrated in Figure 6.108: Example of Permanent Surface Water Control Pond Sign.

Figure 6.108: Example of Permanent Surface Water Control Pond Sign



<u>Sample Specifications:</u>

Size:	48 inches by 24 inches
Material:	0.125-gauge aluminum
Face:	Non-reflective vinyl or 3 coats outdoor enamel (sprayed).
Lettering:	Silk screen enamel where possible, or vinyl letters.
Colors:	Beige background, teal letters.
Type face:	Helvetica condensed. Title: 3 inch; Sub-Title: 1 ½ inch; Text: 1 inch; Outer Border:; ⅛ inch; Border Distance from Edge: ¼ inch; all text 1 ¾ inch from border.
Posts:	Pressure treated, beveled tops, 1 ½ inch higher than sign.
Installation:	Secure to chain link fence if available. Otherwise install on two 4" x 4" posts, pressure treated, mounted atop gravel bed, installed in 30-inch concrete filled post holes (8-inch minimum diameter). Top of sign no higher than 42 inches from ground surface.
Placement:	Face sign in direction of primary visual or physical access. Do not block any access road. Do not place within 6 feet of structural facilities (e.g. manholes, spillways, pipe inlets).
Special Notes:	This facility is lined to protect groundwater (if a liner that restricts infiltration of stormwater exists).

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Example of Permanent Surface Water Control Pond Sign

Revised June 2016

Right of Way

Right-of-way may be needed for detention pond maintenance. It is recommended that any tract not abutting public right-of-way have 15-20 foot wide extension of the tract to an acceptable access location.

Setbacks

It is recommended that detention ponds be a minimum of 20 feet from any structure, property line, and any vegetative buffer required by the local government. The detention pond water surface at the pond outlet invert elevation must be set back 100 feet from proposed or existing septic system drainfields. However, the setback requirements are generally specified by the local government, uniform building code, or other statewide regulation and may be different from those mentioned above.

All detention ponds must be a minimum of 50 feet from the top of any steep (greater than 15%) slope. A geotechnical analysis and report must be prepared addressing the potential impact of the pond on a slope steeper than 15%.

Seeps and Springs

Intermittent seeps along cut slopes are typically fed by a shallow groundwater source (interflow) flowing along a relatively impermeable soil stratum. These flows are storm driven and should discontinue after a few weeks of dry weather. However, more continuous seeps and springs, which extend through longer dry periods, are likely from a deeper groundwater source. When continuous flows are intercepted and directed through detention ponds, adjustments to the pond design may have to be made to account for the additional base flow.

Planting Requirements

Sod or seed exposed earth on the pond bottom and interior side slopes with an appropriate seed mixture. Plant all remaining areas of the tract with grass or landscape and mulch with a 3 inch cover of hog fuel or shredded wood mulch. Shredded wood mulch is made from shredded tree trimmings, usually from trees cleared on site. The mulch should be free of garbage and weeds and should not contain excessive resin, tannin, or other material detrimental to plant growth. Do not use construction materials, wood debris, or wood treated with preservatives for producing shredded wood mulch.

For more information: See BMP C120: Temporary and Permanent Seeding for typical seed mixes.

Landscaping

If provided, landscaping should adhere to the criteria that follow so as not to hinder maintenance operations. Landscaped stormwater tracts may, in some instances, provide a recreational space. In other instances, “naturalistic” stormwater BMPs may be placed in open space tracts.

The following guidelines should be followed if landscaping is proposed for BMPs:

- 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, should be avoided within 50 feet of pipes or structures.
- Planting should be restricted on berms that impound water either permanently or temporarily during storms. 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.

      Note: Grasses allow unobstructed visibility of berm slopes for detecting potential dam safety problems such as animal burrows, slumping, or fractures in the berm.
    - Trees planted on portions of water-impounding berms < 4 feet high must be small, ≤ 20 feet mature height, and have a fibrous root system.

      Note: These trees reduce the likelihood of tree blowdown, or the possibility of channeling or piping of water through the root system, which may contribute to dam failure on berms that retain water.
- All landscape material, including grass, should be planted in good topsoil. Native underlying soils may be made suitable for planting if amended with 4 inches of well-aged compost tilled into the subgrade. Compost used should meet specifications in Chapter 173-350 WAC.
- Soil in which trees or shrubs are planted may need additional enrichment or additional compost topdressing. Consult a nurseryperson, landscape professional, or 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.

  Note: The landscaped islands should 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-foot setback should be counted from the outer dripline of the trees (estimated at maturity). This setback allows a 6-foot-wide mower to pass around and between clumps.
- Evergreen trees and trees that produce relatively little leaf fall (such as ash, locust, and hawthorn) are preferred in areas draining to the pond.
- Trees should be set back so that branches do not overhang the pond (to prevent leaf fall into the water). Drought-tolerant species are recommended.

Maintenance

General

Maintenance is of primary importance if detention ponds are to continue to function as originally designed. A local government, a designated group such as a homeowners' association, or some individual must accept the responsibility for maintaining the control structure(s) and the impoundment area. Formulate a specific maintenance plan outlining the schedule and scope of maintenance operations. Achieve debris removal in detention ponds by using trash racks or other screening devices.

Design with maintenance in mind. Good maintenance will be crucial to successful use of the detention pond. Hence, build in provisions to facilitate maintenance operations into the project when it is installed. Maintenance must be a basic consideration in design and in determination of first cost. See Appendix 6-A: BMP Maintenance Tables for specific maintenance requirements.

Handle any standing water and sediments removed during the maintenance operation in a manner consistent with Appendix 8-B: Management of Street Waste Solids and Liquids.

Vegetation

If a shallow marsh is established, then periodic removal of dead vegetation may be necessary. Since decomposing vegetation can release pollutants captured in the detention pond, especially nutrients, it may be necessary to harvest dead vegetation annually prior to the winter wet season. Otherwise the decaying vegetation can export pollutants out of the pond and can cause nuisance conditions to occur. If harvesting is to be done in BMP T5.73: Stormwater Treatment Wetlands, have a wetland scientist prepare a written harvesting procedure and submitted it with the drainage design to the local government.

Sediment

Maintenance of sediment forebays and attention to sediment accumulation within the pond is extremely important. Continually monitor sediment deposition in the pond. Owners, operators, and maintenance authorities should be aware that significant concentrations of metals (e.g. lead, zinc, and cadmium) as well as some organics such as pesticides, may be expected to accumulate at the bottom of stormwater ponds. Regularly conduct testing of sediment, especially near points of inflow, to determine the leaching potential and level of accumulation of potentially hazardous material before disposal.

Methods of Analysis

Detention Volume and Outflow

Design volumes and outflows for detention ponds vary, and are typically designed to meet the performance standards as required in 2.4.6 CE6: Flow Control and/or 2.4.8 CE8: Wetlands Protection and the hydrologic analysis and design methods in Chapter 4 - Hydrologic Analysis and Design. Design guidelines for control structures are given in 6.13.2 Control Structure Design.

Note: The design water surface elevation is the highest elevation which occurs in order to meet the required outflow performance for the pond.

Detention Ponds in Infiltrative Soils

Detention ponds may be sited on soils that are sufficiently permeable for a properly functioning infiltration system (see 6.5 Infiltration BMPs). These detention ponds have a surface discharge through the control structure, and may also utilize infiltration as a second pond outflow. Detention ponds sized with infiltration as a second outflow must meet all the requirements of BMP F6.21:

Infiltration Ponds, including a soils report, testing, groundwater protection, pre-settling, and construction techniques.

Emergency Overflow Spillway Capacity

For impoundments under 10-acre-feet, the emergency overflow spillway weir section must be designed to pass the 100 year runoff event for developed conditions assuming a broad crested weir. The **broad crested weir equation** for the spillway section in Figure 6.109: Weir Section for Emergency Overflow Spillway, for example, would be:

$$Q_{100} = C(2g)^{1/2}\left[\frac{2}{3}LH^{3/2} + \frac{8}{15}\left(Tan\theta\right)H^{5/2}\right]$$

Where:

C = discharge coefficient (0.6)

g = gravity (32.2 ft/sec^2)

L = length of weir (ft)

H = height of water over weir (ft)

θ = angle of side slopes

Q_{100} = peak flow for the 100-year runoff event (cfs)

Assuming C = 0.6 and Tanθ = 3 (for 3:1 slopes), the equation becomes:

$$Q_{100} = 3.21[LH^{3/2} + 2.4\ H^{5/2}]$$

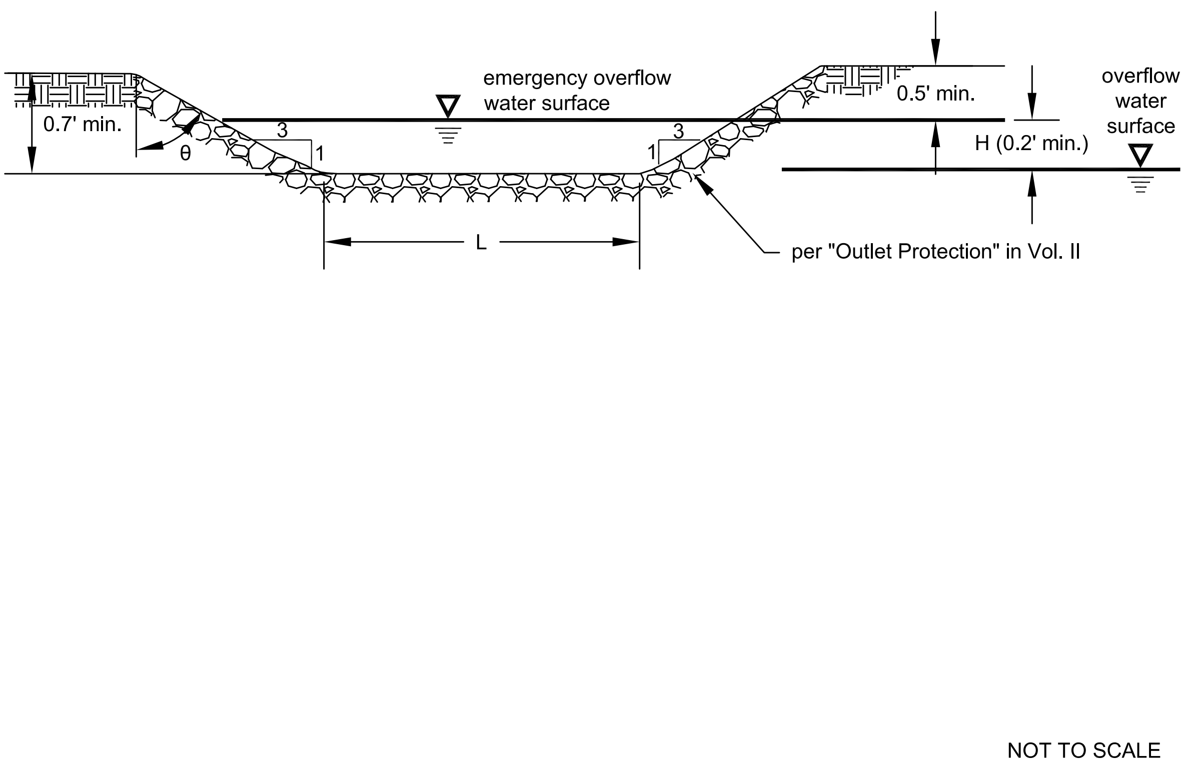
To find the length L for the weir section, the equation is rearranged to use the computed Q_{100} and trial values of H (0.2 feet minimum):

$$L = [Q_{100}/(3.21H^{3/2})] - 2.4H$$

or

6 feet minimum

Figure 6.109: Weir Section for Emergency Overflow Spillway



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Weir Section for Emergency Overflow Spillway

Revised June 2016

BMP F6.11: Detention Tanks

Detention tanks are underground detention BMPs typically constructed with large diameter corrugated metal pipe. Standard detention tank details are shown in Figure 6.110: Typical Detention Tank and Figure 6.111: Detention Tank Access Detail. Control structure details are shown in 6.13.2 Control Structure Design.

Design Criteria

General

Typical design guidelines are as follows:

1. Detention tanks may be designed as flow through systems with manholes in line (see Figure 6.110: Typical Detention Tank) to promote sediment removal and facilitate maintenance. Detention tanks may be designed as back up systems if preceded by Runoff Treatment BMPs, since little sediment should reach the inlet/control structure and low head losses can be expected because of the proximity of the inlet/control structure to the tank.
2. Locate the detention tank bottom 0.5 feet below the inlet and outlet to provide dead storage for sediment.
3. Use a 36-inch minimum pipe diameter.
4. Tanks larger than 36 inches may be connected to each adjoining structure with a short section (2 foot maximum length) of 36 inch minimum diameter pipe.
5. Refer to the details of outflow control structures in 6.13.2 Control Structure Design.
6. Design the emergency overflow to pass the 100 year storm.

Note: Control structures and access manholes should have additional ladder rungs to allow ready access to all detention tank access pipes when the catch basin sump is filled with water (see Figure 6.97: Flow Restrictor (TEE), plan view).

Materials

Galvanized metals leach zinc into the environment, especially in standing water situations. This can result in zinc concentrations that can be toxic to aquatic life. Therefore, use of galvanized materials in stormwater BMPs and conveyance systems is discouraged. When other metals, such as aluminum or stainless steel, or plastics are available, they should be used.

Pipe material, joints, and protective treatment for tanks should be in accordance with Section 9.05 of WSDOT's *Standard Specifications for Road, Bridge, and Municipal Construction* (WSDOT, 2016).

Structural Stability

Tanks must meet structural requirements for overburden support and traffic loading if appropriate. Accommodate H20 live loads for tanks lying under parking areas and access roads. Design metal tank end plates for structural stability at maximum hydrostatic loading conditions. Flat end plates generally require thicker gage material than the pipe and/or require reinforcing ribs. Place detention tanks on stable, well consolidated native material with a suitable bedding. Do not place detention tanks in fill slopes, unless analyzed in a geotechnical report for stability and constructability.

Buoyancy

In moderately pervious soils where seasonal groundwater may induce flotation, balance buoyancy tendencies by either ballasting with backfill or concrete backfill, providing concrete anchors, or increasing the total weight. Calculations that demonstrate stability must be documented.

Primary and Emergency Overflows

Refer to the guidance in BMP F6.10: Detention Ponds for requirements on primary overflow and emergency overflow spillways. For this BMP, the control structure outlet/overflow may be designed to accommodate both the primary and emergency overflow spillways.

Access Openings

The following guidelines for access openings may be used.

1. The maximum depth from finished grade to tank invert should be 20 feet.
2. Position access openings a maximum of 50 feet from any location within the tank.
3. All tank access openings may have round, solid locking lids (usually 1/2 to 5/8-inch diameter Allen-head cap screws).
4. 36 inch minimum diameter corrugated metal pipe (CMP) riser type manholes (Figure 6.111: Detention Tank Access Detail) of the same gage as the tank material may be used for access along the length of the tank and at the upstream terminus of the tank in a backup system. The top slab is separated (1 inch minimum gap) from the top of the riser to allow for deflections from vehicle loadings without damaging the riser tank.
5. Make all tank access openings readily accessible by maintenance vehicles.
6. Tanks must comply with the OSHA confined space requirements, which includes clearly marking entrances to confined space areas. This may be accomplished by hanging a removable sign in the access riser(s), just under the access lid.

Access Roads

Access roads are needed to all detention tank control structures and risers. Design and construct access roads as specified for detention ponds in BMP F6.10: Detention Ponds.

Right-of Way

Right-of-way may be needed for detention tank maintenance. It is recommended that any tract not abutting public right of way have a 15 to 20-foot wide extension of the tract to accommodate an access road to the detention tank.

Setbacks

It is recommended that detention tanks be a minimum of 20 feet from any structure, property line, and any vegetative buffer required by the local government and from any septic drainfield. However, the setback requirements are generally specified by the local government, uniform building code, or other statewide regulation and may be different from those mentioned above.

All detention tankss must be a minimum of 50 feet from the top of any steep (greater than 15%) slope. A geotechnical analysis and report must be prepared addressing the potential impact of the tank on a slope steeper than 15%.

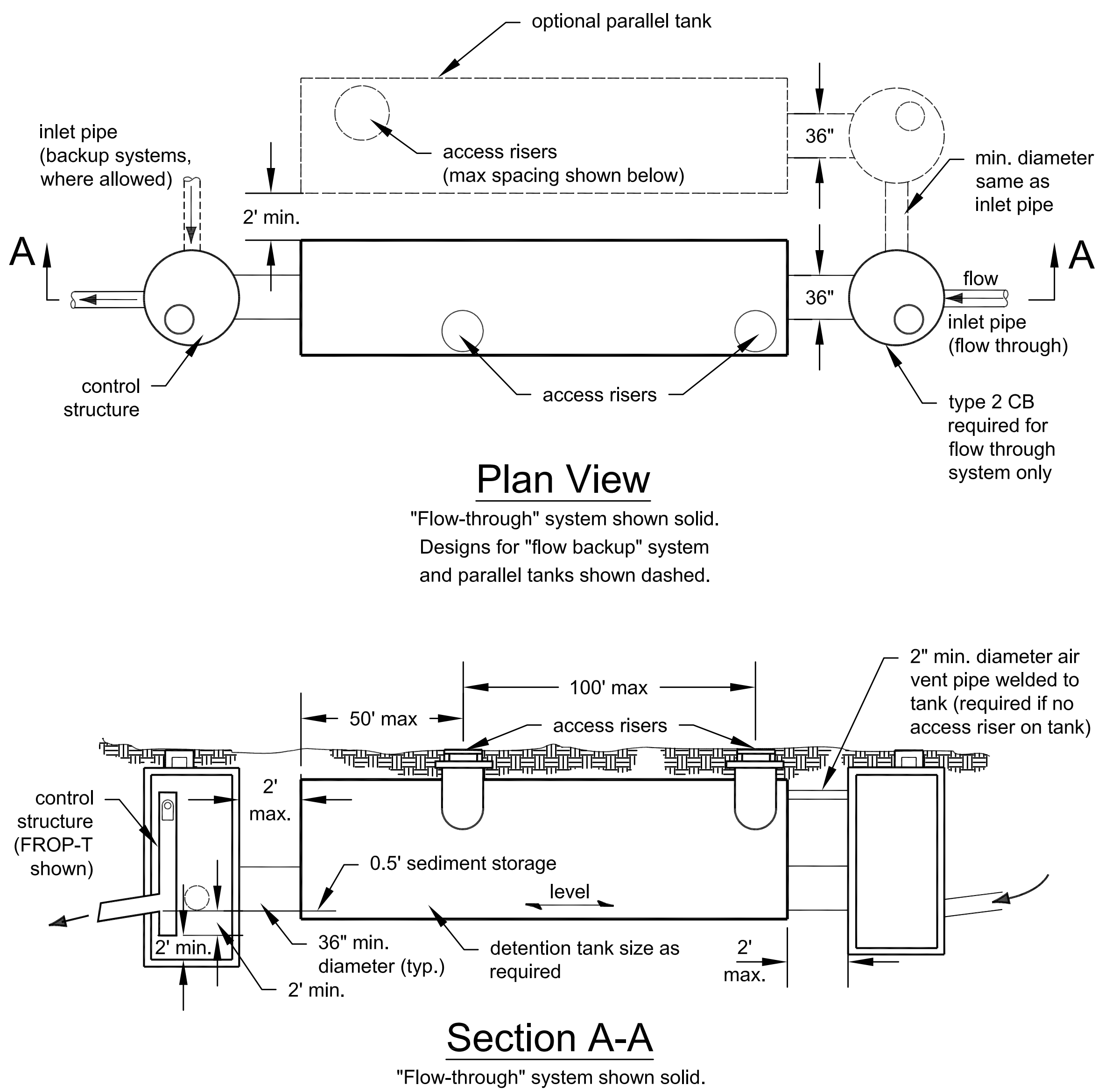
Maintenance

Build in provisions to facilitate maintenance operations into the project when it is installed. Maintenance must be a basic consideration in design and in determination of first cost. See Appendix 6-A: BMP Maintenance Tables for specific maintenance requirements.

Detention Volume and Outflow

Design volumes and outflows for detention tanks vary, and are typically designed to meet the performance standards as required in 2.4.6 CE6: Flow Control and/or 2.4.8 CE8: Wetlands Protectionand the hydrologic analysis and design methods in Chapter 4 - Hydrologic Analysis and Design. Design guidelines for control structures are given in 6.13.2 Control Structure Design.

Figure 6.110: Typical Detention Tank



Note:
All metal parts corrosion resistant. Steel parts galvanized and asphalt coated (Treatment 1 or better), or aluminized steel (Type II or better).

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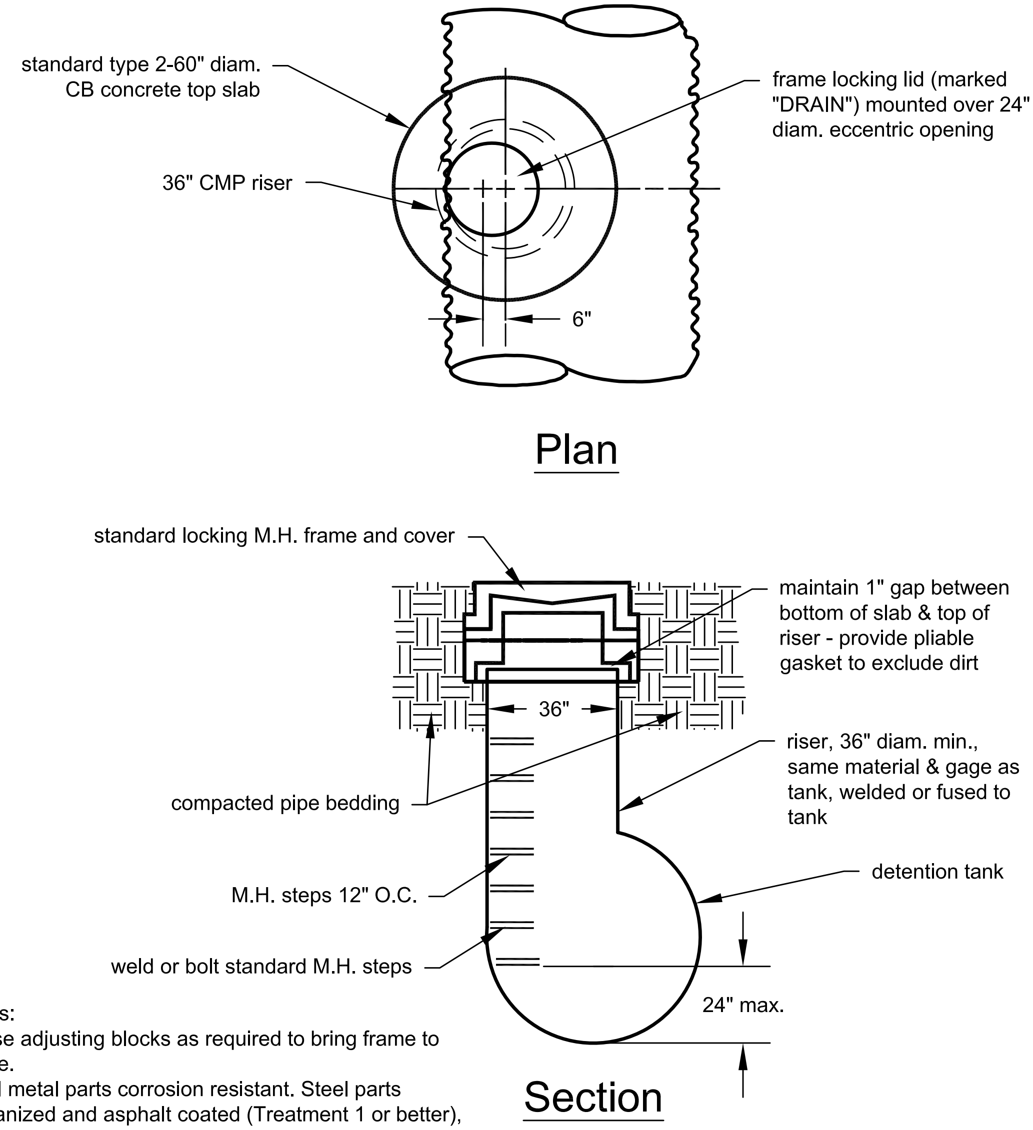
Typical Detention Tank

Revised May 2019

Figure 6.111: Detention Tank Access Detail



Notes:
1. Use adjusting blocks as required to bring frame to grade.
2. All metal parts corrosion resistant. Steel parts galvanized and asphalt coated (Treatment 1 or better), or aluminized steel (Type II or better).
3. Must be located for access by maintenance vehicles.
4. May substitute WSDOT special Type IV manhole (RCP only)

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Detention Tank Access Detail

Revised May 2019

BMP F6.12: Detention Vaults

Detention vaults are box shaped underground detention BMPs typically constructed with reinforced concrete. A standard detention vault detail is shown in Figure 6.112: Typical Detention Vault. Control structure details are shown in 6.13.2 Control Structure Design.

Design Criteria

General

Typical design guidelines for detention vaults are as follows:

1. Detention vaults may be designed as flow-through systems with bottoms level (longitudinally), or sloped toward the inlet to facilitate sediment removal. Maximize the distance between the inlet and outlet as feasible.
2. The detention vault bottom may slope at least 5 percent from each side towards the center, forming a broad "v" to facilitate sediment removal. More than one "v" may be used to minimize vault depth. However, the vault bottom may be flat with 0.5-1 foot of sediment storage if removable panels are provided over the entire vault. It is recommended that the removable panels be at grade, have stainless steel lifting eyes, and weigh no more than 5 tons per panel.
3. Elevate the invert elevation of the outlet above the bottom of the vault to provide an average 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.

Materials

Minimum 3,000 psi structural reinforced concrete may be used for detention vaults. Provide all construction joints with water stops.

Structural Stability

All vaults must meet structural requirements for overburden support and H20 traffic loading (See (AASHTO, 2002)). Vaults located under roadways must meet any live load requirements of the local government. Design cast-in place wall sections as retaining walls. Structural designs for cast in place vaults must be stamped by a licensed engineer in the state of Washington with structural expertise. Place vaults on stable, well consolidated native material with suitable bedding. Do not place vaults in fill slopes, unless analyzed in a geotechnical report for stability and constructability.

Primary and Emergency Overflows

Refer to the guidance in BMP F6.10: Detention Ponds for requirements on primary overflow and emergency overflow spillways. For this BMP, the control structure outlet/overflow may be designed to accommodate both the primary and emergency overflow spillways.

Access Openings

Provide access openings over the inlet pipe and control structure. Use the following guidelines for access.

1. Position access openings a maximum of 50 feet from any location within the vault. Additional access points may be needed on large vaults. Provide access to each “v” if more than one “v” is provided in the vault floor.
2. For vaults with greater than 1,250 square feet of floor area, provide a 5' by 10' removable panel over the inlet pipe (instead of a standard frame, grate and solid cover). Or, provide a separate access vault as shown in Figure 6.112: Typical Detention Vault.
3. For vaults under roadways, locate the removable panel outside the travel lanes. Or, provide multiple standard locking manhole covers. Ladders and hand holds need only be provided at the outlet pipe and inlet pipe, and as needed to meet OSHA confined space requirements.
4. All access openings, except those covered by removable panels, may have round, solid locking lids, or 3 foot square, locking diamond plate covers.
5. Vaults with widths 10 feet or less must have removable lids.
6. The maximum depth from finished grade to the vault invert should be 20 feet.
7. Provide internal structural walls of large vaults with openings sufficient for maintenance access between cells. Size and situate the openings to allow access to the maintenance “v” in the vault floor.
8. The minimum internal height should be 7 feet from the highest point of the vault floor (not sump), and the minimum width should be 4 feet. However, concrete vaults may be a minimum 3 feet in height and width if used as tanks with access manholes at each end, and if the width is no larger than the height. Also, the minimum internal height requirement may not be needed for any areas covered by removable panels.
9. Vaults must comply with the OSHA confined space requirements, which includes clearly marking entrances to confined space areas. This may be accomplished by hanging a removable sign in the access riser(s), just under the access lid.
10. Provide ventilation pipes (minimum 12 inch diameter or equivalent) in all four corners of vaults to allow for artificial ventilation prior to entry of maintenance personnel into the vault. Or, provide removable panels over the entire vault. Vaults providing manhole access at 12 foot spacing need not provide corner ventilation pipes.

Access Roads

Access roads are needed to the access panel (if applicable), the control structure, and at least one access point per cell, and they may be designed and constructed as specified for detention ponds in BMP F6.10: Detention Ponds.

Right-of Way

Right-of-way is needed for detention vault maintenance. It is recommended that any tract not abutting public right of way should have a 15 to 20 foot wide extension of the tract to accommodate an access road to the detention vault.

Setbacks

It is recommended that detention vaults be a minimum of 20 feet from any structure, property line, and any vegetative buffer required by the local government and from any septic drainfield. However, the setback requirements are generally specified by the local government, uniform building code, or other statewide regulation and may be different from those mentioned above.

All detention vaults must be a minimum of 50 feet from the top of any steep (greater than 15%) slope. A geotechnical analysis and report must be prepared addressing the potential impact of the vault on a slope steeper than 15%.

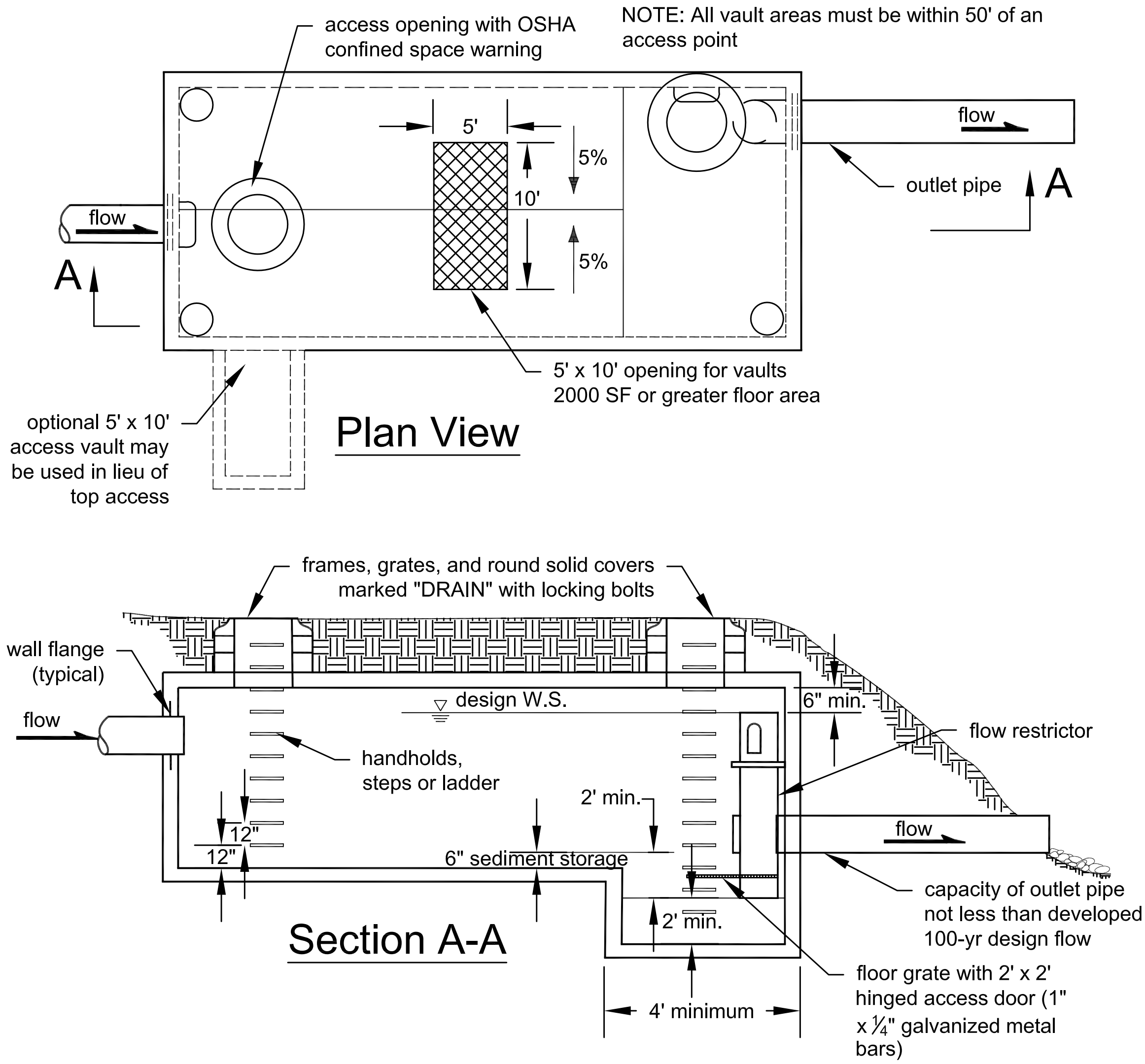
Maintenance

Build in provisions to facilitate maintenance operations into the project when it is installed. Maintenance must be a basic consideration in design and in determination of first cost. See Appendix 6-A: BMP Maintenance Tables for specific maintenance requirements.

Detention Volume and Outflow

Design volumes and outflows for detention vaults vary, and are typically designed to meet the performance standards as required in 2.4.6 CE6: Flow Control and/or 2.4.8 CE8: Wetlands Protectionand the hydrologic analysis and design methods in Chapter 4 - Hydrologic Analysis and Design. Design guidelines for control structures are given in 6.13.2 Control Structure Design.

Figure 6.112: Typical Detention Vault



Notes:

1. All metal parts must be corrosion resistant. Steel parts must be galvanized and asphalt coated (Treatment 1 or better).
2. Provide water stop at all cast-in-place construction joints. Precast vaults shall have approved rubber gasket system.
3. Vaults $\leq$ 10' wide must use removable lids.
4. Prefabricated vault sections may require structural modifications to support 5' x 10' opening over main vault. Alternatively, access can be provided via a side vestibule as shown.

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Typical Detention Vault

Revised June 2016

6.14 Oil and Water Separator BMPs

6.14.1 Introduction to Oil and Water Separator BMPs

The purpose of oil and water separator BMPs is to remove oil and other water-insoluble hydrocarbons, and settleable solids from stormwater runoff. Oil and water separator BMPs typically consist of three bays: a forebay, a separator bay, and an afterbay.

There are two general types of oil and water separators:

- the American Petroleum Institute (API) type (also called baffle type) (API, 1990)
  - API separators are composed of three bays separated by baffles. The efficiency of API separators is dependent on detention time in the center bay and on droplet size. API type separators rarely treat stormwater to reduce oil levels below 10 mg/l. The use of API separators should be limited to protection from large oil spills and not for small amounts of oil on the pavement surfaces. See BMP T5.100: API (Baffle type) Separator.
- the coalescing plate (CP) type
  - CP separators use a series of parallel plates in the separator bay, which improve separation efficiency by providing more surface area. CP separators need considerably less space for separation of the floating oil due to the shorter travel distances between parallel plates. See BMP T5.110: Coalescing Plate (CP) Separator.

Both use gravity to remove floating and dispersed oil.

Oil and water separator BMPs must be located off-line from the primary conveyance/detention system, bypassing flows greater than the Water Quality Design Flow Rate.

Oil and water separator BMPs should be placed upstream of other Runoff Treatment BMPs and as close to the source of oil generation as possible.

Other BMPs that may be used for removal of oil include manufactured treatment devices (if approved as an Oil Control BMP, see 6.11 Manufactured Treatment Devices as BMPs), and BMP T5.83: Linear Sand Filter.

When designed properly, oil and water separator BMPs shall meet the oil control performance goal as described in 6.1.2 Choosing Your Runoff Treatment BMPs.

Applications and Limitations

The following are potential applications of oil and water separator BMPs where free oil is expected to be present at treatable high concentrations and sediment will not overwhelm the separator (Romano, 1990), (Watershed Protection Techniques, 1994), (King County, 1998). For low concentrations of oil, other Runoff Treatment BMPs may be more applicable, such as manufactured treatment devices (if approved as an Oil Control BMP, see 6.11 Manufactured Treatment Devices as BMPs) and BMP T5.83: Linear Sand Filter.

- Commercial and industrial areas including petroleum storage yards, vehicle maintenance facilities, manufacturing areas, airports, utility areas (water, electric, gas), and fueling stations.(King County, 1998)
- Facilities that would require Oil Control BMPs per the thresholds described in 6.1.2 Choosing Your Runoff Treatment BMPs. These may include parking lots at convenience stores, fast food restaurants, grocery stores, shopping malls, discount warehouse stores, banks, truck fleets, auto and truck dealerships, and delivery services. (King County, 1998)
- Without intense maintenance, oil and water separator BMPs may not be sufficiently effective in achieving oil and TPH removal down to the required levels.
- A pretreatment BMP (see 6.10 Pretreatment BMPs) should be considered if the level of TSS in the inlet flow would cause clogging or otherwise impair the long-term efficiency of the oil and water separator BMP.
- For inflows from small drainage areas (such as fueling stations, maintenance shops, etc.) BMP T5.110: Coalescing Plate (CP) Separator is typically considered, due to space limitations. However, if plugging of the plates is likely, then a new design basis for BMP T5.100: API (Baffle type) Separator may be considered on an experimental basis.
- Refer to the manufacturer's recommendations for climate considerations, such as cold weather and/or arid/semiarid areas.

Site Suitability

Consider the following site characteristics:

- Sufficient land area
- Adequate TSS control or pretreatment capability
- Compliance with environmental objectives
- Adequate influent flow attenuation and/or bypass capability
- Sufficient access for operation and maintenance (O & M)

General Design Criteria

There is concern that oil and water separator BMPs used for Runoff Treatment have not performed to expectations (Watershed Protection Techniques, 1994), (Schueler et al., 1992). Therefore, emphasis should be given to proper application, design, O & M, (particularly sludge and oil removal) and prevention of CP fouling and plugging (USACE, 1994). Other Runoff Treatment BMPs, such as manufactured treatment devices (if approved as an Oil Control BMP, see 6.11 Manufactured Treatment Devices as BMPs) and BMP T5.83: Linear Sand Filter, should be considered for the removal of insoluble oil and TPH.

The following are design criteria applicable to both BMP T5.100: API (Baffle type) Separator and BMP T5.110: Coalescing Plate (CP) Separator:

- If practicable, determine oil/grease (or TPH) and TSS concentrations, lowest temperature, pH; and empirical oil rise rates in the runoff, and the viscosity, and specific gravity of the oil.

Also determine whether the oil is emulsified or dissolved. Do not use oil and water separator BMPs for the removal of dissolved or emulsified oils such as coolants, soluble lubricants, glycols, and alcohols.

- Locate the oil and water separator BMP off-line, and bypass the incremental portion of flows that exceed the off-line 15-minute, Water Quality Design Flow Rate. If it is necessary to locate the separator on-line, try to minimize the size of the area needing oil control, and use the on-line Water Quality Design Flow Rate.
- Use only impervious conveyances for oil contaminated stormwater.
- Specify appropriate performance tests after installation and shakedown, and/or certification by a licensed engineer in the state of Washington that the oil and water separator BMP is functioning in accordance with design objectives. Expeditious corrective actions must be taken if it is determined the oil and water separator BMP is not achieving acceptable performance levels.
- Add a pretreatment BMP (see 6.10 Pretreatment BMPs) for TSS that could cause clogging of the CP separator, or otherwise impair the long-term effectiveness of the separator.

Separator Bay Design Criteria

- For an off-line BMP, size the separator bay (the second bay) for the Water Quality Design Flow Rate (as described in 6.1.5 Sizing Your Runoff Treatment BMPs).
- For an on-line BMP, size the separator bay (the second bay) for the Water Quality Design Flow Rate (as described in 6.1.5 Sizing Your Runoff Treatment BMPs.
- To collect floatables and settleable solids, design the surface area of the forebay (the first bay) at ≥ 20 ft^2 per 10,000 ft^2 of area draining to the oil and water separator BMP. The length of the forebay should be 1/3-1/2 of the length of all three bays combined. Include roughing screens for the forebay or upstream of the oil and water separator BMP to remove debris, if needed. Screen openings should be about 3/4 inch.
- Include a submerged inlet pipe with a turned-down elbow in the forebay at least two feet from the bottom. The outlet pipe should be a Tee, sized to pass the Water Quality Design Flow Rate and placed at least 12 inches below the water surface.
- Include a shutoff mechanism at the outlet pipe. (King County, 1998)
- Use absorbents and/or skimmers in the afterbay (the third bay) as needed.

Baffle Design Criteria

- Oil retaining baffles (top baffles) should be located at least at 1/4 of the length of all three bays from the outlet, and should extend down at least 50% of the water depth and at least 1 ft from the oil and water separator BMP bottom.
- The baffle height to water depth ratios should be 0.85 for top baffles and 0.15 for bottom baffles.

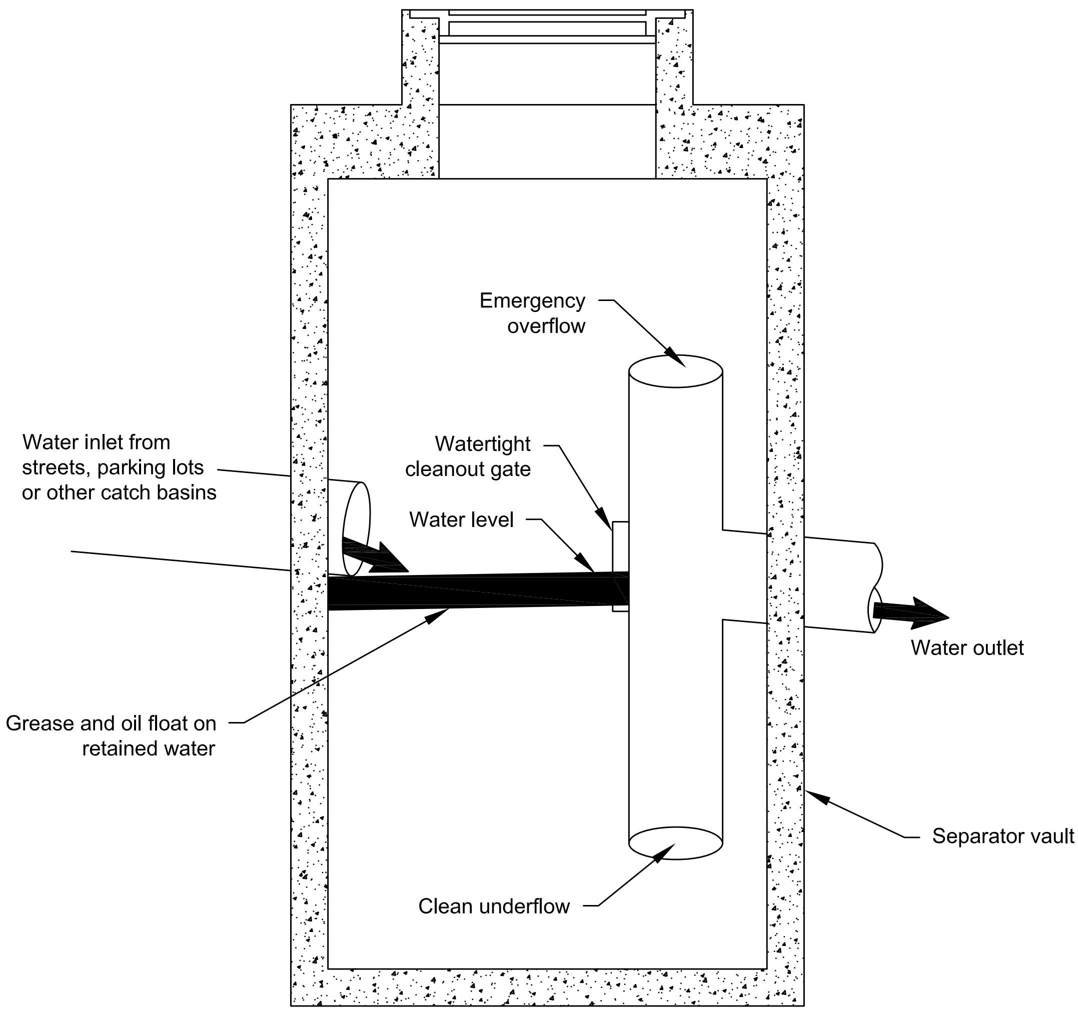
Operation and Maintenance

- Prepare, regularly update, and implement an O & M Manual for the oil and water separators.
- Inspect oil and water separators monthly during the wet season of October 1-June 30 (WEF and ASCE, 1998), (Woodward-Clyde, n.d.) to ensure proper operation, and, during and immediately after a large storm event of ≥ 1 inch per 24 hours.
- In Climate Region 2, it is most important to check these BMPs in the spring before the summer thunderstorm season begins; one annual check at this time of year should be sufficient for oil and water separators in Climate Region 2.
- Clean oil and water separators regularly to keep accumulated oil from escaping during storms. They must be cleaned by October 15 to remove material that has accumulated during the dry season (Woodward-Clyde, n.d.), after all spills, and after a significant storm. Coalescing plates may be cleaned in-situ or after removal from the separator. An eductor truck may be used for oil, sludge, and washwater removal. (King County, 1998) Replace wash water in the separator with clean water before returning it to service.
- Remove the accumulated oil when the thickness reaches 1-inch. Also remove sludge deposits when the thickness reaches 6 inches (King County, 1998).
- Replace oil absorbent pads before their sorbed oil content reaches capacity.
- Train designated employees on appropriate separator operation, inspection, record keeping, and maintenance procedures.
- See Appendix 6-A: BMP Maintenance Tables for additional maintenance recommendations

Spill Control Separators

A spill control (SC) separator (Figure 6.113: Spill Control Separator (not for oil treatment)) is a simple catchbasin with a T-inlet for temporarily trapping small volumes of oil. ***The spill control separator is included here for comparison purposes only and is not designed for, or to be used for Runoff Treatment purposes.***

Figure 6.113: Spill Control Separator (not for oil treatment)



Source: 1992 Ecology Manual

NOT TO SCALE

DEPARTMENT OF ECOLOGY State of Washington

Spill Control Separator (not for oil treatment)

Revised June 2016

BMP T5.100: API (Baffle type) Separator

Refer to 6.14.1 Introduction to Oil and Water Separator BMPs for Applications and Limitations, Site Suitability, General Design Criteria, and Operation and Maintenance guidance for both this BMP and BMP T5.110: Coalescing Plate (CP) Separator. Additional design criteria specific to this BMP is presented below.

Design Criteria

The criteria for small contributing areas is based on V_h (the horizontal velocity of the bulk fluid), V_t (the rise rate of the oil droplet), residence time, width, depth, and length considerations. As a correction factor, API's turbulence criteria is applied to increase the length.

Ecology modified the API criteria for treating stormwater runoff from small contributing areas of ≤ 2 acres (e.g. fueling stations, commercial parking lots, etc.). Ecology's modified criteria differ from the API criteria as follows:

- Use the design hydraulic horizontal velocity (V_h) for the design V_h/V_t ratio, rather than the API minimum of $V_h/V_t = 15$,
- Use an oil droplet diameter (D) of 60 microns, rather than the API formula where $D = (Q / (2 * V_h))^{1/2}$.
- Use a depth to width ratio (d/w) of 0.5, rather than the API range of 0.3 to 0.5.

Ecology considers the API criteria to be applicable for > 2 acres of impervious contributing area. Performance verification of this design basis must be obtained during at least one wet season using the test protocol referenced in 6.11 Manufactured Treatment Devices as BMPs.

Use Method 1 – Modified API Criteria for Contributing Areas Less than 2 Acres for small impervious contributing areas of ≤ 2 acres and Method 2 – API Criteria for Contributing Areas Greater Than 2 Acres for larger areas.

Method 1 – Modified API Criteria for Contributing Areas Less than 2 Acres

The stepwise procedure for designing API separator bay BMPs using Ecology's modified API criterion for small contributing areas of ≤ 2 acres includes the following:

1. Determine the oil rise rate (V_t) in cm/sec, using one of the following three options:

   - Stoke's Law (Water Pollution Control Federation, 1985)
   - Empirical determination
   - Default value of 0.033 feet per minute (ft/min) for a 60-micron droplet of oil

   The use of Stoke's Law or empirical rise rates is preferred over the default value because they account for the actual site-based oil droplet sizes and densities, and better represent the actual site conditions.

   Stoke's Law equation for rise rate:

   Equation 6.11: API Separator Rise Rate (Stoke's Law) (Method 1)

$$V_t = g * (\rho_w - \rho_o) * D^2 / (18 * \mu_w)$$

where:

V_t = rise rate of the oil droplet (centimeters per second [cm/sec])

g = acceleration due to gravity (981 cm/sec²)

ρ_w = density of water at the design temperature (0.999 gm/cc at 32 degrees Fahrenheit [°F])

ρ_o = density of oil at the design temperature (gm/cc). Select conservatively high oil density, for example: if diesel oil @ σ_o = 0.85 gm/cc and motor oil @ σ_o = 0.90 can be present, then use σ_o = 0.90 gm/cc.

D = oil droplet diameter (cm). Use oil droplet diameter d = 60 microns (0.006 cm).

μ_w = absolute viscosity of the water (0.017921 poise at a water temperature of 32°F)

Note that Stoke's Law assumes laminar flow.

2. Use the following separator dimension criteria:
   - Separator water depth (d) = ≥ 3 and ≤ 8 ft to minimize turbulence (API, 1990), (USACE, 1994)
   - Separator width (w) = 6 to 20 ft (WEF and ASCE, 1998), (King County, 2016)
   - Depth to width ratio (d/w) = 0.3 to 0.5 (API, 1990)
3. Calculate the minimum residence time of the separator at depth:

Equation 6.12: API Separator Minimum Residence Time (Method 1)

$$tm = d / Vt$$

where:

tm = minimum residence time (min)

d = depth (cm)

Vt = the rise rate of the oil droplet (cm/sec)

4. Calculate the horizontal velocity of the bulk fluid:

Equation 6.13: API Separator Horizontal Velocity of Bulk Fluid (Method 1)

$$V_h = Q / (d * w) = Q / A_v$$

where:

V_h = horizontal velocity of the bulk fluid (ft/min), maximum value < 2.0 ft/min (API, 1990)

Q = water quality design flow rate (cf/min), at minimum residence time (t_m)

A_v = vertical cross-sectional area (sf) = d * w

5. Determine the API turbulence and short-circuiting factor. Use Figure 6.115: Recommended Values for F for Various Values of vH/Vt based on the ratio of the rise rate of the oil droplet to the horizontal velocity of the bulk fluid (V_h/V_t). F values range from 1.28 to 1.74. (API, 1990)

6. Calculate the minimum length of the separator section:

Equation 6.14: API Separator Minimum Length (Method 1)

$$l(s) = (F * Q * t_m) / (w * d) = F * (V_h/V_t) * d$$

Equation 6.15: API Separator Bay Length (Method 1, Equation 1)

$$l(t) = l(f) + l(s) + l(a)$$

Equation 6.16: API Separator Bay Length (Method 1, Equation 2)

$$l(t) = l(t)/3 + l(s) + l(t)/4$$

where:

l(s) = length of separator section (ft)

F = turbulence and short-circuiting factor (See Figure 6.115: Recommended Values for F for Various Values of vH/Vt)

Q = water quality design flow rate (cf/min), at minimum residence time (t_m)

t_m = minimum residence time (min)

V_h = horizontal velocity of the bulk fluid (ft/min)

V_t = oil rise rate (cm/sec)

l(t) = total length of three bays (ft)

l(f) = length of forebay (ft)

l(a) = length of afterbay (ft)

7. Calculate the minimum hydraulic design volume using:

Equation 6.17: API Separator Minimum Hydraulic Design Volume (Method 1)

$$V = l(s) * w * d = F * Q * t_m$$

where:

V = minimum hydraulic design volume (cf)

l(s) = length of separator section (ft)

w = width (ft)

d = depth (ft)

F = turbulence and short-circuiting factor (Figure 6.115: Recommended Values for F for Various Values of vH/Vt)

Q = water quality design flow rate (cf/min), at minimum residence time (t_m)

t_m = minimum residence time (min)

8. Calculate the minimum horizontal area of the separator using:

Equation 6.18: API Separator Minimum Horizontal Area (Method 1)

$$A_h = w * l(s)$$

where:

A_h = minimum horizontal area of the separator (sf)w = width (ft)

l(s) = length of separator section (ft)

Method 2 – API Criteria for Contributing Areas Greater Than 2 Acres

For stormwater inflow from drainages > 2 acres, repeat Steps 1 through 8 in Method 1, above, using the following values:

Equation 6.19: API Separator Horizontal Velocity of Bulk Fluid (Method 2)

$$V_h = 15 * V_t$$

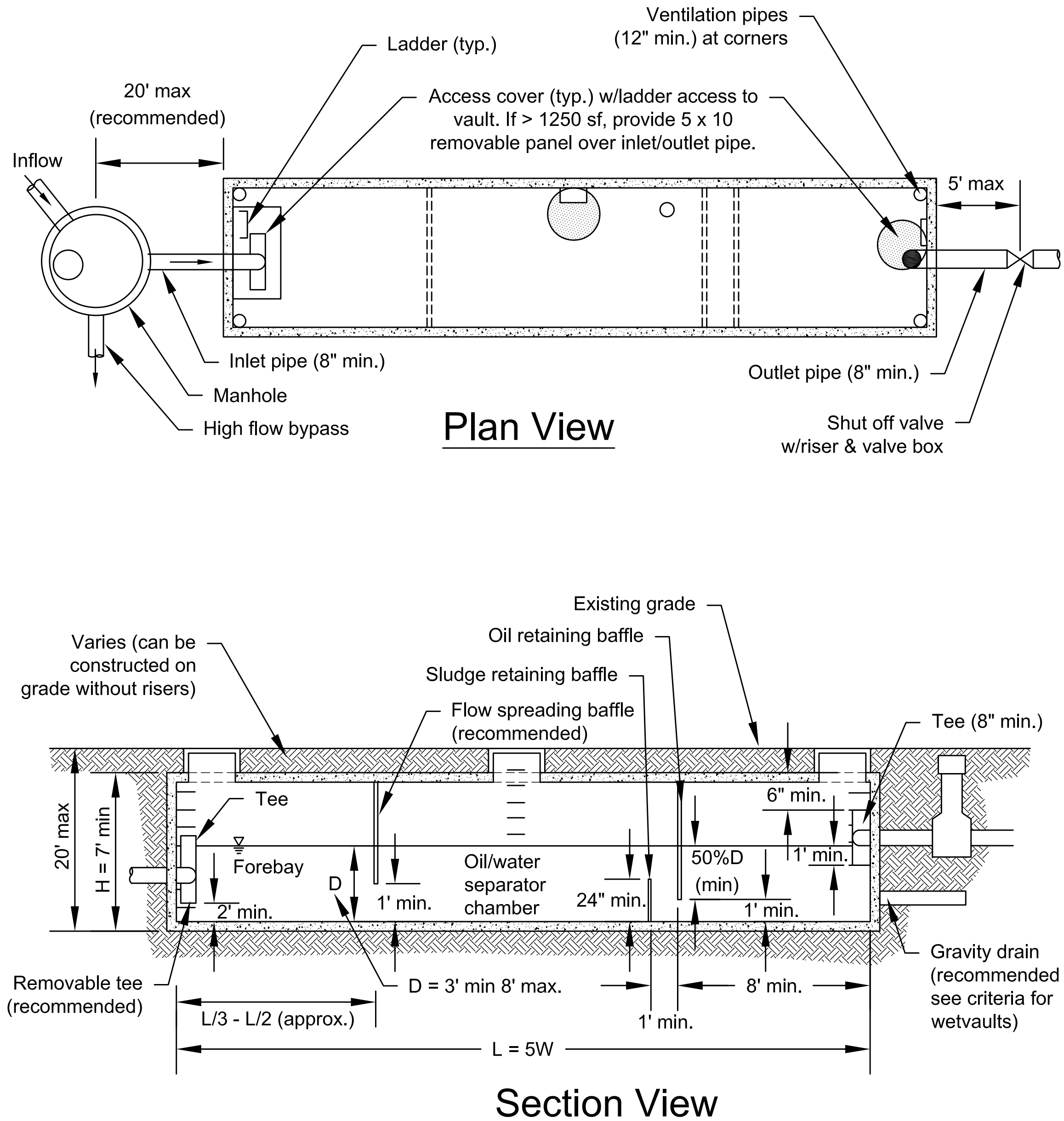
Equation 6.20: API Separator Oil Droplet Diameter (Method 2)

$$D = (Q / (2 \times V_h))^{1/2}$$

Equation 6.21: API Separator Depth to Width Ratio (Method 2)

$$d/w = 0.5$$

Figure 6.114: API (Baffle Type) Separator



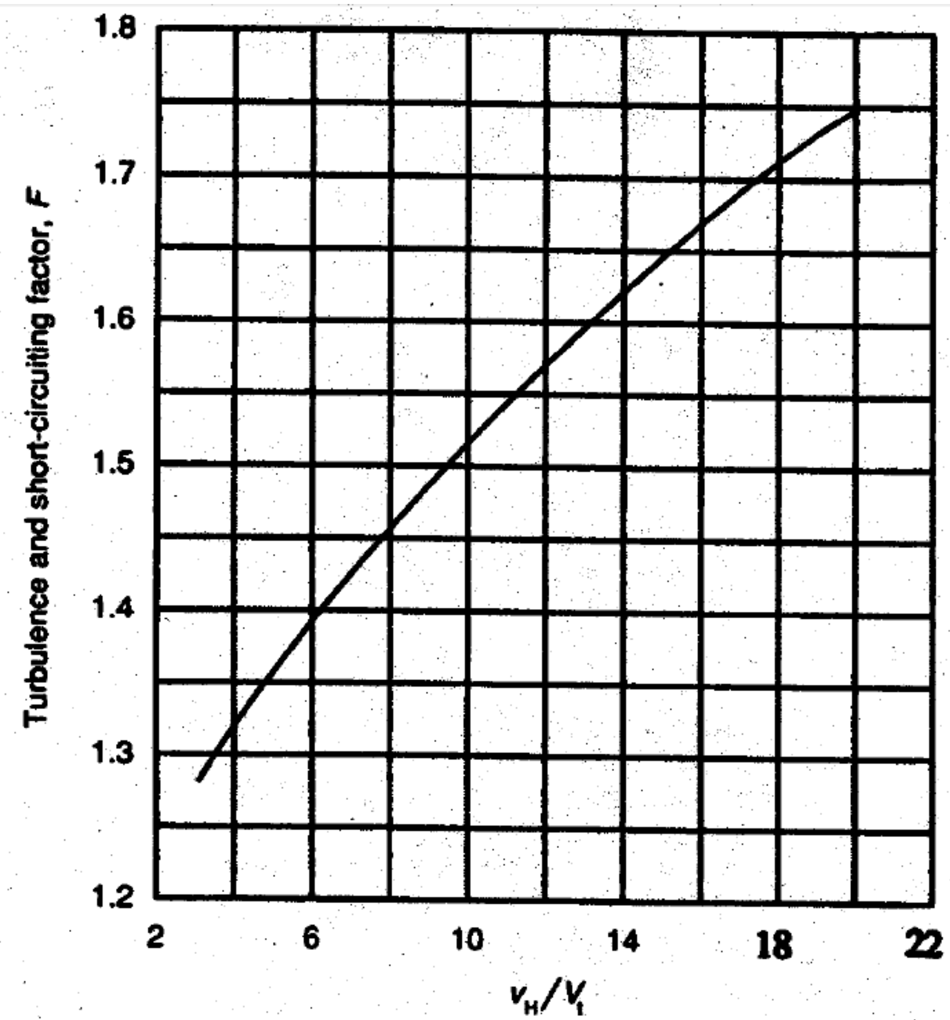
Source: King County (reproduced with permission)

DEPARTMENT OF ECOLOGY State of Washington

API (Baffle Type) Separator

Revised May 2018

Figure 6.115: Recommended Values for F for Various Values of v_H/V_t



v_H/V_t	Turbulence Factor (F_t)	$F = 1.2(F_t)$
20	1.45	1.74
15	1.37	1.64
10	1.27	1.52
6	1.14	1.37
3	1.07	1.28

DEPARTMENT OF ECOLOGY State of Washington

Recommended Values for *F* for Various Values of v_H/V_t

Revised June 2016

BMP T5.110: Coalescing Plate (CP) Separator

Refer to 6.14.1 Introduction to Oil and Water Separator BMPs for Applications and Limitations, Site Suitability, General Design Criteria, and Operation and Maintenance guidance for both this BMP and BMP T5.100: API (Baffle type) Separator. Additional design criteria specific to this BMP is presented below.

Design Criteria

- Calculate the projected (horizontal) surface area of plates needed using the following equation:

  $$A_{hn} = Q/Vt = [Q] / [(.00386) * ((S_w - S_o)/(\mu_w))]$$

  Where

  A_{hn} = needed horizontal surface area of the plates (ft²)

  Vt = rise rate of the oil droplet (ft/min)

  Q = water quality design flow rate, cubic feet per minute (cf/min)

  S_w = specific gravity of water at the design temperature

  S_o = specific gravity of oil at the design temperature

  μ_w = absolute viscosity of the water (poise)

  The above equation is based on an oil droplet diameter of 60 microns.

- Verify that the actual projected (horizontal) surface area of the plates is greater than the surface area needed (as determined above), by using the following equation:

  $$A_{ha} = A_a * (\text{cosine } b)$$

  Where

  A_{ha} = actual horizontal surface area of the plates in square feet (sf)

  A_a = actual plate area in sf (one side only)

  b = angle of the plates with the horizontal in degrees (usually varies from 45 to 60 degrees).

- The plate spacing should be a minimum of 0.75 inches (perpendicular distance between plates), or as determined by the manufacturer. (WEF and ASCE, 1998), (USACE, 1994), (Jaisinghani and Sprenger, 1979)

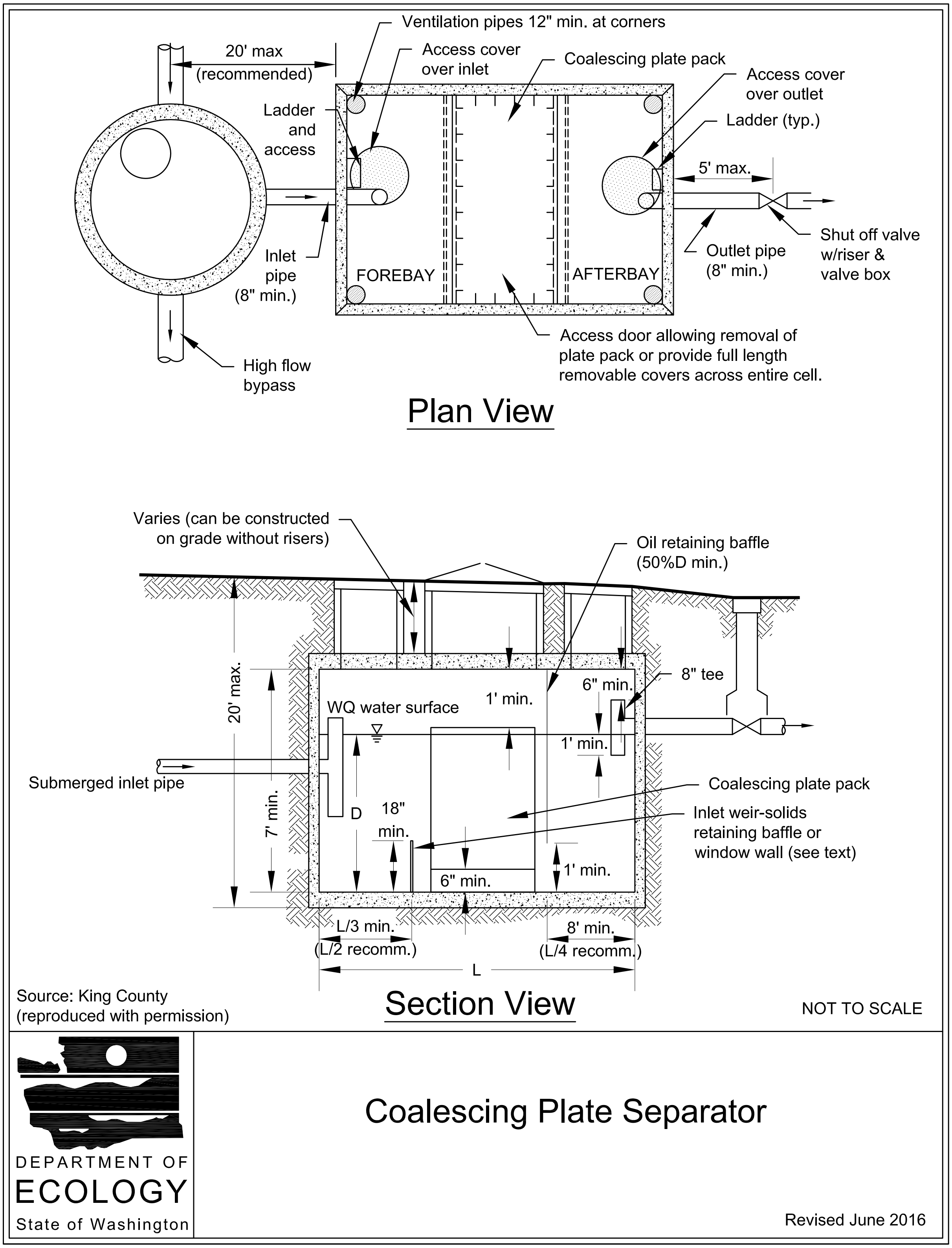
- Select a plate angle between 45° to 60° from the horizontal.

- Locate the plate pack at least 6 inches from the bottom of the separator bay for sediment storage

- Add 12 inches minimum head space from the top of the plate pack and the bottom of the vault cover.

- Design the inlet flow distribution and baffles in the separator bay to minimize turbulence, short-circuiting, and channeling of the inflow especially through and around the plate packs of the CP separator. The Reynolds Number through the separator bay should be <500 (laminar flow).
- Include a forebay for floatables and an afterbay for collection of effluent. (WEF and ASCE, 1998)
- The sediment-retaining baffle must be upstream of the plate pack at a minimum height of 18 in. (King County, 1998).
- Design the coalescing plates for ease of removal, and cleaning with high-pressure rinse or equivalent.

Figure 6.116: Coalescing Plate Separator



Appendix 6-A: BMP Maintenance Tables

6.A.1 How To Use The BMP Maintenance Tables

The Best Management Practice (BMP) specific maintenance criteria contained in this appendix are intended to be conditions for determining if maintenance actions are required as identified through inspection. They are not intended to be measures of the required condition of the BMP at all times between inspections. In other words, exceeding these conditions at any time between inspections and/or maintenance does not automatically constitute a violation of these criteria. However, based on inspection observations, the inspection and maintenance schedules shall be adjusted to minimize the length of time that a BMP is in a condition that requires a maintenance action.

6.A.2 Maintenance Standards - Detention Ponds

Table 6.43: Maintenance Standards - Detention Ponds

Maintenance Component	Defect	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed
General	Trash and Debris	Any trash and debris which exceed 5 cubic feet (cf) per 1,000 square feet (sf), which is about equal to the amount of trash it would take to fill up one standard size garbage can. In general, there should be no visual evidence of dumping. If less than the threshold above, all trash and debris will be removed as part of next scheduled maintenance.	Trash and debris cleared from site
	Poisonous Vegetation and Noxious Weeds	Any poisonous or nuisance vegetation which may constitute a hazard to maintenance personnel or the public. Any evidence of noxious weeds as defined by State or local regulations. (Apply requirements of adopted integrated pest management (IPM) policies for the use of herbicides).	No danger of poisonous vegetation where maintenance personnel or the public might normally be. (Coordinate with local health department). Complete eradication of noxious weeds may not be possible. Compliance with State or local eradication policies required
	Contaminants and Pollution	Any evidence of oil, gasoline, contaminants or other pollutants. (Coordinate removal/cleanup with local water quality response agency).	No contaminants or pollutants present.
	Rodent Holes	Any evidence of rodent holes if the pond is acting as a dam or berm, or any evidence of water piping through dam or berm via rodent holes.	Rodents destroyed and dam or berm repaired. (Coordinate with local health department and Ecology Dam Safety Office if pond exceeds 10 acre-feet).
	Beaver Dams	Dam results in change or function of the BMP.	BMP is returned to design function. (Coordinate trapping of beavers and removal of dams with appropriate permitting agencies).
	Insects	When insects such as wasps and hornets interfere with maintenance activities.	Insects destroyed or removed from site. Apply insecticides in compliance with adopted IPM policies
	Tree Growth and Hazard Trees	Tree growth does not allow maintenance and inspection access, or interferes with maintenance activity (i.e. slope mowing, silt removal, vactoring, or equipment movements). If trees are not interfering with access or maintenance, do not remove. If dead, diseased, or dying trees are identified. (Use a certified arborist to determine health of tree or removal requirements)	Trees do not hinder maintenance activities. Harvested trees should be recycled into mulch or other beneficial uses (e.g. alders for firewood). Remove hazard trees.
Side Slopes of Pond	Erosion	Eroded damage over 2 inches deep where cause of damage is still present or where there is potential for continued erosion.	Slopes should be stabilized using appropriate erosion control measure(s); e.g. rock reinforcement, planting of grass, compaction.

Table 6.43: Maintenance Standards - Detention Ponds (continued)

Maintenance Component	Defect	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed
		Any erosion observed on a compacted berm embankment.	If erosion is occurring on compacted berms a licensed engineer in the state of Washington should be consulted to resolve source of erosion.
Storage Area	Sediment	Accumulated sediment that exceeds 10% of the designed pond depth unless otherwise specified or affects inletting or outletting condition of the BMP.	Sediment cleaned out to designed pond shape and depth; pond reseeded if necessary to control erosion.
	Liner (if applicable)	Liner is visible and has more than three 0.25-inch holes in it.	Liner repaired or replaced. Liner is fully covered.
Pond Berms (Dikes)	Settlements	Any part of berm which has settled 4 inches lower than the design elevation. If settlement is apparent, measure berm to determine amount of settlement. Settling can be an indication of more severe problems with the berm or outlet works. A licensed engineer in the state of Washington should be consulted to determine the source of the settlement.	Dike is built back to the design elevation.
	Piping	Discernible water flow through pond berm. Ongoing erosion with potential for erosion to continue. (Recommend a geotechnical engineer be called in to inspect and evaluate condition and recommend repair of condition.	Piping eliminated. Erosion potential resolved.
Emergency Overflow/Spillway	Tree Growth	Tree growth on emergency spillways creates blockage problems and may cause failure of the berm due to uncontrolled overtopping. Tree growth on berms over 4 feet in height may lead to piping through the berm which could lead to failure of the berm.	Trees should be removed. If root system is small (base less than 4 inches) the root system may be left in place. Otherwise the roots should be removed and the berm restored. A licensed engineer in the state of Washington should be consulted for proper berm/spillway restoration.
	Piping	Discernible water flow through pond berm. Ongoing erosion with potential for erosion to continue. (Recommend a geotechnical engineer be called in to inspect and evaluate condition and recommend repair of condition.	Piping eliminated. Erosion potential resolved.
	Emergency Overflow/Spillway	Only one layer of rock exists above native soil in area five square feet or larger, or any exposure of native soil at the top of outflow path of spillway. (Riprap on inside slopes need not be replaced.)	Rocks and pad depth are restored to design standards.
	Erosion	See Side Slopes of Pond	

6.A.3 Maintenance Standards - Infiltration

Table 6.44: Maintenance Standards - Infiltration

Maintenance Component	Defect	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed
General	Trash & Debris	See 6.A.2 Maintenance Standards - Detention Ponds	
	Poisonous/Noxious Vegetation	See 6.A.2 Maintenance Standards - Detention Ponds	

Table 6.44: Maintenance Standards - Infiltration (continued)

Maintenance Component	Defect	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed
	Contaminants and Pollution	See 6.A.2 Maintenance Standards - Detention Ponds	
	Rodent Holes	See 6.A.2 Maintenance Standards - Detention Ponds	
Storage Area	Sediment	Water ponding in infiltration pond after rainfall ceases and appropriate time allowed for infiltration. (A percolation test pit or test of the pond indicates that the pond is only working at 90% of its designed capabilities. Test every 2 to 5 years. If two inches or more sediment is present, remove).	Sediment is removed and/or pond is cleaned so that infiltration system works according to design.
Filter Bags (if applicable)	Filled With Sediment and Debris	Sediment and debris fill bag more than 1/2 full.	Filter bag is replaced or system is redesigned.
Rock Filters	Sediment and Debris	By visual inspection, little or no water flows through filter during heavy rain storms.	Gravel in rock filter is replaced.
Side Slopes of Pond	Erosion	See 6.A.2 Maintenance Standards - Detention Ponds	
Emergency Overflow Spillway and Berms over 4 feet in height	Tree Growth	See 6.A.2 Maintenance Standards - Detention Ponds	
	Piping	See 6.A.2 Maintenance Standards - Detention Ponds	
Emergency Overflow Spillway	Rock Missing	See 6.A.2 Maintenance Standards - Detention Ponds	
	Erosion	See 6.A.2 Maintenance Standards - Detention Ponds	
Pre-settling Ponds and Vaults	Facility of Sump Filled with Sediment and/or Debris	6" or designed sediment trap depth of sediment.	Sediment is removed.

6.A.4 Maintenance Standards - Evaporation Ponds

Table 6.45: Maintenance Standards - Evaporation Ponds

Maintenance Component	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
General	Trash and Debris	See 6.A.2 Maintenance Standards - Detention Ponds	
	Poisonous/ Noxious Vegetation	See 6.A.2 Maintenance Standards - Detention Ponds	
	Contaminants and Pollution	See 6.A.2 Maintenance Standards - Detention Ponds	
	Rodent Holes	See 6.A.2 Maintenance Standards - Detention Ponds	
Side Slopes of Pond	Erosion	See 6.A.2 Maintenance Standards - Detention Ponds	
Storage Area	Sediment	Accumulated sediment that exceeds 10% of the designed pond depth unless otherwise specified or affects inletting or outletting condition of the pond.	Sediment cleaned out to designed pond shape and depth; pond reseeded if necessary to control erosion.
	Liner (if	Liner is visible and has > three 0.25-inch holes in it.	Liner repaired or replaced. Liner is fully covered.

Table 6.45: Maintenance Standards - Evaporation Ponds (continued)

Maintenance Component	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
	applicable)		
Pond Berms (Dikes)	Settlements	Any part of berm which has settled 4 inches lower than the design elevation. If settlement is apparent, measure berm to determine amount of settlement. Settling can be an indication of more severe problems with the berm or outlet works. A licensed engineer in the state of Washington should be consulted to determine the source of the settlement.	Dike is built back to the design elevation.
	Piping	Discernable water flow through pond berm. Ongoing erosion with potential for erosion to continue. (Recommend a licensed engineer in the state of Washington with geotechnical expertise be called in to inspect and evaluate condition and recommend repair of condition.	Piping eliminated. Erosion potential resolved.
General	Inlet Pipe	Inlet pipe clogged with sediment and/or debris material.	No clogging or blockage in the inlet and outlet piping.
	Oil Sheen on Water	Prevalent and visible oil sheen.	Oil removed from water using oil-absorbent pads or Vactor truck. Source of oil located and corrected. If chronic low levels of oil persist, plant wetland plants such as *Juncus effusus* (soft rush) which can uptake small concentrations of oil.
	Erosion	Erosion of the pond’s side slopes and/or scouring of the pond bottom that exceeds 6 inches, or where continued erosion is prevalent.	Slopes stabilized using proper erosion control measures and repair methods.
	Overflow Spillway	Rock is missing and soil is exposed at top of spillway or outside slope.	Rocks replaced to specifications.
	Snow	Snow removal operations deposit snow into evaporation pond.	This added factor must be considered in the water budget, especially if snow from another basin is put into the system. Temporary sediment ponds should be included in the design, to prevent sediment-laden runoff from entering the pond and storm disposal system during construction.

6.A.5 Maintenance Standards - Tanks and Vaults

Table 6.46: Maintenance Standards - Tanks and Vaults

Maintenance Component	Defect	Conditions When Maintenance is Needed	Results Expected When Maintenance is Performed
Storage Area	Plugged Air Vents	One-half of the cross section of a vent is blocked at any point, or the vent is damaged.	Vents open and functioning.
	Debris and Sediment	Accumulated sediment depth exceeds 10% of the diameter of the storage area for one-half the length of the storage vault, or any point depth exceeds 15% of the diameter. (Example: 72-inch diameter storage tank would require cleaning when sediment reaches depth of 7 inches for more than 1/2 the length of the tank.)	All sediment and debris removed from storage area.
	Joints Between Tank/Pipe Section	Any openings or voids allowing material to be transported into the tank/vault. (Will require engineering analysis to determine structural stability).	All joint between tank/pipe sections are sealed.
	Tank Pipe Bent Out of Shape	Any part of tank/pipe is bent out of shape more than 10% of its design shape. (Review required by engineer to determine structural stability).	Tank/pipe repaired or replaced to design.
	Vault Structure Includes Cracks in Wall, Bottom, Damage to Frame and/or Top Slab	Cracks wider than 0.5-inch and any evidence of soil particles entering the structure through the cracks, or maintenance/inspection personnel determines that the vault is not structurally sound. Cracks wider than 0.5-inch at the joint of any inlet/outlet pipe or any evidence of soil particles entering the vault through the walls.	Vault replaced or repaired to design specifications and is structurally sound. No cracks more than 0.25-inch wide at the joint of the inlet/outlet pipe.
Access Opening(s)	Cover Not in Place	Cover is missing or only partially in place. Any open manhole requires maintenance.	Manhole is closed.
	Locking Mechanism Not Working	Mechanism cannot be opened by one maintenance person with proper tools. Bolts into frame have less than 0.5-inch of thread (may not apply to self-locking lids).	Mechanism opens with proper tools.
	Cover Difficult to Remove	One maintenance person cannot remove lid after applying normal lifting pressure. Intent is to keep cover from sealing off access to maintenance.	Cover can be removed and reinstalled by one maintenance person.
	Ladder Rungs Unsafe	Ladder is unsafe due to missing rungs, misalignment, not securely attached to structure wall, rust, or cracks.	Ladder meets design standards. Allows maintenance person safe access.
Catch Basins	See 6.A.7 Maintenance Standards - Catch Basins		

6.A.6 Maintenance Standards - Control Structures

Table 6.47: Maintenance Standards - Control Structures

Maintenance Component	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
General	Trash and Debris (includes sediment)	Material exceeds 25% of sump depth or 1 foot below orifice plate.	Control structure orifice is not blocked. All trash and debris removed.
	Structural Damage	Structure is not securely attached to manhole wall. Structure is not in upright position (allow up to 10% from plumb). Connections to outlet pipe are not watertight and show signs of rust. Any holes - other than designed holes - in the structure.	Structure securely attached to wall and outlet pipe. Structure in correct position. Connections to outlet pipe are water tight; structure repaired or replaced and works as designed.

Table 6.47: Maintenance Standards - Control Structures (continued)

Maintenance Component	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
			Structure has no holes other than designed holes.
Clean-out Gate	Damaged or Missing	Clean-out gate is not watertight or is missing. Gate cannot be moved up and down by one maintenance person. Chain/rod leading to gate is missing or damaged. Gate is rusted over 50% of its surface area.	Gate is watertight and works as designed. Gate moves up and down easily and is watertight. Chain is in place and works as designed. Gate is repaired or replaced to meet design standards.
Orifice Plate	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.
	Obstructions	Any trash, debris, sediment, or vegetation blocking the plate.	Plate is free of all obstructions and works as designed.
Overflow Pipe	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.
Access Opening	See 6.A.5 Maintenance Standards - Tanks and Vaults		
Catch Basin	See 6.A.7 Maintenance Standards - Catch Basins		

6.A.7 Maintenance Standards - Catch Basins

Table 6.48: Maintenance Standards - Catch Basins

Maintenance Component	Defect	Conditions When Maintenance is Needed	Results Expected When Maintenance is performed
General	Trash & Debris	Trash or debris which is located immediately in front of the catch basin opening or is blocking inletting capacity of the basin by more than 10%. Trash or debris (in the basin) that exceeds 60% of the sump depth as measured from the bottom of basin to invert of the lowest pipe into or out of the basin, but in no case less than a minimum of 6 inches clearance from the debris surface to the invert of the lowest pipe. Trash or debris in any inlet or outlet pipe blocking more than 1/3 of its height. Dead animals or vegetation that could generate odors that could cause complaints or dangerous gases (e.g. methane).	No Trash or debris located immediately in front of catch basin or on grate opening. No trash or debris in the catch basin. Inlet and outlet pipes free of trash or debris. No dead animals or vegetation present within the catch basin.
	Sediment	Sediment (in the basin) that exceeds 60% of the sump depth as measured from the bottom of basin to invert of the lowest pipe into or out of the basin, but in no case less than a minimum of 6 inches clearance from the sediment surface to the invert of the lowest pipe.	No sediment in the catch basin
	Structure Damage to Frame and/or Top Slab	Top slab has holes larger than 2 square inches or cracks wider than 1/4 inch. (Intent is to make sure no material is running into basin). Frame not sitting flush on top slab, i.e. separation of more than 3/4 inch of the frame from the top slab. Frame not securely attached.	Top slab is free of holes and cracks. Frame is sitting flush on the riser rings or top slab and firmly attached.
	Fractures or Cracks in Basin Walls/ Bottom	Maintenance person judges that structure is unsound. Grout fillet has separated or cracked wider than 1/2 inch and longer than 1 foot at the joint of any inlet/outlet pipe or any evidence of soil particles entering catch basin through cracks.	Basin replaced or repaired to design standards. Pipe is regrouted and secure at basin wall.
	Settlement/ Misalignment	If failure of basin has created a safety, function, or design problem.	Basin replaced or repaired to design standards.
	Vegetation	Vegetation growing across and blocking more than 10% of the basin opening.	No vegetation blocking opening to basin.

Table 6.48: Maintenance Standards - Catch Basins (continued)

Maintenance Component	Defect	Conditions When Maintenance is Needed	Results Expected When Maintenance is performed
		Vegetation growing in inlet/outlet pipe joints that is more than 6 inches tall and less than 6 inches apart.	No vegetation or root growth present.
	Contamination and Pollution	See 6.A.2 Maintenance Standards - Detention Ponds	No pollution present.
Catch Basin Cover	Cover Not in Place	Cover is missing or only partially in place. Any open catch basin requires maintenance.	Cover/grate is in place, meets design standards, and is secured.
	Locking Mechanism Not Working	Mechanism cannot be opened by one maintenance person with proper tools. Bolts into frame have less than 1/2 inch of thread.	Mechanism opens with proper tools.
	Cover Difficult to Remove	One maintenance person cannot remove lid after applying normal lifting pressure. (Intent is keep cover from sealing off access to maintenance.)	Cover can be removed by one maintenance person.
Ladder	Ladder Rungs Unsafe	Ladder is unsafe due to missing rungs, not securely attached to basin wall, misalignment, rust, cracks, or sharp edges.	Ladder meets design standards and allows maintenance person safe access.
Metal Grates (if applicable)	Grate opening Unsafe	Grate with opening wider than 7/8 inch.	Grate opening meets design standards.
	Trash and Debris	Trash and debris that is blocking more than 20% of grate surface inletting capacity.	Grate free of trash and debris.
	Damaged or Missing.	Grate missing or broken member(s) of the grate.	Grate is in place, meets the design standards, and is installed and aligned with the flow path.

6.A.8 Maintenance Standards - Debris Barriers (e.g. Trash Racks)

Table 6.49: Maintenance Standards - Debris Barriers (e.g. Trash Racks)

Maintenance Components	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
General	Trash and Debris	Trash or debris that is plugging more than 20% of the openings in the barrier.	Barrier cleared to design flow capacity.
Metal	Damaged/ Missing Bars	Bars are bent out of shape more than 3 inches. Bars are missing or entire barrier missing. Bars are loose and rust is causing 50% deterioration to any part of barrier.	Bars in place with no bends more than 3/4 inch. Bars in place according to design. Barrier replaced or repaired to design standards.
	Inlet/Outlet Pipe	Debris barrier missing or not attached to pipe	Barrier firmly attached to pipe

6.A.9 Maintenance Standards - Energy Dissipators

Table 6.50: Maintenance Standards - Energy Dissipators

Maintenance Components	Defect	Conditions When Maintenance is Needed	Results Expected When Maintenance is Performed
External			
Rock Pad	Missing or Moved Rock	Only one layer of rock exists above native soil in area five square feet or larger, or any exposure of native soil.	Rock pad replaced to design standards.
	Erosion	Soil erosion in or adjacent to rock pad.	Rock pad replaced to design standards.

Table 6.50: Maintenance Standards - Energy Dissipators (continued)

Maintenance Components	Defect	Conditions When Maintenance is Needed	Results Expected When Maintenance is Performed
Dispersion Trench	Pipe Plugged with Sediment	Accumulated sediment that exceeds 20% of the design depth.	Pipe cleaned/flushed so that it matches design.
	Not Discharging Water Properly	Visual evidence of water discharging at concentrated points along trench (normal condition is a "sheet flow" of water along trench). Intent is to prevent erosion damage.	Trench redesigned or rebuilt to standards.
	Perforations Plugged	Over 1/2 of perforations in pipe are plugged with debris and sediment.	Perforated pipe cleaned or replaced.
	Water Flowing out Top of "Distributor" Catch Basin	Maintenance person observes or receives credible report of water flowing out during any storm less than the design storm or is causing or appears likely to cause damage.	Energy dissipator rebuilt or redesigned to standards.
	Receiving Area Oversaturated	Water in receiving area is causing or has potential of causing landslide problems.	No danger of landslides.
Internal			
Manhole/Chamber	Worn or Damaged Post, Baffles, or Side of Chamber	Structure dissipating flow deteriorates to 1/2 of original size or any concentrated worn spot exceeding one square foot, which would make structure unsound.	Structure replaced to design standards.
	Other Defects	See 6.A.7 Maintenance Standards - Catch Basins	

6.A.10 Maintenance Standards - Typical Biofiltration Swale

Table 6.51: Maintenance Standards - Typical Biofiltration Swale

Maintenance Component	Defect or Problem	Condition When Maintenance is Needed	Recommended Maintenance to Correct Problem
General	Sediment Accumulation on Grass	Sediment depth exceeds 2 inches.	Remove sediment deposits on grass treatment area of the biofiltration swale. When finished, swale should be level from side to side and drain freely toward outlet. There should be no areas of standing water once inflow has ceased.
	Standing Water	When water stands in the swale between storms and does not drain freely.	Any of the following may apply: remove sediment or trash blockages, improve grade from head to foot of swale, remove clogged check dams, add underdrains, or convert to a wet biofiltration swale.
	Flow spreader	Flow spreader uneven or clogged so that flows are not uniformly distributed through entire swale width.	Level the spreader and clean so that flows are spread evenly over entire swale width.
	Constant Baseflow	When small quantities of water continually flow through the swale, even when it has been dry for weeks, and an eroded, muddy channel has formed in the swale bottom.	Add a low-flow pea-gravel drain the length of the swale or by-pass the baseflow around the swale.
	Poor Vegetation Coverage	When grass is sparse or bare or eroded patches occur in more than 10% of the swale bottom.	Determine why grass growth is poor and correct that condition. Re-plant with plugs of grass from the upper slope: plant in the swale bottom at 8-inch intervals. Or re-seed into loosened, fertile soil.
	Vegetation	When the grass becomes excessively tall (greater than 10-inches); when nuisance weeds and other vegetation starts to take over.	Mow vegetation or remove nuisance vegetation so that the flow is not impeded. Grass should be mowed to a height of 3 to 4 inches. Remove grass clippings.
	Excessive Shading	Grass growth is poor because sunlight does not reach swale.	If possible, trim back over-hanging limbs and remove brushy vegetation on adjacent slopes.
	Inlet/Outlet	Inlet/outlet areas clogged with sediment and/or debris.	Remove material so that there is no clogging or blockage in the inlet and outlet area.
	Trash and Debris Accumulation	Trash and debris accumulated in the bio-swale.	Remove trash and debris from biofiltration swale.

Table 6.51: Maintenance Standards - Typical Biofiltration Swale (continued)

Maintenance Component	Defect or Problem	Condition When Maintenance is Needed	Recommended Maintenance to Correct Problem
	Erosion/Scouring	Eroded or scoured swale bottom due to flow channelization, or higher flows.	For ruts or bare areas less than 12 inches wide, repair the damaged area by filling with crushed gravel. If bare areas are large, generally greater than 12 inches wide, the swale should be re-graded and re-seeded. For smaller bare areas, overseed when bare spots are evident, or take plugs of grass from the upper slope and plant in the swale bottom at 8-inch intervals.

6.A.11 Maintenance Standards - Wet Biofiltration Swale

Table 6.52: Maintenance Standards - Wet Biofiltration Swale

Maintenance Component	Defect or Problem	Condition When Maintenance is Needed	Recommended Maintenance to Correct Problem
General	Sediment Accumulation	Sediment depth exceeds 2-inches in 10% of the swale treatment area.	Remove sediment deposits in treatment area.
	Water Depth	Water not retained to a depth of about 4 inches during the wet season.	Build up or repair outlet berm so that water is retained in the wet swale.
	Wetland Vegetation	Vegetation becomes sparse and does not provide adequate filtration, OR vegetation is crowded out by very dense clumps of cattail, which do not allow water to flow through the clumps.	Determine cause of lack of vigor of vegetation and correct. Replant as needed. For excessive cattail growth, cut cattail shoots back and compost off-site. Note: normally wetland vegetation does not need to be harvested unless die-back is causing oxygen depletion in downstream waters.
	Inlet/Outlet	Inlet/outlet area clogged with sediment and/or debris.	Remove clogging or blockage in the inlet and outlet areas.
	Trash and Debris Accumulation	See 6.A.2 Maintenance Standards - Detention Ponds	Remove trash and debris from wet swale.
	Erosion/Scouring	Swale has eroded or scoured due to flow channelization, or higher flows.	Check design flows to assure swale is large enough to handle flows. By-pass excess flows or enlarge swale. Replant eroded areas with fibrous-rooted plants such as Juncus effusus (soft rush) in wet areas or snowberry (Symphoricarpos albus) in dryer areas.

6.A.12 Maintenance Standards - Vegetated Filter Strips

Table 6.53: Maintenance Standards - Vegetated Filter Strips

Maintenance Component	Defect or Problem	Condition When Maintenance is Needed	Recommended Maintenance to Correct Problem
General	Sediment Accumulation on Grass	Sediment depth exceeds 2 inches.	Remove sediment deposits, re-level so slope is even and flows pass evenly through strip.
	Vegetation	When the grass becomes excessively tall (greater than 10-inches); when nuisance weeds and other vegetation starts to take over.	Mow grass, control nuisance vegetation, such that flow not impeded. Grass should be mowed to a height between 3-4 inches.
	Trash and Debris Accumulation	Trash and debris accumulated on the filter strip.	Remove trash and Debris from filter.
	Erosion/Scouring	Eroded or scoured areas due to flow channelization, or higher flows.	For ruts or bare areas less than 12 inches wide, repair the damaged area by filling with crushed gravel. The grass will creep in over the rock in time. If bare areas are large, generally greater than 12 inches wide, the filter strip should be re-graded and re-seeded. For smaller bare areas, overseed when bare spots are evident.
	Flow spreader	Flow spreader uneven or clogged so that flows are not uniformly distributed through entire filter width.	Level the spreader and clean so that flows are spread evenly over entire filter width.

6.A.13 Maintenance Standards - Wetponds

Table 6.54: Maintenance Standards - Wetponds

Maintenance Component	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
General	Water Level	First cell is empty, doesn't hold water.	Line the first cell to maintain at least 4 feet of water. Although the second cell may drain, the first cell must remain full to control turbulence of the incoming flow and reduce sediment resuspension.
	Trash and Debris	Any trash and debris > 5 cubic feet (cf) per 1,000 square feet (sf). (This is about equal to the amount of trash it would take to fill up one standard size garbage can). In general, there should be no visual evidence of dumping. If less than threshold, all trash and debris will be removed as part of next scheduled maintenance.	Trash and debris cleared from site.
	Inlet/Outlet Pipe	Inlet/Outlet pipe clogged with sediment and/or debris material.	No clogging or blockage in the inlet and outlet piping.
	Sediment Accumulation in Pond Bottom	Sediment accumulations in pond bottom that exceeds the depth of sediment zone plus 6-inches, usually in the first cell.	Sediment removed from pond bottom.
	Oil Sheen on Water	Prevalent and visible oil sheen.	Oil removed from water using oil-absorbent pads or vactor truck. Source of oil located and corrected. If chronic low levels of oil persist, plant wetland plants such as Juncus effusus (soft rush) which can uptake small concentrations of oil.
	Erosion	Erosion of the pond's side slopes and/or scouring of the pond bottom, that exceeds 6-inches, or where continued erosion is prevalent.	Slopes stabilized using proper erosion control measures and repair methods.
	Settlement of Pond Dike/Berm	Any part of these components that has settled 4 inches or lower than the design elevation, or inspector determines dike/berm is unsound.	Dike/berm is repaired to specifications.
	Internal Berm	Berm dividing cells should be level.	Berm surface is leveled so that water flows evenly over entire length of berm.
	Overflow Spillway	Rock is missing and soil is exposed at top of spillway or outside slope.	Rocks replaced to specifications.
	Poisonous Vegetation and Noxious Weeds	Any poisonous or nuisance vegetation that may constitute a hazard to maintenance personnel or the public. Any evidence of noxious weeds as defined by state or local regulations. (Apply requirements of adopted integrated pest management policies for the use of herbicides).	No danger of poisonous vegetation where maintenance personnel or the public might normally be. (Coordinate with local health department). Complete eradication of noxious weeds may not be possible. Compliance with state or local eradication policies required.
	Contaminants and Pollution	Any evidence of oil, gasoline, contaminants or other pollutants (Coordinate removal/cleanup with local water quality response agency).	No contaminants or pollutants present.
	Rodent Holes	Any evidence of rodent holes if wetpond is acting as a dam or berm, or any evidence of water piping through dam or berm via rodent holes.	Rodents destroyed and dam or berm repaired. (Coordinate with local health department; coordinate with the Washington State Department of Ecology Dam Safety Office if pond ≥ 10 acre-feet.)
	Beaver Dams	Dam results in change or function of the wetpond.	Wetpond is returned to design function. (Coordinate trapping of beavers and removal of dams with appropriate permitting agencies.)
	Insects	When insects such as wasps and hornets interfere with maintenance activities.	Insects destroyed or removed from site.

Table 6.54: Maintenance Standards - Wetponds (continued)

Maintenance Component	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
			Apply insecticides in compliance with adopted integrated pest management policies.
	Tree Growth and Hazard Trees	Tree growth does not allow maintenance access or interferes with maintenance activity (i.e., slope mowing, silt removal, Vactoring, or equipment movements). If trees are not interfering with access or maintenance, do not remove. If dead, diseased, or dying trees are identified. (Use a certified arborist to determine health of tree or removal requirements.)	Trees do not hinder maintenance activities. Harvested trees should be recycled into mulch or other beneficial uses (e.g., alders for firewood). Remove hazard trees.
Side Slopes of Pond	Erosion	Eroded damage > 2 inches deep where cause of damage is still present or where there is potential for continued erosion. Any erosion observed on a compacted berm embankment.	Slopes should be stabilized using appropriate erosion control measure(s); e.g., rock reinforcement, planting of grass, compaction. If erosion is occurring on compacted berms, a licensed engineer in the state of Washington should be consulted to resolve source of erosion.
Storage Area	Sediment	Accumulated sediment > 10% of the designed pond depth unless otherwise specified or affects inletting or outletting condition of the wetpond.	Sediment cleaned out to designed pond shape and depth; pond reseeded if necessary to control erosion.
	Liner (if applicable)	Liner is visible and has > three 0.25-inch holes in it.	Liner repaired or replaced. Liner is fully covered.
Pond Berms (Dikes)	Settlements	Any part of berm that has settled 4 inches lower than the design elevation. If settlement is apparent, measure berm to determine amount of settlement. Settling can be an indication of more severe problems with the berm or outlet works. A licensed engineer in the state of Washington should be consulted to determine the source of the settlement.	Dike is built back to the design elevation.
	Piping	Discernible water flow through pond berm. Ongoing erosion with potential for erosion to continue. (Recommend a licensed engineer in the state of Washington with geotechnical expertise be called in to inspect and evaluate condition and recommend repair of condition.)	Piping eliminated. Erosion potential resolved.
Emergency Overflow/ Spillway and Berms Over 4 Feet in Height	Tree Growth	Tree growth on emergency spillways creates blockage problems and may cause failure of the berm due to uncontrolled overtopping. Tree growth on berms > 4 feet in height may lead to piping through the berm, which could lead to failure of the berm.	Trees should be removed. If root system is small (base < 4 inches) the root system may be left in place. Otherwise the roots should be removed and the berm restored. A licensed engineer in the state of Washington should be consulted for proper berm/spillway restoration.
	Piping	Discernible water flow through pond berm. Ongoing erosion with potential for erosion to continue. (Recommend a licensed engineer in the state of Washington with geotechnical expertise be called in to inspect and evaluate condition and recommend repair of condition.)	Piping eliminated. Erosion potential resolved.
Emergency Overflow/ Spillway	Emergency Overflow/ Spillway	Only one layer of rock exists above native soil in area ≥ 5 sf, or any exposure of native soil at the top of outflow path of spillway. (Riprap on inside slopes need not be replaced.)	Rocks and pad depth are restored to design standards.

6.A.14 Maintenance Standards - Wetvaults

Table 6.55: Maintenance Standards - Wetvaults

Maintenance Component	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
General	Trash/Debris Accumulation	Trash and debris accumulated in vault, pipe or inlet/outlet (includes floatables and non-floatables).	Remove trash and debris from vault.
	Sediment Accumulation in Vault	Sediment accumulation in vault bottom exceeds the depth of the sediment zone plus 6 inches.	Remove sediment from vault.
	Damaged Pipes	Inlet/outlet piping damaged or broken and in need of repair.	Pipe repaired and/or replaced.
	Access Cover Damaged/Not Working	Cover cannot be opened or removed, especially by one person.	Cover repaired or replaced to proper working specifications.
	Ventilation	Ventilation area blocked or plugged.	Blocking material removed or cleared from ventilation area. A specified percentage of the vault surface area must provide ventilation to the vault interior (see design specifications).
	Vault Structure Damage - Includes Cracks in Walls Bottom, Damage to Frame and/or Top Slab	Maintenance/inspection personnel determine that the vault is not structurally sound. Cracks wider than 0.5 inch at the joint of any inlet/outlet pipe or evidence of soil particles entering through the cracks.	Vault replaced or repairs made so that vault meets design specifications and is structurally sound. Vault repaired so that no cracks exist wider than 0.25 inch at the joint of the inlet/outlet pipe.
	Baffles	Baffles corroding, cracking, warping and/or showing signs of failure as determined by maintenance/inspection staff.	Baffles repaired or replaced to specifications.
	Access Ladder Damage	Ladder is corroded or deteriorated, not functioning properly, not attached to structure wall, missing rungs, has cracks and/or misaligned. Confined space warning sign missing.	Ladder replaced or repaired to specifications, and is safe to use as determined by inspection personnel. Replace sign warning of confined space entry requirements. Ladder and entry notification complies with OSHA standards.

6.A.15 Maintenance Standards - Sand Filters (Aboveground/Open)

Table 6.56: Maintenance Standards - Sand Filters (Aboveground/Open)

Maintenance Component	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
Above Ground (open sand filter)	Sediment Accumulation on top layer	Sediment depth exceeds 1/2-inch.	No sediment deposit on grass layer of sand filter that would impede permeability of the filter section.
	Trash and Debris Accumulations	Trash and debris accumulated on sand filter bed.	Trash and debris removed from sand filter bed.
	Sediment/ Debris in Clean-Outs	When the clean-outs become full or partially plugged with sediment and/or debris.	Sediment removed from clean-outs.
	Sand Filter Media	Drawdown of water through the sand filter media takes longer than 24-hours, and/or flow through the overflow pipes occurs frequently.	Top several inches of sand are scraped. May require replacement of entire sand filter depth depending on extent of plugging (a sieve analysis is helpful to determine if the lower sand has too high a proportion of fine material).
	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 BMPs.	Low, continuous flows are limited to a small portion of the facility by using a low wooden divider or slightly depressed sand surface.
	Short Circuiting	When flows become concentrated over one section of the sand filter rather than	Flow and percolation of water through sand filter is uniform and dispersed across the entire filter area.

Table 6.56: Maintenance Standards - Sand Filters (Aboveground/Open) (continued)

Maintenance Component	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
		dispersed.	
	Erosion Damage to Slopes	Erosion over 2-inches deep where cause of damage is prevalent or potential for continued erosion is evident.	Slopes stabilized using proper erosion control measures.
	Rock Pad Missing or Out of Place	Soil beneath the rock is visible.	Rock pad replaced or rebuilt to design specifications.
	Flow Spreader	Flow spreader uneven or clogged so that flows are not uniformly distributed across sand filter.	Spreader leveled and cleaned so that flows are spread evenly over sand filter.
	Damaged Pipes	Any part of the piping that is crushed or deformed more than 20% or any other failure to the piping.	Pipe repaired or replaced.

6.A.16 Maintenance Standards - Sand Filters (Belowground/Enclosed)

Table 6.57: Maintenance Standards - Sand Filters (Belowground/Enclosed)

Maintenance Component	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
Below Ground Vault.	Sediment Accumulation on Sand Media Section	Sediment depth exceeds 0.5 inch.	No sediment deposits on sand filter section that would impede permeability of the filter section.
	Sediment Accumulation in Pre-Settling Portion of Vault	Sediment accumulation in vault bottom exceeds the depth of the sediment zone plus 6-inches.	No sediment deposits in first chamber of vault.
	Trash/Debris Accumulation	Trash and debris accumulated in vault, or pipe inlet/outlet, floatables and non-floatables.	Trash and debris removed from vault and inlet/outlet piping.
	Sediment in Drain Pipes/Cleanouts	When drain pipes, cleanouts become full with sediment and/or debris.	Sediment and debris removed.
	Short Circuiting	When seepage/flow occurs along the vault walls and corners. Sand eroding near inflow area.	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.
	Damaged Pipes	Inlet or outlet piping damaged or broken and in need of repair.	Pipe repaired and/or replaced.
	Access Cover Damaged/Not Working	Cover cannot be opened, corrosion/deformation of cover. Maintenance person cannot remove cover using normal lifting pressure.	Cover repaired to proper working specifications or replaced.
	Ventilation	Ventilation area blocked or plugged	Blocking material removed or cleared from ventilation area. A specified percentage of the vault surface area must provide ventilation to the vault interior (see design specifications).
	Vault Structure Damaged; Includes Cracks in Walls, Cracks in Bottom, or Damage to Frame and/or Top Slab.	Cracks wider than 0.5 inch or evidence of soil particles entering the structure through the cracks, or maintenance/inspection personnel determine that the vault is not structurally sound.	Vault replaced or repairs made so that vault meets design specifications and is structurally sound. Vault repaired so that no cracks exist wider than 0.25 inch at the joint of the

Table 6.57: Maintenance Standards - Sand Filters (Belowground/Enclosed) (continued)

Maintenance Component	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
		Cracks wider than 0.5 inch at the joint of any inlet/outlet pipe or evidence of soil particles entering through the cracks.	inlet/outlet pipe.
	Baffles/Internal walls	Baffles or walls corroding, cracking, warping and/or showing signs of failure as determined by maintenance/inspection person.	Baffles repaired or replaced to specifications.
	Access Ladder Damaged	Ladder is corroded or deteriorated, not functioning properly, not securely attached to structure wall, missing rungs, cracks, and/or misaligned.	Ladder replaced or repaired to specifications, and is safe to use as determined by inspection personnel.

6.A.17 Maintenance Standards - Manufactured Media Filters

Table 6.58: Maintenance Standards - Manufactured Media Filters

Maintenance Component	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
Below Ground Vault	Sediment Accumulation on Media	Sediment depth exceeds 0.25 inches.	No sediment deposits that would impede permeability of the media.
	Sediment Accumulation in Vault	Sediment depth exceeds 6 inches in first chamber.	No sediment deposits in vault bottom of first chamber.
	Trash/Debris Accumulation	Trash and debris accumulated on filter bed.	Trash and debris removed from the filter bed.
	Sediment in Drain Pipes/Clean-Outs	When drain pipes, clean-outs, become full with sediment and/or debris.	Sediment and debris removed.
	Damaged Pipes	Any part of the pipes that are crushed or damaged due to corrosion and/or settlement.	Pipe repaired and/or replaced.
	Access Cover Damaged/Not Working	Cover cannot be opened; one person cannot open the cover using normal lifting pressure, corrosion/deformation of cover.	Cover repaired to proper working specifications or replaced.
	Vault Structure Includes Cracks in Wall, Bottom, Damage to Frame and/or Top Slab	Cracks wider than 0.5 inch or evidence of soil particles entering the structure through the cracks, or maintenance/inspection personnel determine that the vault is not structurally sound. Cracks wider than 0.5 inch at the joint of any inlet/outlet pipe or evidence of soil particles entering through the cracks.	Vault replaced or repairs made so that vault meets design specifications and is structurally sound. Vault repaired so that no cracks exist wider than 0.25 inch at the joint of the inlet/outlet pipe.
	Baffles	Baffles corroding, cracking, warping, and/or showing signs of failure as determined by maintenance/inspection person.	Baffles repaired or replaced to specifications.
	Access Ladder Damaged	Ladder is corroded or deteriorated, not functioning properly, not securely attached to structure wall, missing rungs, cracks, and/or misaligned.	Ladder replaced or repaired and meets specifications, and is safe to use as determined by inspection personnel.
Below Ground Cartridge Type	Filter Media	Drawdown of water through the media takes longer than 1 hour, and/or overflow occurs frequently.	Media cartridges replaced.
	Short Circuiting	Flows do not properly enter filter cartridges.	Filter cartridges replaced.

6.A.18 Maintenance Standards - API (Baffle Type) Oil/Water Separators

Table 6.59: Maintenance Standards - API (Baffle Type) Oil/Water Separators

Maintenance Component	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
General	Monitoring	Inspection of discharge water for obvious signs of poor water quality.	Effluent discharge from vault should be clear with out thick visible sheen.
	Sediment Accumulation	Sediment depth in bottom of vault exceeds 6-inches in depth.	No sediment deposits on vault bottom that would impede flow through the vault and reduce separation efficiency.
	Trash and Debris Accumulation	Trash and debris accumulation in vault, or pipe inlet/outlet, floatables and non-floatables.	Trash and debris removed from vault, and inlet/outlet piping.
	Oil Accumulation	Oil accumulations that exceed 1-inch, at the surface of the water.	Extract oil from vault by vactoring. Disposal in accordance with state and local rules and regulations.
	Damaged Pipes	Inlet or outlet piping damaged or broken and in need of repair.	Pipe repaired or replaced.
	Access Cover Damaged/Not Working	Cover cannot be opened, corrosion/deformation of cover.	Cover repaired to proper working specifications or replaced.
	Vault Structure Damage - Includes Cracks in Walls Bottom, Damage to Frame and/or Top Slab	See 6.A.7 Maintenance Standards - Catch Basins Cracks wider than 0.5 inch at the joint of any inlet/outlet pipe or evidence of soil particles entering through the cracks.	Vault replaced or repairs made so that vault meets design specifications and is structurally sound. Vault repaired so that no cracks exist wider than 0.25 inch at the joint of the inlet/outlet pipe.
	Baffles	Baffles corroding, cracking, warping and/or showing signs of failure as determined by maintenance/inspection person.	Baffles repaired or replaced to specifications.
	Access Ladder Damaged	Ladder is corroded or deteriorated, not functioning properly, not securely attached to structure wall, missing rungs, cracks, and misaligned.	Ladder replaced or repaired and meets specifications, and is safe to use as determined by inspection personnel.

6.A.19 Maintenance Standards - Coalescing Plate (CP) Oil/Water Separators

Table 6.60: Maintenance Standards - Coalescing Plate (CP) Oil/Water Separators

Maintenance Component	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
General	Monitoring	Inspection of discharge water for obvious signs of poor water quality.	Effluent discharge from vault should be clear with no thick visible sheen.
	Sediment Accumulation	Sediment depth in bottom of vault exceeds 6 inches in depth and/or visible signs of sediment on plates.	No sediment deposits on vault bottom and plate media, which would impede flow through the vault and reduce separation efficiency.
	Trash and Debris Accumulation	Trash and debris accumulated in vault, or pipe inlet/outlet, floatables and non-floatables.	Trash and debris removed from vault and inlet/outlet piping.
	Oil Accumulation	Oil accumulation that exceeds 1 inch at the water surface.	Oil is extracted from vault using vactoring methods. Coalescing plates are cleaned by thoroughly rinsing and flushing. Should be no visible oil depth on water.
	Damaged Coalescing Plates	Plate media broken, deformed, cracked and/or showing signs of failure.	A portion of the media pack or the entire plate pack is replaced depending on severity of failure.
	Damaged Pipes	Inlet or outlet piping damaged or broken and in need of repair.	Pipe repaired and or replaced.
	Baffles	Baffles corroding, cracking, warping and/or showing signs of failure as determined by maintenance/inspection person.	Baffles repaired or replaced to specifications.
	Vault Structure Damage - Includes Cracks in Walls, Bottom, Damage to Frame and/or Top Slab	Cracks wider than 0.5 inch or evidence of soil particles entering the structure through the cracks, or maintenance/inspection personnel determine that the vault is not structurally sound. Cracks wider than 0.5 inch at the joint of any inlet/outlet pipe or evidence of soil particles entering through the cracks.	Vault replaced or repairs made so that vault meets design specifications and is structurally sound. Vault repaired so that no cracks exist wider than 0.25 inch at the joint of the inlet/outlet pipe.
	Access Ladder Damaged	Ladder is corroded or deteriorated, not functioning properly, not securely attached to structure wall, missing rungs, cracks, and misaligned.	Ladder replaced or repaired and meets specifications, and is safe to use as determined by inspection personnel.

6.A.20 Maintenance Standards - Catch Basin Inserts

Table 6.61: Maintenance Standards - Catch Basin Inserts

Maintenance Component	Defect	Conditions When Maintenance is Needed	Results Expected When Maintenance is Performed
General	Sediment Accumulation	When sediment forms a cap over the insert media of the insert and/or unit.	No sediment cap on the insert media and its unit.
	Trash and Debris Accumulation	Trash and debris accumulates on insert unit creating a blockage/restriction.	Trash and debris removed from insert unit. Runoff freely flows into catch basin.
	Media Insert Not Removing Oil	Effluent water from media insert has a visible sheen.	Effluent water from media insert is free of oils and has no visible sheen.
	Media Insert Water Saturated	Catch basin insert is saturated with water and no longer has the capacity to absorb.	Remove and replace media insert
	Media Insert-Oil Saturated	Media oil saturated due to petroleum spill that drains into catch basin.	Remove and replace media insert.
	Media Insert Use Beyond Product Life	Media has been used beyond the typical average life of media insert product.	Remove and replace media at regular intervals, depending on insert product.

6.A.21 Maintenance Standards - Media Filter Drains

Table 6.62: Maintenance Standards - Media Filter Drains

Maintenance Component	Defect	Conditions When Maintenance is Needed	Results Expected When Maintenance is Performed
General	Sediment accumulation on grass filter strip	Sediment depth exceeds 2 inches or creates uneven grading that interferes with sheet flow.	Remove sediment deposits on grass treatment area of the embankment. When finished, embankment should be level from side to side and drain freely toward the toe of the embankment slope. There should be no areas of standing water once inflow has ceased.
	No-vegetation zone/flow spreader	Flow spreader is uneven or clogged so that flows are not uniformly distributed over entire embankment width.	Level the spreader and clean to spread flows evenly over entire embankment width.
	Poor vegetation coverage	Grass is sparse or bare, or eroded patches are observed in more than 10% of the grass strip surface area.	Determine why grass growth is poor and correct the offending condition. Reseed into loosened, fertile soil or compost; or, replant with plugs of grass from the upper slope.
	Vegetation	Grass becomes excessively tall (greater than 10 inches); nuisance weeds and other vegetation start to take over.	Mow vegetation or remove nuisance vegetation to not impede flow. Mow grass to a height of 6 inches.
	Media filter drain mix replacement	Water is seen on the surface of the media filter drain mix long after the storms have ceased. Typically, the 6-month, 24-hour precipitation event should drain within 48 hours. More common storms should drain within 24 hours. Maintenance also needed on a 10-year cycle and during a preservation project.	Excavate and replace all of the media filter drain mix contained within the media filter drain.
	Excessive shading	Grass growth is poor because sunlight does not reach embankment.	If possible, trim back overhanging limbs and remove brushy vegetation on adjacent slopes.
	Trash and debris	Trash and debris have accumulated on embankment.	Remove trash and debris from embankment.
	Flooding of Media filter drain	When media filter drain is inundated by flood water	Evaluate media filter drain material for acceptable infiltration rate and replace if media filter drain does not meet long-term infiltration rate standards.

6.A.22 Maintenance Standards - Compost-Amended Vegetated Filter Strips (CAVFS)

Table 6.63: Maintenance Standards - Compost-Amended Vegetated Filter Strips (CAVFS)

Maintenance Component	Defect	Conditions When Maintenance is Needed	Results Expected When Maintenance is Performed
General	Sediment Accumulation on Grass	Sediment depth exceeds 2 inches.	Remove sediment deposits. Relevel so slope is even and flows pass evenly through strip.
	Vegetation	Grass becomes excessively tall (greater than 10 inches); nuisance weeds and other vegetation start to take over.	Mow grass and control nuisance vegetation so that flow is not impeded. Grass should be mowed to a height of 6 inches.
	Trash and debris	Trash and debris have accumulated on the vegetated filter strip.	Remove trash and debris from filter.
	Erosion/Scouring	Areas have eroded or scoured due to flow channelization or high flows.	For ruts or bare areas less than 12 inches wide, repair the damaged area by filling with a 50/50 mixture of crushed gravel and compost. The grass will creep in over the rock in time. If bare areas are large, generally greater than 12 inches wide, the vegetated filter strip should be regraded and reseeded. For smaller bare areas, overseed when bare spots are evident.

Table 6.63: Maintenance Standards - Compost-Amended Vegetated Filter Strips (CAVFS) (continued)

Maintenance Component	Defect	Conditions When Maintenance is Needed	Results Expected When Maintenance is Performed
	Flow Spreader	Flow spreader is uneven or clogged so that flows are not uniformly distributed over entire filter width.	Level the spreader and clean so that flows are spread evenly over entire filter width.

6.A.23 Maintenance Standards - Bioretention

Table 6.64: Maintenance Standards - Bioretention

Maintenance Component	Activity	Objective	Schedule	Notes
Routine Maintenance				
Vegetation	Maintain drip irrigation system without breaks or blockages. Hand water as needed for specific plants.	Establish vegetation with a minimum 80% survival rate	Twice annually (May and July) or as indicated by plant health	Plants should be selected to be drought tolerant and not require watering after establishment (2 to 3 years). Watering may be required during prolonged dry periods after plants are established.
	Remove and/or prune vegetation	Maintain adequate plant coverage and plant health. Reduce shading of understory if species require sun. Maintain soil health and infiltration capability. Maintain clearances from utilities and sight distances.	Once or twice annually	Depending on aesthetic requirements, occasional pruning and removing dead plant material may be necessary.
	Remove undesired vegetation by hand weeding.	Reduce competition for desired vegetation. Improve aesthetics.	Prior to major weed species disbursing seeds (usually twice annually)	Periodic weeding is necessary until plants are established. The weeding schedule should become less frequent if the appropriate plant species and planting density have been used and, as a result, undesirable plants excluded.
Curb cuts	Remove any accumulation of debris from gutter and entrance to bioretention area.	Maintain proper flow of stormwater from paved/ impervious areas to bioretention BMP.	Twice annually (October and January)	
Mulch	Replace or add mulch with hand tools to a depth of 2 to 3 inches.	Replenish organic material in soil, reduce erosion, prolong good soil moisture level, and filter pollutants.	Once annually or every 2 years	Consider replacing mulch annually in bioretention BMPs where high pollutant loading is likely (e.g., contributing areas that include quick marts). Use compost in the bottom of the BMP and wood chips on side slopes and rim (above typical water levels).
General	Trash removal	Maintain aesthetics and prevent clogging of infrastructure.	Twice annually	
Nonroutine Maintenance				
Inlets/ Outlets	Clear vegetation within 1 foot of inlets and outlets to maintain access pathways.	Prevent clogging of infrastructure and maintain sight lines and access for inspections.	Once annually	If sediment is deposited in the bioretention area, immediately determine the source within the contributing area and stabilize.
Bioretention Area	Shovel or rake out sediment within vegetated areas. Vacuum catch basins or other sediment structures.	Reduce sediment transport and clogging of infrastructure. Maintain desired plant survival and appearance of the BMP. Maintain proper elevations and ponding depths.	Determined by inspection	

Table 6.64: Maintenance Standards - Bioretention (continued)

Maintenance Component	Activity	Objective	Schedule	Notes
Underdrains	Jet clean or rotary cut debris/roots from underdrains.	Maintain proper subsurface drainage, ponding depths, and dewatering rates.	Determined by inspection of clean-outs	Bioretention BMPs should be designed with a proper elevation drop from pavement to vegetated area to prevent blockage of storm flows by vegetation into infiltration area.
Vegetation	Reseed or replant bare spots or poorly performing plants.	Maintain dense vegetation cover to prevent erosion, encourage infiltration and exclude unwanted weed species.	Determined by inspection	Soil mixes for bioretention BMPs are designed to maintain long-term fertility and pollutant processing capability. Estimates from metal attenuation research suggest that metal accumulation should not present an environmental concern for at least 20 years in bioretention systems. Replacing mulch in bioretention BMPs where heavy metal and hydrocarbon deposition is likely provides additional of protection for prolonged performance.
Soil Medium	Remove vegetation (save as much plant material as possible for replanting) and excavated soil with backhoe, excavator or, if small BMP, by hand.	Replace soil medium to maintain infiltration, soil fertility, and pollutant removal capability	Determined by inspection (visual, infiltration, pollutant, and soil fertility tests)	
General	Remove excess vegetation at the intersection of pavement and vegetation with a line trimmer, vacuum sweeper, rake or shovel.	Prevent accumulation of vegetation at pavement edge and maintain proper sheet flow of stormwater from paved/impervious areas to bioretention BMP.	Determined by inspection	If specific plants have a high mortality rate, assess the cause and replace with appropriate species.
	Various activities to maintain walls, intake and outfall pads, weirs, and other hardscape elements.	Rebuild or reinforce structures to maintain proper drainage and aesthetics and prevent erosion.	Determined by inspection	
	Maintain proper slope with hand tools, back hoe, or excavator; replant exposed areas.	Regrade or recontour side slopes to prevent erosion where side slopes have been disturbed by foot or vehicle intrusion.	Determined by inspection	

6.A.24 Maintenance Standards - Permeable Pavement

Table 6.65: Maintenance Standards - Permeable Pavement

Maintenance Component	Activity	Objective	Schedule	Notes
Routine Maintenance				
All Permeable Paving Surfaces	**Erosion and sediment control:** Mulch and/or plant all exposed soils that may erode to paving installation.	Minimize sediment inputs to pavement, reduce clogging and maintain infiltration of pavement.	Once annually	Erosion control is critical for long-term performance of permeable paving.
Porous Asphalt or Pervious Concrete	**Clean permeable pavement installation:** Use street cleaning equipment with suction, sweeping and suction or high-pressure wash and suction.	Maintain infiltration capability	Once or twice every year	Street cleaning equipment using high-pressure wash with suction provides the best results for improving infiltration rates. Sweeping with suction provides adequate results and sweeping alone is minimally effective. Handheld pressure washers are effective for cleaning void spaces and appropriate for smaller areas such as sidewalks (may require special spray nozzle).
Eco-Stone Pavers	**Clean permeable pavement installation:** Use street cleaning equipment with sweeping and suction when surface and debris are dry.	Maintain infiltration capability	Once annually	Washing should not be used to remove debris and sediment in the openings between the pavers. Vacuum settings may have to be adjusted to prevent excess uptake of aggregate from paver openings or joints.

Table 6.65: Maintenance Standards - Permeable Pavement (continued)

Maintenance Component	Activity	Objective	Schedule	Notes
All Permeable Paving Surfaces	**Backfill utility cuts:** Use same aggregate base as under permeable paving.	Maintain conveyance of stormwater through base and prevent migration of fines from standard base aggregate to the more open graded permeable pavement base material.	Determined by inspection	Small utility cuts can be repaired with permeable top course or with conventional asphalt or concrete if small batches of permeable material are not available or are too expensive.
	Replace aggregate in paver cells: Remove aggregate with suction equipment.	Maintain infiltration capacity	Determined by inspection	Clogging is usually an issue in the upper most few centimeters of aggregate. Check infiltration at various depths in the aggregate profile to determine excavation depth.
	Utility maintenance: Remove pavers individually by hand and replaced when utility work is complete.	Repair utilities, maintain structural integrity of pavement.	When maintaining utilities	Pavers can be removed individually and replaced when utility work is complete.
	Replace broken pavers: Remove individual pavers by hand and replace.	Maintain structural integrity of pavement.	Determined by inspection	
Nonroutine Maintenance				
Gravelpave 2	**Clean permeable pavement installation:** Use vacuum trucks for storm drains to remove and replace top course aggregate if clogged with sediment or contaminated.	Restore infiltration capability	Determined by inspection	Permeable gravel pavement systems have a very high void to surface coverage ratio. System failure due to clogging is unlikely except in unusual circumstances.
	Replenish aggregate material: Spread gravel with rake.	Maintain structural integrity	Determined by inspection	Gravel level should be maintained at the same level as the plastic rings or slightly above the top of rings. In high traffic areas, such as aisle ways, entrances or exits, gravel may become compacted or transported.
	Remove and replace grid segments: Remove pins, pry up grid segments, replace gravel.	Maintain structural integrity	Determined by inspection	Replace grid segments where three or more adjacent rings are broken or damaged. Potholes should be remedied in the same way; the base course should be brought to the proper grade and compaction before replacing grid.
Grasspave2	**Aeration:** See Notes.			**Do not aerate Grasspave 2 installations.** Aeration equipment will damage the structure of Grasspave2 and could prevent its long-term function. Soil compaction and poor water penetration can be the result of soil types or local conditions and should be treated accordingly.
	Replace Grasspave2 installation: Place units over porous gravel base, fill with grass.	Restore system capability	Determined by inspection	Do not place any form of topsoil between sandy gravel base and Grasspave2 units.
	Invasive or nuisance plants: Remove manually and without herbicide applications.	Promote selected plant growth and survival, maintain aesthetics	Twice annually	At a minimum, schedule weeding with inspections to coincide with important horticultural cycles (e.g., prior to major weed varieties dispersing seeds).
	Fertilization: If necessary apply by hand. See Notes.	Plant growth and survival	Determined by inspection	Installations should be designed to not require fertilization after plant establishment. If fertilization is necessary during plant establishment or for plant health and survivability after establishment, use an encapsulated, slow release fertilizer (excessive fertilization can contribute to increased nutrient loads in the stormwater system and receiving waters).
	Irrigate: Use subsurface or drip irrigation.		Determined by inspection and only when absolutely	Surface irrigation systems can promote weed establishment, root development near the drier surface layer of the soil substrate, and increase plant dependence on irrigation. Accordingly, subsurface irrigation methods are preferred. If surface irrigation is the only method available, use drip irrigation to

Table 6.65: Maintenance Standards - Permeable Pavement (continued)

Maintenance Component	Activity	Objective	Schedule	Notes
			necessary for plant survival.	deliver water to the base of the plant.
	Replace permeable pavement material	Maintain infiltration and stormwater storage capability	Determined by inspection	If BMP is designed, installed and maintained properly, permeable pavement should last as long as conventional pavement.

6.A.25 Maintenance Standards - Vegetated Roofs

Table 6.66: Maintenance Standards - Vegetated Roofs

Activity	Objective	Schedule	Notes
Structural and Drainage Components			
Clear inlet pipes: Remove soil substrate, vegetation or other debris.	Maintain free drainage of inlet pipes.	Twice annually.	
Inspect drain pipe: Check for cracks settling and proper alignment, and correct and re-compact soils or fill material surrounding pipe, if necessary.	Maintain free drainage of inlet pipes.	Twice annually.	
Inspect fire ventilation points for proper operation	Fire and safety.	Twice annually.	
Maintain egress and ingress: Clear routes of obstructions and maintained to design standards.	Fire and safety.	Twice annually.	
Insects: See Notes			Vegetated roof design should provide drainage rates that do not allow pooling of water for periods that promote insect larvae development. If standing water is present for extended periods correct drainage problem. Chemical sprays should not be used.
Prevent release of contaminants: Identify activities (mechanical systems maintenance, pet access, etc.) that can potentially release pollutants to the vegetated roof and establish agreements to prevent release.	Water quality protection.	During construction of roof and then as determined by inspection.	Any cause of pollutant release should be corrected as soon as identified and the pollutant removed.
Vegetation and Growth Medium			
Invasive or nuisance plants: Remove manually and without herbicide applications.	Promote selected plant growth and survival, maintain aesthetics.	Twice annually.	At a minimum, schedule weeding with inspections to coincide with important horticultural cycles (e.g., prior to major weed varieties dispersing seeds).
Removing and replacing dead material: See Notes	See Notes.	Once annually.	Normally, dead plant material will be recycled on the roof; however specific plants or aesthetic considerations may warrant removing and replacing dead material (see manufacturer's recommendations).
Fertilization: If necessary apply by hand. See Notes	Plant growth and survival.	Determined by inspection.	Extensive vegetated roofs should be designed to not require fertilization after plant establishment. If fertilization is necessary during plant establishment or for plant health and survivability after establishment, use an encapsulated, slow release fertilizer (excessive fertilization can contribute to increased nutrient loads in the stormwater system and receiving waters).
Mulching: See Notes			Avoid application of mulch on extensive vegetated roofs. Mulch should be used only in unusual situations and according to the

Table 6.66: Maintenance Standards - Vegetated Roofs (continued)

Activity	Objective	Schedule	Notes
			vegetated roof provider guidelines. In conventional landscaping, mulch enhances moisture retention; however, moisture on a vegetated roof should be controlled by proper design of the soil/growth medium. Mulch will also increase establishment of weeds.
Irrigate: Use subsurface or drip irrigation.		Determined by inspection and only when necessary for plant survival.	Surface irrigation systems on extensive vegetated roofs can promote weed establishment, root development near the drier surface layer of the soil substrate, and increase plant dependence on irrigation. Accordingly, subsurface irrigation methods are preferred. If surface irrigation is the only method available, use drip irrigation to deliver water to the base of the plant.
Source: Eastern Washington LID Guidance Manual (June 2013)			

6.A.26 Maintenance Standards - Rainwater Harvesting

Table 6.67: Maintenance Standards - Rainwater Harvesting

Activity	Objective	Schedule
Remove debris from roof: Sweep, rake or use leaf blower.	Prevent debris from entering collection and filter system	Determined by inspection
Clean gutters: By hand or use leaf blower.	Prevent debris from entering collection and filter system	Determined by inspection (generally September, November, January, and April). The most critical cleaning is in mid-spring to late spring to flush the pollen deposits from surrounding trees.[a]
Clean downspout basket screens: Remove debris from screens at top of downspout.	Prevent debris from entering collection and filter system, and clogging of system	Same as gutters
Clean prefilters	Prevent debris from entering collection and filter system, and clogging of system	Monthly
Clean storage tanks of debris: Drain tank and remove debris from bottom of tank.	Prevent contamination	Determined by inspection
Clean particle filters	Prevent contamination	6 months or determined by pressure drop in system.
Clean and replace ultraviolet (UV) filters	Prevent contamination	Clean every 6 months and replace bulb every 12 months or according to manufacturer's recommendation.
Chlorinate storage tank: Chlorinate to 0.2 to 0.5 parts per million (ppm) (0.25 cup of household bleach [5.25%] at the rate of 1 cup of bleach to 1,000 gallons of stored water)	Prevent contamination	Quarterly
Flush household taps: Remove carbon filter and flush until chlorine odor is noticed at taps. Chlorinated water should be left standing in the piping for 30 minutes. Replace the carbon filter.	Prevent contamination	When storage tanks are cleaned
[a] Covers for gutters may be appropriate for specific locations, but can make regular cleaning more difficult and will not prevent pollen from entering filter system.		

6.A.27 Maintenance Standards - Downspout, Sheet Flow, and Concentrated Dispersion Systems

Table 6.68: Maintenance Standards - Downspout, Sheet Flow, and Concentrated Dispersion Systems

Maintenance Component	Recommended Frequency [a]		Condition when Maintenance is Needed (Standards)	Action Needed (Procedures)
	Inspection	Routine Maintenance		
Splash Block (Downspout Dispersion)				
Splash block	B		Water is being directed towards building structure	Reconfigure/ repair blocks to direct water away from building structure
	B		Water disrupts soil media	Reconfigure/ repair blocks
Transition Zone (Sheet Flow Dispersion)				
Transition zone	A		Adjacent soil erosion; uneven surface creating concentrated flow discharge; or less than 2 foot of width	Repair/replace transition zone to meet design criteria and eliminate concentrated flows
Dispersion Trench (Downspout Dispersion)				
Dispersion trench	A		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)	• Remove debris from trench surface, if necessary • Realign notched grade board or other distributor type, if possible • Rebuild trench to standards, if necessary
Surface of trench	Fall and Spring		Accumulated trash, debris, or sediment on drain rock surface impedes sheet flow from facility	Remove/dispose in accordance with local solid waste requirements
	A, W		Vegetation/moss present on drain rock surface impedes sheet flow from facility	Maintain open, freely draining drain rock surface
Pipe(s) to trench	A, W		Accumulation of trash, debris, or sediment in roof drains, gutters, driveway drains, area drains, etc.	Remove/ dispose
	A, W		Pipe from sump to trench or drywell has accumulated sediment or is plugged	Clear sediment from inlet/outlet pipe screen and inlet/outlet pipe
	A, W		Cracked, collapsed, broken, or misaligned drain pipes	• Repair/seal cracks • Replace when repair is insufficient
Sump	A		Sediment in the sump	• Remove/ dispose in accordance with local solid waste requirements • Clear sediment from inlet/outlet pipe screen and/or inlet/outlet pipe
Access lid	A		Cannot be easily opened	Repair/ replace
	A		Buried	Refer to record drawings for design intent. If the access lid was designed to be exposed, expose and restore to surface grade
	A		Cover missing	Replace
Rock Pad (Concentrated Flow Dispersion)				
Rock pad	A		Only one layer of rock exists above native soil in area 6 square	• Replace/ repair rock pad to meet design standards

Table 6.68: Maintenance Standards - Downspout, Sheet Flow, and Concentrated Dispersion Systems (continued)

Maintenance Component	Recommended Frequency [a]		Condition when Maintenance is Needed (Standards)	Action Needed (Procedures)
	Inspection	Routine Maintenance		
			feet or larger, or any exposure of native soil	• Enlarge pad size or add additional courses of rock, if necessary
	A		Soil erosion in or adjacent to rock pad	Repair/replace rock pad to meet design standards
Dispersal Area				
Dispersal area (general)	B, S		Erosion (gullies/ rills) greater than 2 inches deep in dispersal area	Eliminate cause of erosion and stabilize damaged area (regrade, rock, revegetate)
	B, S		Accumulated sediment or debris to extent that blocks or channelizes flow path	• Remove excess sediment or debris • Identify and control the sediment source (if feasible)
Ponded water	B, S		Standing surface water in dispersion area remains for more than 3 days after the end of a storm event	Identify the cause of the standing water (e.g. grade depressions, compacted soil) and take appropriate actions to address the problem (e.g. regrade to eliminate depressions or aerate/ amend soils)
Plant establishment	B	Once every 1-2 weeks or as needed during prolonged dry periods [b]	Dispersal area vegetation in establishment period (1-2 years, or additional 3rd year during extreme dry weather)	Water weekly during periods of no rain to ensure plant establishment
Vegetation	As needed		Poor vegetation cover such that erosion is occurring	• Ensure proper care (e.g. watering) • Assess for nutrient deficiencies • Replant as needed with appropriate plant species for the soil and moisture conditions • Consider amending soils to promote plant health
	B, S		Vegetation inhibits dispersed flow along flow path	Trim, weed or replant to restore dispersed flow path
Storage Sump				
Sump	A		Accumulated sediment in the sump	• Remove/ dispose in accordance with local solid waste requirements • Clear sediment from inlet/outlet pipe screen and/or inlet/outlet pipe
Access lid	A		Cannot be easily opened	Repair/ replace
	A		Buried	Expose and restore to surface grade
	A		Cover missing	Replace
Pest Control				
General Pests	As needed		Signs of pest infestations (IPM protocol threshold(s) are exceeded)	Follow IPM protocols for weed and pest management
Mosquitoes	B, S		Standing surface water in dispersion area remains for more than 3 days after the end of a storm	• Identify the cause of the standing water and take appropriate actions to address the problem (see “Ponded water”)

Table 6.68: Maintenance Standards - Downspout, Sheet Flow, and Concentrated Dispersion Systems (continued)

Maintenance Component	Recommended Frequency [a]		Condition when Maintenance is Needed (Standards)	Action Needed (Procedures)
	Inspection	Routine Maintenance		
				• Do not use pesticides or Bacillus thuringiensis israelensis (Bti)
Rodents	As needed		Rodent holes or mounds disturb dispersion flow paths	Fill and compact soil around the holes and vegetate to restore flow path

Note that the inspection and routine maintenance frequencies listed above are recommended by Ecology. They do not supersede or replace the municipal stormwater permit requirements for inspection frequency required of municipal stormwater permittees for "stormwater treatment and flow control BMPs/facilities".

a) Frequency: A = Annually; B = Biannually (twice per year); W = At least once during the wet season (for debris/clog related maintenance, this visit should occur in the early fall, after deciduous trees have lost their leaves); S = Perform inspections after major storm events (24-hour storm event with a 10-year or greater recurrence interval).

b) Inspection should occur during plant establishment period (1-2 years, or additional 3rd year during extreme dry weather).

IPM - Integrated Pest Management

Source: (Herrera and WSC, 2013)

6.A.28 Maintenance Standards - Downspout Full Infiltration

Table 6.69: Maintenance Standards - Downspout Full Infiltration

Maintenance Component	Recommended Frequency [a]		Condition when Maintenance is Needed (Standards)	Action Needed (Procedures)
	Inspection	Routine Maintenance		
Rock Trench / Well				
Surface of trench/well (i.e. water enters through exposed aggregate)	Fall and Spring		Accumulated trash, debris, or sediment on drain rock surface impedes sheet flow into facility	Remove/dispose in accordance with local solid waste requirements
	A, W		Vegetation/moss present on drain rock surface impedes sheet flow into facility	Maintain open, freely draining drain rock surface
Drain rock	Fall and Spring		• 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 port or cleanout	• Clear piping through facility when ponding occurs • Replace rock/sand reservoirs as necessary • Tilling of subgrade below reservoir may be necessary (for trenches) prior to backfill
Inlet / Outlet Pipe Conveyance				
Pipe(s)	A, W		Accumulation of trash, debris, or sediment in roof drains, gutters, driveway drains, area drains, etc.	Remove / dispose
	A, W		Pipe from sump to trench or drywell has accumulated sediment or is plugged	Clear sediment from inlet/outlet pipe screen and inlet/outlet pipe
	A, W		Cracked, collapsed, broken, or misaligned drain pipes	• Repair/seal cracks • Replace when repair is insufficient

Table 6.69: Maintenance Standards - Downspout Full Infiltration (continued)

Maintenance Component	Recommended Frequency [a]		Condition when Maintenance is Needed (Standards)	Action Needed (Procedures)
	Inspection	Routine Maintenance		
Roof downspout	B, W		Splash pad missing or damaged	Repair / replace
	A, W		Leaves or other debris plugging downspout	Remove / dispose
Storage Sump				
Sump	A		Sediment in the sump	Remove/dispose in accordance with local solid waste requirements
Access lid	A		Cannot be easily opened	Repair/replace
	A		Buried	Refer to record drawings for design intent. If the access lid was designed to be exposed, expose and restore to surface grade
	A		Cover missing	Replace

Note that the inspection and routine maintenance frequencies listed above are recommended by Ecology. They do not supersede or replace the municipal stormwater permit requirements for inspection frequency required of municipal stormwater permittees for "stormwater treatment and flow control BMPs/facilities".

a) Frequency: A = Annually; B = Biannually (twice per year); W = At least one visit should occur during the wet season (for debris/clog related maintenance, this inspection/maintenance visit should occur in the early fall, after deciduous trees have lost their leaves).

Source: (Herrera and WSC, 2013)

6.A.29 Maintenance Standards - Post-Construction Soil Quality and Depth

Table 6.70: Maintenance Standards - Post-Construction Soil Quality and Depth

Maintenance Component	Recommended Frequency [a]		Condition when Maintenance is Needed (Standards)	Action Needed (Procedures)
	Inspection	Routine Maintenance		
Soil media (maintain high organic soil content)	A		Vegetation not fully covering ground surface or vegetation health is poor	• Maintain 2 to 3 inches of mulch over bare areas in landscape beds • Add plants if sufficient space • Re-seed bare turf areas until the vegetation fully covers ground surface
		Ongoing	None (routine maintenance)	Return leaf fall and shredded woody materials from the landscape to the site when possible in order to replenish soil nutrients and structure
		Ongoing	None (routine maintenance)	On turf areas, “grasscycle” (mulch-mow or leave the clippings) to build turf health
		Ongoing	None (routine maintenance)	Avoiding use of pesticides (bug and weed killers), like “weed & feed”, which damage the soil
		A	None (routine maintenance)	• Where fertilization is needed (mainly turf and annual flower beds), a moderate fertilization program should be used which relies on compost, natural fertilizers or slow-release synthetic balanced fertilizers • Follow IPM protocols for fertilization procedures

Table 6.70: Maintenance Standards - Post-Construction Soil Quality and Depth (continued)

Maintenance Component	Recommended Frequency [a]		Condition when Maintenance is Needed (Standards)	Action Needed (Procedures)
	Inspection	Routine Maintenance		
Soil media (maintain infilt-ration)	A[b]		Soils become waterlogged, do not appear to be infiltrating	• To remediate compaction, aerate soil, till to at least 8-inch depth, or further amend soil with compost and re-till • If areas are turf, aerate compacted areas and topdress them with 1/4 to 1/2 inch of compost to renovate them • If drainage is still slow, consider investigating alternative causes (e.g. high wet season groundwater levels, low permeability soils) • Also consider site use and protection from compacting activities
Erosion / Scouring	A, W, S		Areas of potential erosion are visible	• Identify and address cause of erosion (e.g. concentrate flow entering area, channel-ization of runoff) and stabilize damaged area (regrade, rock, vegetation, erosion control matting) • For deep channels or cuts (over 3 inches in ponding depth), temporary erosion control measures should be put in place until permanent repairs can be made.
Grass / Vegetation		A	Less than 75% of planted vegetation is healthy with a generally good appearance	• Take appropriate maintenance actions (e.g. remove/ replace plants) • If problem persists, evaluate if vegetation is appropriate for the location (e.g. exposure, soil, soil moisture)
Noxious weeds		M (March – October, preceding seed dispersal)	Listed noxious vegetation is present (refer to current county noxious weed list)	• By law, class A & B noxious weeds must be removed, bagged and disposed as garbage immediately • Reasonable attempts must be made to remove and dispose of class C noxious weeds • Watch for and respond to new occurrences of especially aggressive weeds such as Himalayan blackberry, Japanese knotweed, morning glory, English ivy, and reed canary grass to avoid invasions • It is strongly encouraged that herbicides and pesticides not be used in order to protect water quality; use of herbicides and pesticides may be prohibited in some jurisdictions
Weeds		M (March – October, preceding seed dispersal)	Weeds are present	• Remove weeds with their roots manually with pincer-type weeding tools, flame weeders, or hot water weeders as appropriate • Follow IPM protocols for weed management

Note that the inspection and routine maintenance frequencies listed above are recommended by Ecology. They do not supersede or replace the municipal stormwater permit requirements for inspection frequency required of municipal stormwater permittees for "stormwater treatment and flow control BMPs/facilities".

a) Frequency: A = Annually; B = Biannually (twice per year); M = Monthly; W = At least one visit should occur during the wet season (for debris/clog related maintenance, this visit should occur in the early fall, after deciduous trees have lost their leaves); S = Perform inspections after major storm events (24-hour storm event with a 10-year or greater recurrence interval).

b) Inspection should occur during a storm event.

Table 6.70: Maintenance Standards - Post-Construction Soil Quality and Depth (continued)

Maintenance Component	Recommended Frequency [a]		Condition when Maintenance is Needed (Standards)	Action Needed (Procedures)
	Inspection	Routine Maintenance		
IPM - Integrated Pest Management				
Source: (Herrera and WSC, 2013)				

Appendix 6-B: Planting Recommendations

6.B.1 Introduction

This appendix summarizes planting recommendations for the following Best Management Practices (BMPs):

- BMP F6.21: Infiltration Ponds
- BMP F6.22: Infiltration Trenches
- BMP T5.21: Infiltration Swales
- BMP T5.21: Infiltration Swales
- BMP F6.23: Bioretention
- BMP T10.10: Wetponds - Basic and Large
- BMP T5.73: Stormwater Treatment Wetlands
- BMP F6.30: Evaporation Ponds

Recommendations for permanent seeding mixes are provided in Chapter 7 - Construction Stormwater Pollution Prevention, and their applicability to runoff treatment Best Management Practices (BMPs) is discussed in 6.B.2 Seeding Recommendations. Detailed planting recommendations for bioretention (BMP F6.23: Bioretention) are provided in 6.B.3 Bioretention Planting Recommendations. Detailed planting recommendations for stormwater treatment wetlands (BMP T5.73: Stormwater Treatment Wetlands) are provided in 6.B.4 Stormwater Treatment Wetlands Plant List.

Detailed recommendations have not been provided for vegetated roofs (BMP F6.63: Vegetated Roofs); however, designers should select plants that:

- Cover and anchor the substrate surface relatively quickly,
- Form a self-repairing mat,
- Take up and transpire the available/retained water, and
- Survive the extreme climatic conditions (cold hardy, drought-tolerant, and wind-tolerant).

Eastern Washington has many good native and highly adapted plant choices that are appropriate to vegetated roof settings. These plant choices are tolerant of the extreme climatic conditions that exist. For extensive roof designs, designers should consider selecting naturally occurring plant species that survive with little to no input. Meadow-like bunchgrass mixes and desert shrub-steppe plants may also be appropriate in some settings of eastern Washington.

6.B.2 Seeding Recommendations

Seeding recommendations are in BMP C120: Temporary and Permanent Seeding.

Table 6.71: Recommended Seeding Mixes for Runoff Treatment BMPs

BMP	Table Title(s)
BMP F6.21: Infiltration Ponds	See Table 7.5: Temporary and Permanent Seed Mixes for Eastern Washington (continued) (Permanent Seed Mixes: Grassed Waterways with More Than 18 Inches Precipitation)
BMP F6.22: Infiltration Trenches	See Table 7.5: Temporary and Permanent Seed Mixes for Eastern Washington (continued) (Permanent Seed Mixes: Grassed Waterways with 15 to 18 Inches Precipitation) and (Permanent Seed Mixes: Grassed Waterways with More Than 18 Inches Precipitation)
BMP T5.21: Infiltration Swales	See Table 7.5: Temporary and Permanent Seed Mixes for Eastern Washington (continued) (Permanent Seed Mixes: Grassed Waterways with Fewer Than 15 Inches Precipitation) and (Permanent Seed Mixes: Grassed Waterways with 15 to 18 Inches Precipitation)
BMP T5.21: Infiltration Swales	See Table 7.5: Temporary and Permanent Seed Mixes for Eastern Washington (continued) (Permanent Seed Mixes: Grassed Waterways with Fewer Than 15 Inches Precipitation) and (Permanent Seed Mixes: Grassed Waterways with 15 to 18 Inches Precipitation)
BMP F6.23: Bioretention – Zone 1	See Table 7.5: Temporary and Permanent Seed Mixes for Eastern Washington (continued) (Permanent Seed Mixes: Upland Areas with 18 to 24 Inches Precipitation) and (Permanent Seed Mixes: Upland Areas with More Than 24 Inches Precipitation
BMP F6.23: Bioretention – Zone 2	See Table 7.5: Temporary and Permanent Seed Mixes for Eastern Washington (continued) (Permanent Seed Mixes: Upland Areas with

Table 6.71: Recommended Seeding Mixes for Runoff Treatment BMPs (continued)

BMP	Table Title(s)
	Less Than 12 Inches Precipitation) and (Permanent Seed Mixes: Upland Areas with 12 to 15 Inches Precipitation)
Large Wetpond - see BMP T10.10: Wetponds - Basic and Large	See Table 7.5: Temporary and Permanent Seed Mixes for Eastern Washington (continued) (Permanent Seed Mixes: Upland Areas with More Than 24 Inches Precipitation
BMP T5.73: Stormwater Treatment Wetlands	See Table 7.5: Temporary and Permanent Seed Mixes for Eastern Washington (continued) (Permanent Seed Mixes: Upland Areas with 12 to 15 Inches Precipitation) and (Permanent Seed Mixes: Upland Areas with 18 to 24 Inches Precipitation) and (Permanent Seed Mixes: Upland Areas with More Than 24 Inches Precipitation
BMP F6.30: Evaporation Ponds	See Table 7.5: Temporary and Permanent Seed Mixes for Eastern Washington (continued) (Permanent Seed Mixes: Upland Areas with 18 to 24 Inches Precipitation) and (Permanent Seed Mixes: Upland Areas with More Than 24 Inches Precipitation

6.B.3 Bioretention Planting Recommendations

This section is intended to provide guidance for the selection of trees, shrubs, grasses, perennials, wildflowers, and ground cover for bioretention BMPs. The plant list contains both native and nonnative species that are well suited for planting bioretention Planting Zone 1 and/or Zone 2.

This is not an exhaustive list. There are likely plants not listed here which would be particularly well suited to the climatic and physiographical conditions of an eastern Washington bioretention

BMP. Rather this list is intended to form the basis for low impact development (LID) plant selection in the region, and should be amended, as appropriate, over time. Project proponents should also check with local jurisdictions to determine if local planting lists are available.

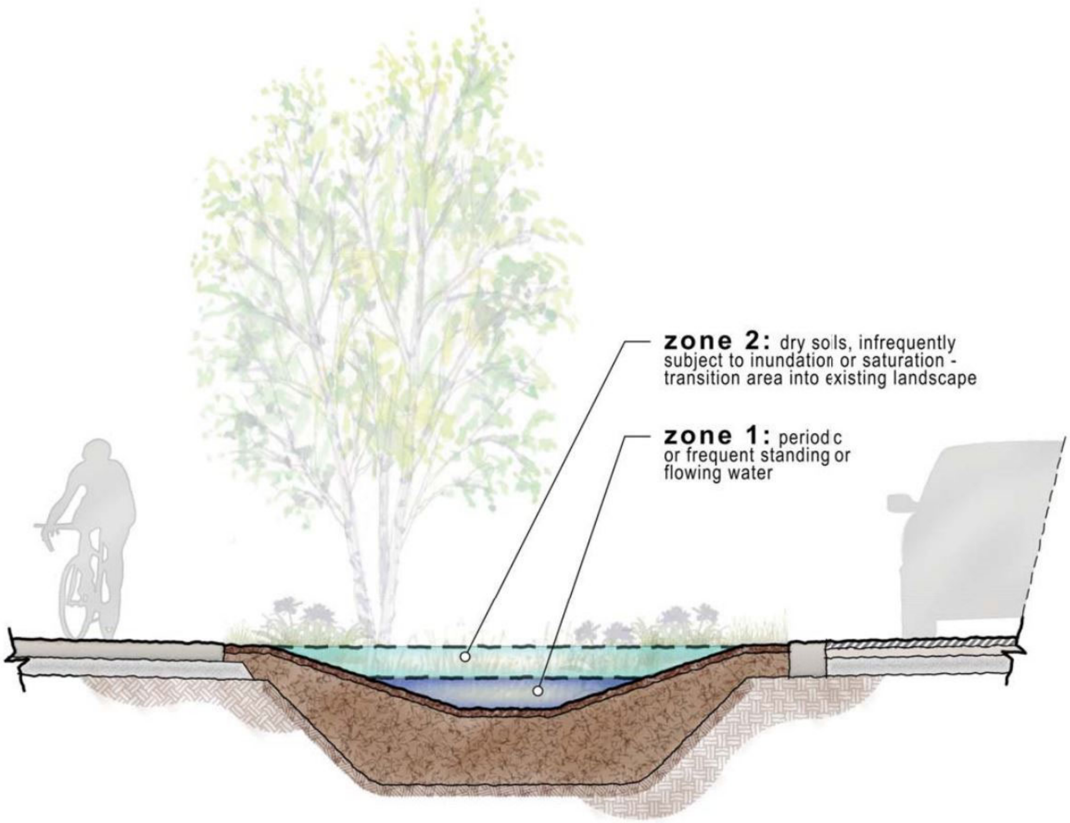
The list is organized by scientific name but also includes information identifying the climate zones (see Figure 4.1: Average Annual Precipitation and Climate Regions) and bioretention planting zones (see Figure 6.117: Bioretention Soil Moisture Zones) applicable to each planting. Each plant listing includes the following information:

- Scientific name
- Common name
- Bioretention zones
- Climate Region (see 4.3.1 Climate Regions)
- Notes

In bioretention BMPs, soil surface is sloped, resulting in differing planting conditions across the structure (Bioretention Planting Zones 1 and 2). Plants located at the bottom where ponding occurs, must be able to tolerate periodic stormwater inundation and will have different requirements than those placed on the side slopes, which receive runoff, but not ponding. Designers should also consider local jurisdiction requirements for maximum height, overhang, and sight distance where applicable. An example planting scheme for a bioretention swale in Spokane is provided as Figure 6.118: Example Planting Scheme for a Bioretention Swale in Spokane.

When selecting any plant species for LID projects, designers should consider xeriscape practices. Xeriscaping is a landscaping or gardening practice that focuses on efficient irrigation practices, grouping plants together with the same soil, water, and sunlight requirements, and minimizing the need for fertilizers and pesticides.

Figure 6.117: Bioretention Soil Moisture Zones



Source: AHBL, Inc.

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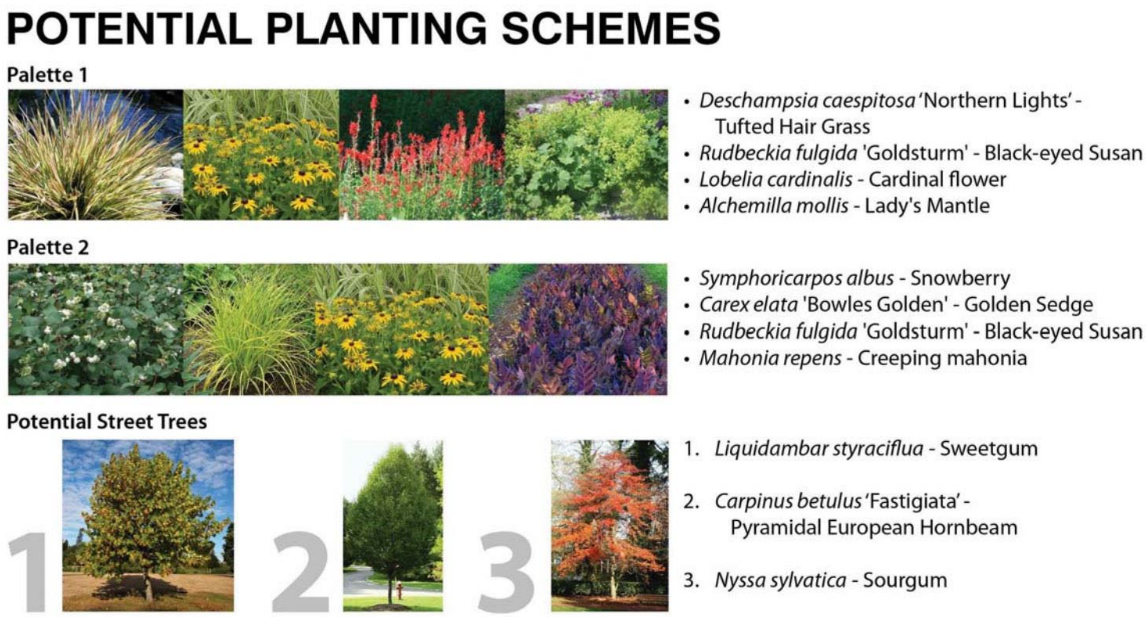
Bioretention Soil Moisture Zones

Revised June 2013

Figure 6.118: Example Planting Scheme for a Bioretention Swale in Spokane



Source: AHBL, Inc.

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Example Planting Scheme for a Bioretention Swale in Spokane

Revised June 2013

Table 6.72: Recommended Trees for Bioretention BMPs

Species	Common Name	Notes	Climate Region	Bioretention Zone
Acer glabrum	Rocky Mountain maple	Multitrunked. Best in moist, partly sunny areas	1, 4	2
Acer rubrum	Red maple	Grows tall and spindly in stands. Dense shrub alone. Reddish-orange fall color.	1, 3, 4	1, 2
Alnus incana	Mountain alder	Small- to medium-size tree with smooth grey bark, even in old age.	3, 4	1, 2
Betula nigra	River birch	Peeling bark lends winter interest. Unaffected by birch borers.	1, 2, 3, 4	1, 2
Betula occidentalis	Water birch	Spring catkins. Yellow fall color.	1, 3	1, 2
Celtis occidentalis	Common hackberry	Can tolerate a variety of soil conditions.	1, 2, 3, 4	2
Celtis laevigata	Netleaf hackberry trees	Native to eastern Washington. Prefers moist soils.	1, 2, 3, 4	2
Crataegus douglasii	Douglas hawthorn	Clusters of white flowers in spring followed by large edible scarlet berries that turn black and persist into winter.	1, 2, 3, 4	2
Frangula purshiana	Cascara	Attractive in all seasons. Leaves are bright green in spring, turning dark and glossy in the summer.	1, 4	1, 2
Ginkgo biloba	Maidenhair tree	Unique leaf and beautiful fall color. Select male plants to avoid foul smelling fruit.	1, 2, 3, 4	2
Gleditsia triacanthos var. *inermis*	Thornless honey locust	Airy, lacy leaves appear in late spring. Yellow fall color.	1, 2, 3, 4	2
Gymnocladus dioicus	Kentucky coffee tree	Bold year-round texture. Late to leaf out. Fruit pods can be messy. Prefers rich soil.	1, 3, 4	2
Juglans nigra	Black walnut	Deep tap root	1, 3, 4	2
Juniperus scopulorum	Rocky Mountain juniper	Evergreen. Can tolerate a variety of soils and moisture conditions.	1, 2, 3, 4	2

Table 6.72: Recommended Trees for Bioretention BMPs (continued)

Species	Common Name	Notes	Climate Region	Bioretention Zone
Larix occidentalis	Western larch	Deciduous conifer. Leaves turn bright yellow in autumn and eventually fall.	1, 2, 3, 4	2
Nyssa sylvatica	Black tupelo	Bright reds, oranges, yellows, and greens. Interesting form.	1, 3, 4	2
Pinus contorta	Lodgepole pine	Tall evergreen pine. Can tolerate dry, sandy conditions once established.	1, 2, 3 ,4	2
Pinus nigra	Austrian pine	Good in the city and for windbreaks.	1, 2, 3 ,4	2
Pinus ponderosa	Ponderosa pine	Native to upland sites.	1, 2, 3, 4	2
Pinus sylvestris	Scotch pine	Colorful bark.	1, 2, 3, 4	2
Populus tremuloides	Quaking aspen	Fast grower. Bright gold fall color and attractive bark.	1, 2, 3, 4	1, 2
Prunus virginiana	Chokecherry	Spikes of white creamy flowers with red berries that attract wildlife. Dark green leaves turn maroon and gold in fall.	1, 2, 3, 4	2
Sequoiadendron giganteum	Giant sequoia	Dense, pyramidal to columnar evergreen with reddish, furrowed bark. Can grow extremely large; may be better suited to larger planting areas.	1, 3, 4	2
Quercus garryana	Oregon white oak	Native oak. Drought tolerant once established. Adapts to moist or dry soils.	1, 3	2
Quercus macrocarpa	Bur oak	Adapts to moist or dry soils.	1,2,3,4	2
Quercus palustris	Pin oak	Rusty red fall color. Holds leaves in winter.	1,2,3,4	2
Tilia tomentosa	Silver linden	Fragrant yellow flowers clusters around fruit.	1,2,3,4	2

Table 6.73: Recommended Shrubs for Bioretention BMPs

Species	Common Name	Notes	Climate Region	Bioretention Zone
Amelanchier alnifolia	Western serviceberry	Very hardy. Drought tolerant. Needs some supplemental watering during dry months. White flowers in early spring.	1, 3, 4	2
Artemesia sp.	Sagebrush	Sprawling woody shrub with finely divided silver leaves. Some drought-tolerant varieties include *A. frigida*, *A. tripartita*, and *A. ludoviciana*.	1, 2, 3	2
Atriplex canescens	Four-wing saltbush	Extremely tolerant of all conditions.	2, 3	2
Betula glandulosa	Bog birch	Moist soils only. Not drought tolerant.	1, 3, 4	1
Caragana arborescens	Siberian pea shrub	Pealike bloom and seedpods that resemble string beans.	2, 3	2
Caragana frutex	Russian pea shrub	More erect than Siberian pea shrub.	1, 2, 3	1, 2
Caryopteris x clandonensis	Blue mist spiraea	Blue blooms in late summer. May be used as a perennial.	1, 3, 4	2
Cercocarpus ledifolius	Curl leaf mountain mahogany	Multistemmed large shrub or small tree. Evergreen.	2, 3, 4	2
Chamaebatiaria millefolium	Fernbush, desert sweet	Fragrant. Fern-like leaves. Showy flowers attract bees. Drought tolerant.	2, 3, 4	2
Cornus alba	Tatarian dogwood	Variegated leaf. Red twig lends winter interest. Deer resistant.	1, 2, 3, 4	2
Cornus sericea	Redosier dogwood	Red twig lends winter interest. Deer resistant.	1, 2, 3, 4	2
Cornus sericea 'Flaviramea'	Yellowtwig dogwood	Yellow twig lends winter interest. Some variegated cultivars. Deer resistant.	1, 2, 3, 4	2
Cotinus coggygria	Smoke tree	Multistemmed shrub. Soft, cloudlike masses of pinkish clusters. 'Royal Purple' cultivar with brownish-purple foliage is also a nice option.	1, 2, 3, 4	2

Table 6.73: Recommended Shrubs for Bioretention BMPs (continued)

Species	Common Name	Notes	Climate Region	Bioretention Zone
Dasiphora fruticosa	Shrubby cinquefoil	Yellow blooms in summer. Newer varieties in other colors. Flowers best in full sun.	1, 2, 3, 4	1, 2
Ericameria nauseosa	Rabbitbrush	Bright yellow blooms in fall. Upright foliage. Thin narrow grey leaves make attractive foliage. Green rabbitbrush is also an option. Recommend 'Tall Blue' cultivar.	2, 3	2
Fallugia paradoxa	Apache plume	Pink, silky plumed seed heads cover plant for many months.	2	2
Forestiera neomexicana	New Mexico privet	Only females produce black berries. Beautiful bark. Yellow fall color. Substitute for aspen and birch.	2	2
Helianthemum cultivars	Sunrose	Clumping evergreen, low spreading shrub with brightly colored flowers. Tolerates poor soils.	1, 2, 3, 4	2
Holodiscus discolor	Ocean spray	White flower, red or burgundy fall color. Dwarf cultivars available.	2	2
Krascheninnikovia lanata	Winterfat	Good for erosion control.	2, 3, 4	2
Mahonia aquifolium	Tall Oregon grape	Prefers partial shade in hot, dry areas.	1, 2, 3, 4	2
Mahonia nervosa	Dull Oregon grape	Prefers partial shade in hot, dry areas.	1, 2, 3, 4	1,2
Mahonia repens	Creeping Oregon grape	Green leathery leaves turn reddish in fall. Yellow flowers followed by tasty purple berries.	1, 2, 3, 4	1, 2
Paxistima myrsinites	Oregon boxleaf	Found in higher elevations in relatively dry, open, sunny sites or open forests. Prefers partial shade in hot, dry area.	1, 2, 3, 4	2
Penstemon fruticosus	Shrubby penstemon	Showy, drought-tolerant, and low-growing native.	1, 3, 4	2

Table 6.73: Recommended Shrubs for Bioretention BMPs (continued)

Species	Common Name	Notes	Climate Region	Bioretention Zone
Philadelphus lewisii	Mock orange	Beautiful, fragrant white blooms in late spring.	1, 2, 3, 4	2
Physocarpus malvaceus	Mallow ninebark	Exfoliating bark. Attractive seed pods.	1, 2, 3, 4	1
Pinus mugo var. *mugo*	Mugo pine	Protect from drying summer winds.	1, 2, 3, 4	2
Prunus sp.	Shrub cherry	Several cultivars available.	1, 2, 3, 4	2
Purshia tridentata	Bitterbrush	Small yellow blooms with small, fresh-scented silvery leaves.	1, 2, 3, 4	2
Rhus glabra	Smooth sumac	Striking red fall color.	1, 2, 3, 4	2
Rhus trilobata	Oakleaf Sumac	Does well in wet and dry conditions. Striking fall color. Forms dense thickets by spread of rhizomes or underground root structures.	1, 2, 3, 4	1,2
Ribes aureum	Golden currant	Scented yellow flowers from April to May. Flowers attract hummingbirds.	1, 2, 3, 4	1,2
Ribes cereum	Wax currant	Small white blossoms followed by bright red berries. Attracts several bird species.	1, 2, 3, 4	2
Ribes lacustre	Swamp currant	Appropriate for BMPs near riparian and wetland areas.	1, 2, 3, 4	1, 2
Ribes sanguineum	Red flowering currant	Early leaf-out. Fragrant pinkish-red flower. Edible fruit. Drought tolerant.	1, 2, 3, 4	2
Ribes viscossimum	Sticky current	Appropriate for BMPs near riparian and wetland areas.	1, 2, 3, 4	1, 2
Rosa gymnocarpa	Bald hip rose	Native shrub that grows well in part shade to shade. Plant spreads by underground rhizomes.	1, 2, 3, 4	2
Rosa nutkana var. *hispida*	Nootka rose	Fragrant, long-lasting blooms. Bright red hips.	1, 2, 3, 4	2
Rosa woodsii	Woods' rose	Clusters of aromatic pink flowers and bright red fruits.	1, 2, 3, 4	2
Rubus parviflorus	Thimbleberry	Showy flowers. Forms	1, 3, 4	2

Table 6.73: Recommended Shrubs for Bioretention BMPs (continued)

Species	Common Name	Notes	Climate Region	Bioretention Zone
		thickets. Good for wildlife; native.		
Rubus ursinus	Pacific blackberry	Vining plant native to Walla Walla region. Good ground cover near natural areas.	1, 2, 3, 4	2
Salix exigua	Coyote willow	Native plant used for erosion control and bank stabilization in streams and wetlands. Spreads rapidly. Use near natural areas.	1, 2, 3, 4	1
Salix scouleriana	Scoulers willow	Tall shrub to small tree, this native species is good in full sun to part shade. Large species excellent near natural areas. Forms thickets. Not for dry conditions.	1, 2, 3, 4	1
Salvia dorrii	Purple sage	Native species. Purple flowers attract butterflies. Very drought tolerant once established.	1, 2, 3, 4	2
Sambucus cerulea	Blue elderberry	Tall shrub with masses of small berries in August and September.	1, 2, 3, 4	2
Sambucus racemosa	Red elderberry	Large multistem deciduous shrub. Sun to shade. Prefers moist soils, but somewhat drought tolerant.	1, 2, 3, 4	1, 2
Sorbus scopulina	Western mountain ash	Native shrub with large showy clusters of white flowers in later spring and summer and yellow foliage with red berries in winter. Good for pollinators and wildlife. Sun to shade. Excellent near natural areas.	1, 3, 4	2
Spiraea betulifolia	Birch-leaf spiraea	Small, erect shrub with many fluffy white flowers in flat-topped clusters. Less than 2 feet tall. Blooms appear June to August.	1, 4	2
Spiraea douglasii	Western spiraea	Fragrant pink summer flower.	1, 2, 3, 4	1

Table 6.73: Recommended Shrubs for Bioretention BMPs (continued)

Species	Common Name	Notes	Climate Region	Bioretention Zone
Symphoricarpos albus	Snowberry	White flower, white berry that attracts birds, winter interest.	1, 3, 4	2
Symphoricarpos x chenaultii	Chenault coralberry	Pink blooms in spring. Likes moist to dry soils. Attractive fruit.	1, 2, 3, 4	2
Syringa vulgaris	Common lilac	Clustered blooms. White, pink, purple, and blue blooming cultivars available. Deep green foliage.	1, 2, 3, 4	2
Taxus cuspidata	Japanese yew	Evergreen. Can be heavily pruned.	1, 3, 4	2
Viburnum burkwoodii	Burkwood viburnum	Attractive to wildlife. Nearly pest free.	1, 2, 3, 4	2
Vaccinium membranaceum	Mountain huckleberry	Native species excellent for wildlife habitat. Prefers moist shady conditions. Good plant for sites near natural areas.	1, 4	1, 2
Yucca filamentosa	Adam's needle	Cluster of green, spike-tipped leaves has a tall, showy cluster of white flowers in the summer. Hardy, drought tolerant, tough, and beautiful.	2, 3	2

Table 6.74: Recommended Grasses for Bioretention BMPs

Species	Common Name	Notes	Climate Region	Bioretention Zone
Calamagrostis x acutiflora	Feather reed grass	Natives and cultivars, upright habit, attractive flower, fall and winter interest, deer resistant. Suggest 'Karl Foerster' or 'Overdam.' Grows 4 to 6 feet high.	1, 2, 3, 4	2
Carex flacca	Blue sedge	Drought-tolerant evergreen sedge. Variable color. Spreads rhizomatously. Grows 12 to 16 inches high.	1, 2, 3, 4	1, 2
Carex pensylvanica	Pennsylvania sedge	Full sun to part shade. Height of 8 to 10 inches. Drought	1, 2, 3, 4	1, 2

Table 6.74: Recommended Grasses for Bioretention BMPs (continued)

Species	Common Name	Notes	Climate Region	Bioretention Zone
		tolerant after establishment.		
Deschampsia caespitosa	Tufted hair grass	Attractive native grass with open flowers. Grows up to 3 feet high.	1, 2, 3, 4	2
Festuca ovina glauca	Blue fescue	Tufted mound of bluish-green grass to 10 inches. Keeps color throughout winter. Full to part sun.	1, 2, 3, 4	2
Helictotrichon sempervirens	Blue oat grass	Drought tolerant once established. Full sun.	1, 2, 3, 4	2
Juncus effusus	Common rush	Native species typical of alternately dry and wet sites. Height up to 4 feet. Can spread aggressively.	1, 3, 4	1, 2
Leymus cinereus	Basin wildrye	Robust plant that prefers moist sites like ditches or swales. Will form large clumps. Plant at a depth of 0.5 inches. Grows 3 to 6 feet high.	1, 2, 3, 4	1, 2
Panicum virgatum	Switchgrass	Attractive lacy flower, fall color, winter interest, salt-tolerant. Many varieties. Grows 3 to 5 feet high.	1, 2, 3, 4	1, 2
Pennisetum sp.	Fountain grass	Select for drought-tolerance. 'Hameln' is a drought-tolerant, dwarf variety.	1, 2, 3, 4	2
Pseudoroegneria spicata	Bluebunch wheatgrass	Large bunchgrass grows 1.5 to 4 feet tall. Slow to establish, but very hardy once established. Plant at a depth of 0.25 inches. Sun. Intolerant to flooding.	1, 2, 3, 4	2
Schizachyrium scoparium	Little bluestem	Reddish tones in fall. Suggest 'The Blues.' Sun. Best on side slopes and top of slopes due to moderate tolerance to flooding.	1, 2, 3, 4	1, 2

Table 6.75: Recommended Perennials and Wildflowersfor Bioretention BMPs

Species	Common Name	Notes	Climate Region	Bioretention Zone
Achillea millefolium	Common yarrow	A perennial herb that produces one to several stems.	1, 2, 3, 4	2
Achillea tomentosa	Wooly yarrow	Fire-resistant, fern-like leaves, flat clusters of yellow flowers in spring.	1, 2, 3, 4	2
Aethionema schistosum	Fragrant Persian rock cress	Evergreen foliage. Powder-blue bloom. Reseeds.	1, 2, 3, 4	2
Agastache sp.	Hyssop	Purple blooms. Sage-like appearance. Attracts butterflies. *A. canna* is hardy to Zone 3. Also suggest *A. rupestris*.	1, 3	2
Alchemilla mollis	Lady's mantle	Needs more water in full sun. Prefers moist to somewhat dry soil.	1, 2, 3, 4	1, 2
Alyssum saxatile compactum	Goldkugel Basket of gold	Compact. Attractive silver-gray foliage.	1, 2, 3, 4	2
Amsonia sp.	Blue star flower	Star-shaped blossoms.	1, 3	2
Anaphalis margaritacea	Pearly everlasting	Tiny, white flowers crowded in small, flat, fluffy heads.	1, 2, 3, 4	2
Anemone sp.	Anemone wildflower	White, pink, or rose flowers, depending on variety.	1, 2, 3, 4	2
Anthemis sp.	Marguerite daisy	*A. biebersteinana* features feathery silver foliage and blooms in late spring. *A. tinctoria* is a taller, shrubbier species with a golden-yellow, daisy-like bloom.	1, 2, 3, 4	2
Armeria maritima 'Compacta'	Compact sea pink	Tidy, grass-like foliage with flowers held on stems above.	1, 2, 3, 4	2
Artemisia sp.	Sage, Silvermound	Used for silvery, lacy foliage. Drought-tolerant species include *A.* 'Powis Castle,' *A. abortanum*, and *A. stelleriana*.	1, 2, 3, 4	2
Asclepias speciosa	Showy milkweed	Native. The abundant nectar of milkweed flowers attracts hummingbirds, butterflies, honey bees, native bees, and other	1, 2, 3, 4	1, 2

Table 6.75: Recommended Perennials and Wildflowersfor Bioretention BMPs (continued)

Species	Common Name	Notes	Climate Region	Bioretention Zone
		beneficial insects. Spread by rhizomes and seeds.		
Asclepias tuberosa	Milkweed Butterfly weed	Orange blooms. Attracts butterflies.	1, 2, 3, 4	2
Aster sp.	Aster	Many varieties, later summer bloom, deer resistant, *Symphyotrichum spathulatum* is a native species. *A. tataricus* known to be drought-tolerant.	1, 2, 3, 4	2
Aquilegia coerulea	Blue columbine	Attractive to bees, butterflies, and birds.	1, 2, 3, 4	2
Aquilegia formosa	Western columbine	Native hummingbird species with showy orange and yellow flowers in spring. Drought tolerant after establishment. Prefers full to part shade but will tolerate full sun in moist soils.	1, 2, 3, 4	1, 2
Arnica cordifolia	Heart-leaf leopard bane	Drought tolerant native plant found in sun to shade.	1, 3, 4	1, 2
Balsamorhiza sagittata	Arrow-leaf Balsamroot	Sunflower-like bloom. Trident-shaped silver blue leaves.	1, 2, 3, 4	2
Baptisia australis	Blue false indigo	Blue blooms in late spring.	1, 2, 3, 4	2
Callirhoe involucrata	Poppy mallow	Reddish-purple bloom. Long-lived.	1, 2, 3, 4	2
Calylophus serrulatus	Dwarf sundrops	Heavy bloomer.	1, 2, 3, 4	2
Camassia leichtlinii	Large camas	Native to western Washington, this lily has showy blue, purple, pink, or lavender flowers. Plants need moist soil and are not drought tolerant.	3, 4	1
Camassia quamash	Blue camas	Blooms early summer.	3, 4	1, 2
Castilleja sp.	Indian paintbrush	Excellent pollinator species.	1, 2, 3, 4	1, 2
Coreopsis grandiflora	Coreopsis	Low grower. Yellow flowers from mid- to late summer. Prefers well-	1, 2, 3, 4	2

Table 6.75: Recommended Perennials and Wildflowersfor Bioretention BMPs (continued)

Species	Common Name	Notes	Climate Region	Bioretention Zone
		drained soils. Drought-tolerant.		
Dianthus sp.	Pink	Pink, red, or white blooms. Dainty appearance. Select for hardiness.	1, 2, 3, 4	2
Dryas octopetala	White dryas	Small white flowers on short stalks with wispy seed heads. Alpine. Forms a low carpet. Spreads slowly.	1, 2, 3, 4	2
Echinacea purpurea	Purple coneflower	Purple flowers in May through August. Excellent for attracting butterflies. Drought tolerant.	1, 2, 3, 4	2
Echinops ritro	Globe thistle	Blooms appear in June and can last until fall. Tolerant of a variety of light conditions and soil types. Suggest 'Taplow Blue.'	1, 2, 3, 4	2
Erigeron speciosus	Showy fleabane	Yellow flowers for many weeks in late spring to early summer. Blooms in May and June.	1,2,3,4	2
Eriogonum umbellatum	Sulphur-flower buckwheat	Needs pruning to keep compact. Very drought tolerant.	1, 3, 4	2
Eryngium sp.	Sea holly	Select for hardiness and perennial growth. Suggest 'Sapphire Blue.'	1, 2, 3, 4	2
Eschscholzia californica	California poppy	Bluish green fern-like leaves with orange flowers. Flowers open during day and close at night. Spicy fragrance.	1, 2, 3, 4	2
Filipendula vulgaris	Dropwort	Basal growing fern-like leaves.	1, 2, 3, 4	1, 2
Gaillardia aristata	Blanket flower	Hardy brilliant red flowers with yellow rims.	1, 2, 3, 4	2
Geranium sp.	Cranesbill	Many species/varieties. Finely lobed foliage. Select for drought-tolerance. *G. sanguineum* features rose, pink, white, or purple flowers throughout summer. *G. macrorrhizum* is attractive to wildlife.	1, 2, 3, 4	2
Geum macrophyllum	Large leaf avens	Hairy perennial with short rhizomes and big leaves topped by small	1, 2, 3, 4	1

Table 6.75: Recommended Perennials and Wildflowersfor Bioretention BMPs (continued)

Species	Common Name	Notes	Climate Region	Bioretention Zone
		yellow flowers. Prefers part to full shade. Spreads readily by seed. Great for sites near natural areas.		
Geum triflorum	Prairie smoke	Large stands of the plant create a gauzy effect that resembles smoke hovering close to the ground. Full sun. Drought tolerant.	1, 2, 3, 4	2
Helianthella uniflora	Little sunflower	Sunflower-like bloom. Single flower stalk.	1, 2, 3, 4	2
Hemerocallis 'Stella d'Oro'	Stella d'Oro daylily	Long bloom in spring and summer. Tough plant. Yellow blooms. Smaller than other daylilies.	1, 2, 3, 4	2
Heuchera cylindrica	Roundleaf alumroot	Plant in full sun to partial shade and in well-drained moist to dry soil. Drought tolerant.	1, 2, 3, 4	1, 2
Hosta sp.	Hosta	Variegated foliage.	1, 2, 3, 4	2
Hypericum calycinum	St. John's wort	Yellow blooms in summer.	1, 3, 4	2
Ipomopsis aggregata	Scarlet gilia	Bright red flowers on long stem and higher germination success and seedling survival in disturbed soils. Drought tolerant and shade tolerant.	1, 2, 3, 4	2
Iris sibirica	Siberian iris	Blue flower in spring, attractive leaf, deer resistant.	1, 2, 3, 4	2
Lavandula sp.	Lavender	Showy, fragrant purple flowers. Several varieties. Requires pruning once per year for first 3 years of establishment. Drought tolerant after establishment.	1, 2, 3, 4	1, 2
Lewisia rediviva	Bitterroot	Various blooms. Good for rock gardens.	1, 2, 3, 4	2
Liatris punctata	Gayfeather	Sends up dense flower stalks. Blooms in the later summer. Prefers well-drained soils. More drought-tolerant than *L. spicata*. Also consider *L. aspera*.	1, 2, 3, 4	2
Limonium	Sea lavender	Looks like a delicate cloud of	1, 2, 3, 4	1, 2

Table 6.75: Recommended Perennials and Wildflowersfor Bioretention BMPs (continued)

Species	Common Name	Notes	Climate Region	Bioretention Zone
latifolium		lavender, pink, or white flowers.		
Linum lewisii	Wild blue-flax	Native. Blue blooms in summer. Reseeds if not cut back. There is a nonnative blue flax that is very aggressive. Take precautions to plant the native.	1, 2 ,3, 4	2
Lupinus sp.	Lupine	Many species and varieties. Select for drought-tolerance. *L. sericeus* is a native, purple-flowered lupine of dry areas with short-lived blooms.	1, 2, 3, 4	2
Matteuccia struthiopteris	Ostrich fern	Striking size and form. Feathery fronds.	1, 2, 3, 4	1,2
Nepeta sp.	Catmint	Dainty purple blooms throughout the summer. Prefers well-drained soils. Drought-tolerant.	1, 2, 3, 4	2
Oenothera caespitosa	Evening primrose	*O. missouriensis* has a yellow flower; native to the Midwest.	1, 2, 3, 4	2
Opunitia sp.	Prickly pear	Various blooms. Desert plant. Suggest *O. humifusa*.	2, 3	2
Origanum vulgare	Oregano	Do not overwater. Edible.	1, 2, 3, 4	2
Penstemon x gloxinoides	Garden penstemon	Blooms in spring in dry rocky sites.	1, 2, 3, 4	2
Perovskia atriplifolia	Russian sage	Silvery foliage. Lavender spikes.	1, 2, 3, 4	2
Polystichum munitum	Sword fern	Drought tolerant once established.	1, 4	2
Ratibida columnifera	Prairie coneflower	Red and yellow, columnar flower heads up to 3 inches.	1, 2, 3, 4	2
Rudbeckia fulgida 'Goldsturm'	Black-eyed Susan	Bright yellow blooms with dark centers midsummer through early fall.	1, 2, 3, 4	2
Salvia sp.	Sage (gray ball)	Small gray-green shrub. Intolerant of shade.	1, 2, 3, 4	2
Salvia pachyphylla	Giant flowered purple sage	Giant flowered purple sage blooms all summer and is evergreen.	1, 2, 3, 4	2
Salvia x	Purple sage	'Mainacht' is drought-tolerant.	1, 2, 3, 4	2

Table 6.75: Recommended Perennials and Wildflowersfor Bioretention BMPs (continued)

Species	Common Name	Notes	Climate Region	Bioretention Zone
sylvestris				
Solidago sp.	Goldenrod	Bright yellow blooms on stalks. May lie horizontal or upright. *S. canadensis* and *S. occidentalis* are native. Some varieties of *S. rugosa* are drought-tolerant.	1, 2, 3, 4	2
Sphaeralcea sp.	Globe-mallow	Select for drought-tolerance. Suggest current-leaved globemallow (*S. grossularifolia*) and orange globemallow (*S. incana*).	1, 2, 3, 4	2
Stanleya pinnata	Prince's plume	Spectacular spires of yellow flowers. Takes 1 to 2 years to become well established. Very susceptible to herbicides.	1, 2, 3, 4	2
Xerophyllum tenax	Bear grass	Bear grass is a fire-resistant species that does best in xeric to fairly dry conditions. It grows well in sun and part shade and is often associated with evergreen trees.	1, 2, 3, 4	2

Table 6.76: Recommended Ground Covers for Bioretention BMPs

Species	Common Name	Notes	Climate Region	Bioretention Zone
Arctostaphylos uva-ursi	Kinnickinnick	Ground-hugging evergreen plant with glossy green leaves change to red color in fall. Small, bell-shaped pink flowers in spring, followed by small, 0.5-inch red berries.	1, 2, 3, 4	2
Antennaria rosea	Pink pussytoes	Spreads and self-sows rapidly.	1, 2, 3, 4	2
Arabis caucasica	Wall cress	White or pink blooms emerge in spring.	1, 2, 3, 4	1, 2
Asarum caudatum	Wild ginger	Partial to full shade. Drought tolerant after establishment. Good species under evergreen tree canopy.	1, 4	2

Table 6.76: Recommended Ground Covers for Bioretention BMPs (continued)

Species	Common Name	Notes	Climate Region	Bioretention Zone
Campsis radicans	Trumpet creeper	Vigorous vine often used for green walls and other vertical structures or as a ground cover. Needs some support. Plant with care; can become aggressive. Deciduous to partly evergreen.	1, 2, 3, 4	2
Ceanothus prostratus	Squaw carpet	Evergreen. Showy blue/purple flowers.	1, 4	1, 2
Clematis columbiana	Blue rock clematis	Native ground cover or climbing vine with pale purple flowers.	1, 2, 3, 4	2
Clematis ligusti-cifolia	Western white clematis	Excellent native clematis ground cover that is good for erosion control. Drought tolerant. Be careful to not mix this species up with the invasive clematis species.	1, 2, 3, 4	2
Cornus canadensis	Bunchberry	Native to northern areas of state. Requires full shade. Associated with conifer species.	1, 4	2
Eriogonum sp.	Buckwheat	Evergreen, ground covering shrub is native to the western United States. Large clusters of creamy white flowers grace low shrubs with narrow, frosty-green leaves. Drought-tolerant varieties include *E. heracleoides*, *E. niveum*, and *E. umbellatum*.	1, 3	1, 2
Fragaria virginiana	Wild strawberry	White or pink flower, edible berries, spreads by surface runners, deer resistant.	1, 3, 4	2
Helianthemum nummularium	Sunrose	Evergreen. Gray or green leaves, very colorful flowers in midsummer. Shear after first flower to encourage fall bloom.	1, 2, 3, 4	2
Juniperus horizontalis	Creeping juniper	Ground-hugging evergreen plant with glossy green leaves change to red color in fall. Small, bell-shaped pink flowers in spring, followed by small, 0.5-inch red berries.	1, 2, 3, 4	2

Table 6.76: Recommended Ground Covers for Bioretention BMPs (continued)

Species	Common Name	Notes	Climate Region	Bioretention Zone
Linnaea borealis	Twinflower	Creeping evergreen vine. Grows best in moist, shady woods and forests.	1, 4	2
Lonicera ciliosa	Orange honeysuckle	Bright orange flower clusters. Drought tolerant after established, but prefers moist soils. Full sun, but best in part shade. Deer resistant.	1, 3, 4	2
Microbiota decussata	Russian cypress	Foliage turns bronze in winter if in full sun.	1, 2, 3, 4	2
Persicaria affinis	Himalayan fleeceflower	Pink blooms in late summer.	1, 2, 3, 4	1, 2
Phlox sp.	Phlox	Many species and varieties, some native. Select for drought-tolerance. *P. subulata* is readily available.	1, 2, 3, 4	2
Potentilla sp.	Cinquefoil	Delicate, bright green leaves with bright yellow flowers in spring and summer. Fast growing.	1, 2, 3, 4	2
Sedum sp.	Stonecrop	Mat-forming evergreen plant. Tolerates some shade, requires good drainage. 'Cape Blanco' and 'Purpureum' are drought-tolerant.	1, 2, 3, 4	2
Sempervivum sp.	Hen and chicks	Does best in gravely soil.	1, 2, 3, 4	2
Teucrium sp.	Germander	Evergreen. Woody upright stems with dark green, toothy leaves.	1, 2, 3, 4	2
Thymus sp.	Thyme	Mat forming, spreading plants. Silver gray foliage. *T. lanuginosus* and *T. pseudolanuginosus* are low evergreen species. T. praecox is deciduous and grows to 6 inches.	1, 2, 3, 4	2
Veronica sp.	Speedwell	Suggest *V. oltensis* and *V. pectinata*.	1, 2, 3, 4	2
Zinnia grandiflora	Rocky Mountain zinnia	Deer resistant.	1, 2, 3, 4	1, 2

6.B.4 Stormwater Treatment Wetlands Plant List

Table 6.77: Emergent Wetland Plant Species Recommended for Stormwater Treatment Wetlands in Arid and Cold Climates in Eastern Washington

Species	Common Name	Notes	Saturation Tolerance
Moist to Saturated Soils			
Agrostis idahoensis	Idaho bent grass	Prairie, wet meadows	Does not withstand flooding or moist soil
Calamagrostis canadensis	Bluejoint reedgrass	Meadows and open understory, along streams and pond margins	High tolerance to anaerobic conditions
Carex praegracilis	Clustered field sedge	Moist meadows, along ponds and streams	High tolerance to anaerobic conditions
Deschampsia caespitosa	Tufted hairgrass	Prairie to coast	Moist to dry soils
Distichlis spicata	Saltgrass	Useful in saline/alkaline soils	High tolerance to anaerobic conditions
Juncus confusus	Colorado rush	Moist meadows, along streams	High tolerance to anaerobic conditions
Poa palustris	Fowl bluegrass	Meadows	Medium tolerance to anaerobic conditions
Puccinellia nuttalliana	Nuttall's alkaligrass	Moist alkaline soils	High tolerance to anaerobic conditions
Spartina pectinata	Prairie chordgrass	Floodplains, wet meadows, seasonally dry sites, tolerates alkaline conditions and high groundwater table	Does not withstand prolonged inundation
Inundation to 1 Foot			
Beckmania syzigachne[a]	American sloughgrass	Wet meadows to pond margins	High tolerance to anaerobic conditions
Carex nebras-censis	Nebraska sedge	Wet meadows to pond margins	Can tolerate standing water about 3 months, as long as there are periods when the soil is dry.
Carex utriculata	Northwest territory sedge	Wet soil to standing water	High tolerance to anaerobic conditions
Glyceria occidentalis	Western mannagrass	Marshes, pond margins	Best adapted to semiaquatic habitat, flooded or saturated for up

Table 6.77: Emergent Wetland Plant Species Recommended for Stormwater Treatment Wetlands in Arid and Cold Climates in Eastern Washington (continued)

Species	Common Name	Notes	Saturation Tolerance
			to 25% of the growing season
Juncus articulatus	Jointed rush	Wet soils, wetland margins	High tolerance to anaerobic conditions
Juncus ensifolius	Dagger-leaf rush	Wet meadows, pastures, wetland margins	High tolerance to anaerobic conditions
Juncus torreyi	Torrey's rush	Moist to wet meadows, margins of streams, often where saline or alkaline	Medium anaerobic tolerance
Inundation 1 to 3 Feet			
Eleocharis palustris	Common spike rush	Margins of ponds, wet meadows	Inundation up to 3 feet; can survive where water table drops to 1 foot below surface
Schoenoplectus acutus[b]	Hardstem bulrush	Single tall stems, not clumping	3 feet
Schoenoplectus tabernaemontani[b]	Softstem bulrush	Wet ground to shallow water	Deep or shallow water
Scirpus microcarpus[b]	Small-fruited bulrush	Wet ground to 18 inches depth	Does best in < 18 inches of water
Inundation Greater Than 3 Feet			
Nuphar polysepalum	Yellow water-lily	Deep water; aquatic species	3 to 7.5 feet
Potamogeton natans	Floating-leaf pondweed	Shallow to deep ponds; aquatic species	6 feet

Primary sources: (Ecology, 1993b), (Hortus Northwest, 1993), (Hitchcock and Cronquist, 1973).

[a]Nonnative species. However *Beckmania syzigachne* is native to Oregon.

[b]*Scirpus* tubers must be protected from foraging waterfowl (e.g., using methods such as biodegradable stakes, coyote decoys, canine patrols, etc.) until established. Emerging aerial stems should project above water surface to allow oxygen transport to the roots.

Chapter 7 - Construction Stormwater Pollution Prevention

7.1 Soil Erosion and Sedimentation from Construction Sites

7.1.1 Soil Erosion

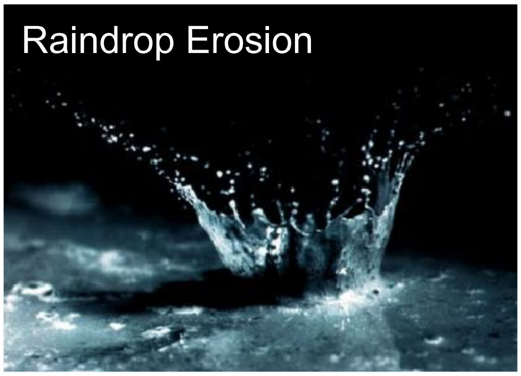
What is Soil Erosion?

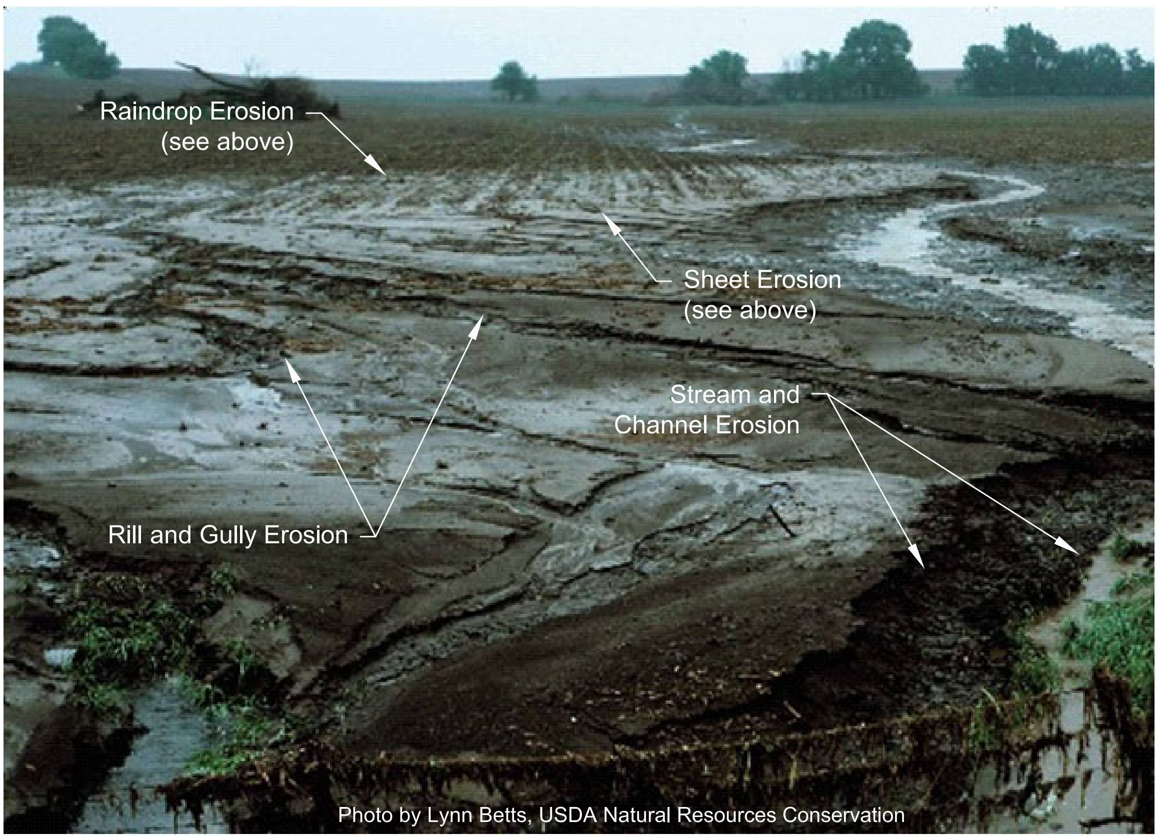
Soil erosion is defined as the removal of soil from its original location by the action of water, ice, gravity, or wind. In construction activities, soil erosion is largely caused by the force of falling and flowing water. Erosion by water includes the following processes:

- Raindrop Erosion: The direct impact of falling drops of rain on soil dislodges soil particles so that they can then be easily transported by runoff.
- Sheet Erosion: The removal of a layer of exposed soil by the action of raindrop splash and runoff, as water moves in broad sheets over the land (not confined in small depressions).
- Rill and Gully Erosion: As runoff concentrates in rivulets, it cuts grooves called rills into the soil surface. If the flow of water is sufficient, rills may develop into larger gullies.
- Stream and Channel Erosion: Increased volume and velocity of runoff in an unprotected, confined channel may cause stream meander instability and scouring of significant portions of the stream or channel banks and bottom.

Soil erosion by wind creates a water quality problem when dust is blown into water. Dust control on paved streets using washdown waters, if not conducted properly, can also create water quality problems.

Figure 7.1: Types of Erosion





DEPARTMENT OF ECOLOGY
State of Washington

Types of Erosion

Revised November 2023

Factors Influencing Erosion Potential

The erosion potential of soils can be readily determined using various models such as the Flaxman Method or the Revised Universal Soil Loss Equation (RUSLE).

The soil erosion potential of an area, including a construction site, is determined by four interrelated factors:

- Soil characteristics
- Vegetative cover
- Topography
- Climate

Collect, analyze, and use detailed information specific to the construction site for each of these four factors when selecting Construction Stormwater BMPs to prevent erosion.

The first three factors (soil characteristics, vegetative cover, and topography) are constant with respect to time until altered by construction. The designer, the project proponent, and the construction contractor should have a working knowledge of, and control over, these factors to provide high quality stormwater results.

The fourth factor, climate, is predictable by season, historical record, and probability of occurrence. While predicting a specific rainfall event is not possible, plan appropriate seasonal construction activity and use properly designed BMPs to minimize or avoid many of the impacts of construction stormwater runoff.

How Soil Characteristics Affect Erosion Potential

The vulnerability of soil to erosion is determined by the following soil characteristics:

Particle Size: Soils that contain high proportions of silt and very fine sand are generally the most erodible and are easily detached and carried away. The erosion potential of soil decreases as the percentage of clay or organic matter increases; clay acts as a binder and tends to limit erosion potential. Most soils with high clay content are relatively resistant to detachment by rainfall and runoff. Once eroded, however, clays are easily suspended and settle out very slowly.

Organic Content: Organic matter creates a favorable soil structure, improving its stability and permeability. This increases infiltration capacity, delays the start of erosion, and reduces the amount of runoff.

The addition of organic matter increases infiltration rates (and, therefore, reduces surface flows and erosion potential), water retention, pollution control, and pore space for oxygen.

Soil Structure: Organic matter, particle size, and gradation affect soil structure, which is the arrangement, orientation, and organization of particles. When the soil system is protected from compaction, the natural decomposition of plant debris on the surface maintains a healthy soil food web. The soil food web in turn maintains the porosity both on and below the surface.

Soil Permeability: Soil permeability refers to the ease with which water passes through a given soil. Well-drained and well-graded gravel and gravel mixtures with little or no silt are the least erodible soils. Their high permeability and infiltration capacity helps prevent or delay runoff.

How Vegetative Cover Affects Erosion Potential

Vegetative cover plays an extremely important role in controlling erosion by:

- Shielding the soil surface from the impact of falling rain.
- Slowing the velocity of runoff, thereby permitting greater infiltration.
- Maintaining the soil's capacity to absorb water through root zone uptake and evapotranspiration.
- Holding soil particles in place.

Limiting the removal of existing vegetation and decreasing duration of soil exposure to rainfall events can reduce erosion. Give special consideration to preserving existing vegetation on areas with a high potential for erosion such as erodible soils, steep slopes, drainage ways, and the banks of streams. When it is necessary to remove vegetation, such as removing noxious weeds, revegetate these areas immediately.

How Topography Affects Erosion Potential

The size, shape, and slope of a construction site influence the amount and rate of stormwater runoff. Each site’s unique dimensions and characteristics provide both opportunities for and limitations on the use of specific control measures to protect vulnerable areas from high runoff amounts and rates. Slope length, steepness, and surface texture are key elements in determining the volume and velocity of runoff. As slope length and/or steepness increase, the rate of runoff and the potential for erosion increases. Slope orientation is also a factor in determining erosion potential. For example, a slope that faces south and contains dry soils may provide such poor growing conditions that vegetation will be difficult to re-establish.

How Climate Affects Erosion Potential

Seasonal temperatures and the frequency, intensity, and duration of rainfall are fundamental factors in determining amounts of runoff. As the volume and the velocity of runoff increase, the likelihood of erosion increases. Where storms are frequent, intense, or long, erosion risks are high. Seasonal changes in temperature, as well as variations in rainfall, help to define the period of the year when there is a high erosion risk. When precipitation falls as snow, erosion may not occur until the spring, when melting snow adds to the runoff, and erosion potential will be higher. Partially frozen ground reduces infiltration capacity.

In fall, winter, and spring, eastern Washington is characterized by storms that are mild and long lasting. The fall and early winter events may saturate the soil profile and fill stormwater detention ponds, increasing the amount of runoff leaving the construction site. Shorter term, more intense storms occur in the summer. These storms can cause problems if adequate BMPs have not been installed on-site.

7.1.2 Sedimentation

Sedimentation is defined as the gravity-induced settling of soil particles transported by water. The process is accelerated in slower-moving, quiescent stretches of natural waterbodies or in Runoff Treatment BMPs such as sediment ponds and wetponds.

Sedimentation occurs when the velocity of water in which soil particles are suspended is slowed for a sufficient time to allow the soil particles to settle. The settling rate depends on the soil particle size. Heavier particles, such as sand and gravel, settle more rapidly than fine particles such as clay and silt. Sedimentation of clay soil particles is reduced due to clay's relative low density and electro-charged surfaces, which discourage aggregation. The presence of clay particles in stormwater runoff can result in highly turbid water, which is not amenable to treatment by settling.

Turbidity, an indirect measure of soil particles in water, is one of the primary water quality standards in Washington State law (WAC 173-201A-200). Turbidity is increased when erosion carries soil particles into receiving waters. Treating stormwater to reduce turbidity can be an expensive, difficult process with limited effectiveness. Any actions or prevention measures that reduce the volume of water needing treatment for turbidity are beneficial.

7.1.3 Soil Erosion and Sedimentation Impacts

Soil erosion and sedimentation caused by land development impact the environment, damaging aquatic and recreational resources, as well as affecting aesthetic qualities. Erosion and sedimentation ultimately affect everyone.

Common examples of soil erosion and sedimentation impacts are:

- Natural, nutrient-rich topsoils erode. Re-establishing vegetation is difficult without applying soil amendments and fertilizers.
- Silt from poorly stabilized areas fills culverts and storm drains, decreasing capacities and increasing flooding, maintenance frequencies, and costs.
- Runoff Treatment and Flow Control BMPs fill rapidly with sediment, decreasing capacities and and increasing flooding, maintenance frequencies, and costs.
- Sediment clogs infiltration devices, causing failure.
- Sediment causes obstructions in streams and harbors, requiring dredging to restore navigability.
- Shallow areas in lakes form rapidly, resulting in growth of aquatic plants and reduced usability.
- Nutrient loading from phosphorus and nitrogen attached to soil particles and transported to lakes and streams cause a change in the water pH, algal blooms, and oxygen depletion, leading to eutrophication and fish kills.
- Water treatment for domestic uses becomes more difficult and costly.
- Turbid water replaces aesthetically pleasing, clear, clean water in streams and lakes.

- Eroded soil particles decrease the viability of macro-invertebrates and food-chain organisms, impair the feeding ability of aquatic animals, clog gill passages of fish, and reduce photosynthesis.

- Sediment-clogged gravel diminishes fish spawning and can smother eggs or young fry.

Costs associated with these impacts may be obvious or subtle. Some are difficult to quantify, such as the loss of aesthetic values or recreational opportunities. Restoration and management of a single lake can cost millions of dollars. Reductions in spawning habitat, and subsequent reduction in salmon and trout production, cause economic losses to sport fisheries, traditional Native American fisheries, and the fishing industry. The maintenance costs of man-made structures and harbors are readily quantifiable. Citizens pay repeatedly for these avoidable costs in their tax dollars.

Effective erosion and sediment control (ESC) BMPs on construction sites can greatly reduce undesirable environmental impacts and costs. Being aware of the erosion and sedimentation process is helpful in understanding the role of Construction Stormwater BMPs in controlling stormwater runoff.

7.2 13 Elements of Construction Stormwater Pollution Prevention

7.2.1 Element 1: Preserve Vegetation / Mark Clearing Limits

a. Before beginning land disturbing activities, including clearing and grading, clearly mark all clearing limits, sensitive areas and their buffers, and trees that are to be preserved within the construction area.

b. Retain the duff layer, top soil, and natural vegetation in an undisturbed state to the maximum degree practicable.

The text in this box originates from one or more of the following Permits:
Appendix 1 of the Phase I / Phase II Municipal Stormwater Permits
Construction Stormwater General Permit

Additional Guidance for Element 1

- Plastic, metal, fabric fence, or other physical barriers may be used to mark the clearing limits. Note the difference between the practical use and proper installation of BMP C233: Silt Fence and the proper use and installation of BMP C103: High-Visibility Fence.

- If it is not practical to retain the duff layer in place, then stockpile it on site, cover it to prevent erosion, and replace it immediately when you finish disturbing the site.

Suggested BMPs for Element 1

- BMP C101: Preserving Natural Vegetation

- BMP C102: Buffer Zones

- BMP C103: High-Visibility Fence
- BMP C233: Silt Fence

7.2.2 Element 2: Establish Construction Access

a. Limit construction vehicle access and exit to one route, if possible.

b. Stabilize access points with a pad of quarry spalls, crushed rock, or other equivalent BMPs, to minimize tracking of sediment onto roads.

c. Locate wheel wash or tire baths on site, if the stabilized construction entrance is not effective in preventing tracking sediment onto roads.

d. If sediment is tracked off site, clean the affected roadway(s) thoroughly at the end of each day, or more frequently as necessary (for example, during wet weather). Remove sediment from roads by shoveling, sweeping, or picking up and transporting the sediment to a controlled sediment disposal area.

e. Conduct street washing only after sediment is removed in accordance with 2.d (above).

f. Control street wash wastewater by pumping back on site, or otherwise prevent it from discharging into systems tributary to waters of the State.

The text in this box originates from one or more of the following Permits:
Appendix 1 of the Phase I / Phase II Municipal Stormwater Permits
Construction Stormwater General Permit

Additional Guidance for Element 2

Minimize construction site access points along linear projects, such as roadways. Street washing may require local jurisdiction approval.

Suggested BMPs for Element 2

- BMP C105: Stabilized Construction Access
- BMP C106: Wheel Wash
- BMP C107: Construction Road / Parking Area Stabilization

7.2.3 Element 3: Control Flow Rates

a. Protect properties and waterways downstream of construction sites from erosion and the associated discharge of turbid waters due to increases in the velocity and peak volumetric flow rate of stormwater runoff from the project site.

b. Where necessary to comply with 3.a (above), construct stormwater infiltration or detention BMPs as one of the first steps in grading. Ensure that detention BMPs function properly before constructing site improvements (e.g. impervious surfaces).

c. If permanent infiltration BMPs are used for temporary flow control during construction, protect these BMPs from sedimentation during the construction phase.

The text in this box originates from one or more of the following Permits:
Appendix 1 of the Phase I / Phase II Municipal Stormwater Permits
Construction Stormwater General Permit

Additional Guidance for Element 3

- Conduct an off-site analysis if changes in flows could impair or alter conveyance systems, streambanks, bed sediment, or aquatic habitat. See 2.5.3 APM2: Off-Site Analysis Report for off-site analysis guidelines.
- Even gently sloped areas need flow controls such as BMP C235: Wattles or other energy dissipation / filtration structures. Place dissipation facilities closer together on steeper slopes. These methods prevent water from building higher velocities as it flows downstream within the construction site.
- Control structures designed for permanent detention BMPs are not appropriate for use during construction without modification. If used during construction, modify the control structure to allow for long-term storage of runoff and enable sediment to settle. Verify that the BMP is sized appropriately for this purpose. Restore BMPs to their original design dimensions, remove sediment, and install a final control structure at completion of the project.
- Erosion has the potential to occur because of increases in the volume, velocity, and peak flow rate of stormwater runoff from the project site. The local permitting agency may require infiltration or detention BMP designs that provide additional or different stormwater flow control than the designs detailed in this manual. These requirements may be necessary to address local conditions or to protect properties and waterways downstream.
- Velocity of water leaving the site should not exceed 3 feet/second, if the discharge is to a stream or ditch. Install velocity dissipation, such as BMP C207: Check Dams or BMP C202: Riprap Channel Lining to ensure reduction of the flow velocity to a non-erosive level.
- If the discharge from a project site is to a municipal storm drainage system, the allowable discharge rate may be limited by the capacity of the public system. It may be necessary to clean the municipal storm drainage system prior to the start of the discharge to prevent scouring solids from the drainage system. Obtain permission from the owner of the collection system before discharging to it. Ensure that no downstream pipes are surcharged as a result of increased flows from the project site.
- If the discharge from a project site is such that:
    - it would meet the requirements for a "Core Element Exemption" as described in 2.4.6 CE6: Flow Control, or

- it is directed to an infiltration system,

then there is no discharge flow limit.

Suggested BMPs for Element 3

- BMP C203: Water Bars
- BMP C207: Check Dams
- BMP C209: Outlet Protection
- BMP C235: Wattles
- BMP C240: Sediment Trap
- BMP C241: Sediment Pond (Temporary)
- See also 6.13 Detention BMPs

7.2.4 Element 4: Install Sediment Controls

Design, install, and maintain effective erosion controls and sediment controls to minimize the discharge of pollutants. At a minimum:

a. Construct sediment control BMPs (sediment ponds, traps, filters, etc.) as one of the first steps in grading. These BMPs must be functional before other land disturbing activities take place.

b. Minimize sediment discharges from the site. The design, installation and maintenance of erosion and sediment controls must address factors such as the amount, frequency, intensity and duration of precipitation, the nature of resulting stormwater runoff, and soil characteristics, including the range of soil particle sizes expected to be present on the site.

c. Direct stormwater runoff from disturbed areas through BMP C241: Sediment Pond (Temporary) or other appropriate sediment removal BMP, before the runoff leaves a construction site or before discharge to an infiltration facility. Runoff from fully stabilized areas may be discharged without a sediment removal BMP, but must control flow rates per 7.2.3 Element 3: Control Flow Rates.

d. Locate BMPs intended to trap sediment on site in a manner to avoid interference with the movement of juvenile salmonids attempting to enter off-channel areas or drainages.

e. Provide and maintain natural buffers around surface waters, direct stormwater to vegetated areas to increase sediment removal and maximize stormwater infiltration, unless infeasible.

f. Where feasible, design outlet structures that withdraw impounded stormwater from the surface to avoid discharging sediment that is still suspended lower in the water column.

The text in this box originates from one or more of the following Permits:
Appendix 1 of the Phase I / Phase II Municipal Stormwater Permits
Construction Stormwater General Permit

Additional Guidance for Element 4

- Outlet structures that withdraw impounded stormwater from the surface to avoid discharging sediment that is still suspended lower in the water column are for the construction period only. If installing a floating pump structure, include a stopper to prevent the pump basket from hitting the bottom of the pond.
- If a sediment trapping BMP utilizes a control structure that will also be used in a permanent detention BMP application, the control structure construction must be finalized for the permanent BMP application upon project completion.
- Install sediment controls in a manner that protects the sensitive areas and their buffers marked in accordance with 7.2.1 Element 1: Preserve Vegetation / Mark Clearing Limits.
- Seed and mulch earthen structures such as dams, dikes, and diversions according to the timing indicated in 7.2.5 Element 5: Stabilize Soils.
- Full stabilization includes concrete or asphalt paving; quarry spalls used as ditch lining; or the use of rolled erosion products, a bonded fiber matrix product, or vegetative cover in a manner that will fully prevent soil erosion.
- The Local Permitting Authority may inspect and approve areas fully stabilized by means other than pavement or quarry spalls.

Suggested BMPs for Element 4

- BMP C231: Brush Barrier
- BMP C232: Gravel Filter Berm
- BMP C233: Silt Fence
- BMP C234: Vegetated Strip
- BMP C235: Wattles
- BMP C240: Sediment Trap
- BMP C241: Sediment Pond (Temporary)
- BMP C250: Construction Stormwater Chemical Treatment
- BMP C251: Construction Stormwater Filtration

7.2.5 Element 5: Stabilize Soils

a. Stabilize exposed and unworked soils by application of effective BMPs that prevent erosion. Applicable BMPs include, but are not limited to: temporary and permanent seeding, sodding, mulching, plastic covering, erosion control fabrics and matting, soil application of polyacrylamide (PAM), the early application of gravel base on areas to be paved, and dust control.

b. Control stormwater volume and velocity within the site to minimize soil erosion.

c. Control stormwater discharges, including both peak flow rates and total stormwater volume, to minimize erosion at outlets and to minimize downstream channel and stream bank erosion.

d. Soils must not remain exposed and unworked for more than the time periods set forth below to prevent erosion:

- **All of eastern Washington, except for the Central Basin** (Climate Region 2, see 4.3.1 Climate Regions)**:**
  - During the dry season (July 1 - September 30): 10 days
  - During the wet season (October 1 - June 30): 5 days
- **The Central Basin** (Climate Region 2, see 4.3.1 Climate Regions)**:**
  - During the dry season (July 1 - September 30): 30 days
  - During the wet season (October 1 - June 30): 15 days

e. Stabilize soils at the end of the shift before a holiday or weekend if needed based on the weather forecast.

f. Stabilize soil stockpiles from erosion, protect with sediment trapping measures, and where possible, locate away from storm drain inlets, waterways and drainage channels.

g. Minimize the amount of soil exposed during construction activity.

h. Minimize the disturbance of steep slopes.

i. Minimize soil compaction and, unless infeasible, preserve topsoil.

The text in this box originates from one or more of the following Permits:
Appendix 1 of the Phase I / Phase II Municipal Stormwater Permits
Construction Stormwater General Permit

Additional Guidance for Element 5

- Soil stabilization BMPs should be appropriate for the time of year, site conditions, estimated duration of use, and potential water quality impacts that stabilization agents may have on downstream waters or groundwater.

- Ensure that gravel base used for stabilization is clean and does not contain fines or sediment.
- The greatest potential for soil erosion, particularly in the driest parts of eastern Washington, is during summer thunderstorms.

Suggested BMPs for Element 5

- BMP C120: Temporary and Permanent Seeding
- BMP C121: Mulching
- BMP C122: Nets and Blankets
- BMP C123: Plastic Covering
- BMP C124: Sodding
- BMP C125: Topsoiling / Composting
- BMP C126: Polyacrylamide (PAM) for Soil Erosion Protection
- BMP C130: Surface Roughening
- BMP C131: Gradient Terraces
- BMP C140: Dust Control

7.2.6 Element 6: Protect Slopes

a. Design and construct cut-and-fill slopes in a manner to minimize erosion. Applicable practices include, but are not limited to, reducing continuous length of slope with terracing and diversions, reducing slope steepness, and roughening slope surfaces (for example, track walking).

b. Divert off-site stormwater (run-on) or groundwater away from slopes and disturbed areas with interceptor dikes, pipes and/or swales. Off-site stormwater should be managed separately from stormwater generated on site.

c. At the top of slopes, collect drainage in pipe slope drains or protected channels to prevent erosion. Temporary pipe slope drains must be sized to convey the flow rate calculated by the following method:

    - **All of eastern Washington:** The expected peak flow rate from a 6-month, 3-hour storm for the developed condition (referred to as the short-duration storm).

d. Place excavated material on the uphill side of trenches, consistent with safety and space considerations.

e. Place check dams at regular intervals within constructed channels that are cut down a slope.

The text in this box originates from one or more of the following Permits:
Appendix 1 of the Phase I / Phase II Municipal Stormwater Permits
Construction Stormwater General Permit

Additional Guidance for Element 6

- Consider soil type and its potential for erosion.
- Stabilize soils on slopes, as specified in 7.2.5 Element 5: Stabilize Soils.
- BMP combinations are the most effective method of protecting slopes with disturbed soils. For example, use both BMP C121: Mulching and BMP C122: Nets and Blankets in combination.

Suggested BMPs for Element 6

- BMP C120: Temporary and Permanent Seeding
- BMP C121: Mulching
- BMP C122: Nets and Blankets
- BMP C123: Plastic Covering
- BMP C124: Sodding
- BMP C130: Surface Roughening
- BMP C131: Gradient Terraces
- BMP C200: Interceptor Dike and Swale
- BMP C201: Grass-Lined Channels
- BMP C203: Water Bars
- BMP C204: Pipe Slope Drains
- BMP C205: Subsurface Drains
- BMP C206: Level Spreader
- BMP C207: Check Dams
- BMP C208: Triangular Silt Dike (TSD)

7.2.7 Element 7: Protect Storm Drain Inlets

a. Protect all storm drain inlets made operable during construction so that stormwater runoff does not enter the conveyance system without first being filtered or treated to remove sediment.

b. Clean or remove and replace storm drain inlet protection devices when sediment has filled one-third of the available storage (unless a different standard is specified by the product manufacturer).

The text in this box originates from one or more of the following Permits:
Appendix 1 of the Phase I / Phase II Municipal Stormwater Permits
Construction Stormwater General Permit

Additional Guidance for Element 7

- Protect all existing storm drain inlets so that stormwater runoff does not enter the conveyance system without first being filtered or treated to remove sediment.
- Keep all approach roads clean. Do not allow sediment and street wash water to enter storm drains without prior and adequate treatment (as defined above) unless treatment is provided before the storm drain discharges to waters of the State.
- Storm drain inlets should be inspected weekly at a minimum and daily during storm events.

Suggested BMPs for Element 7

- BMP C220: Inlet Protection

7.2.8 Element 8: Stabilize Channels and Outlets

a. Design, construct, and stabilize all on-site conveyance channels to prevent erosion from the flow rate calculated by the following method:

   - **All of eastern Washington:** The expected peak flow rate from a 6-month, 3-hour storm for the developed condition (referred to as the short-duration storm).

b. Provide stabilization, including armoring material, adequate to prevent erosion of outlets, adjacent stream banks, slopes and downstream reaches at the outlets of all conveyance systems.

The text in this box originates from one or more of the following Permits:
Appendix 1 of the Phase I / Phase II Municipal Stormwater Permits
Construction Stormwater General Permit

Additional Guidance for Element 8

The best method for stabilizing channels is to completely line the channel with BMP C122: Nets and Blankets first, then add BMP C207: Check Dams as necessary to function as an anchor and to slow the flow of water.

Suggested BMPs for Element 8

- BMP C122: Nets and Blankets
- BMP C202: Riprap Channel Lining

- BMP C207: Check Dams
- BMP C209: Outlet Protection

7.2.9 Element 9: Control Pollutants

Design, install, implement and maintain effective pollution prevention measures to minimize the discharge of pollutants. The project proponent must:

a. Handle and dispose of all pollutants, including waste materials and demolition debris that occur on site in a manner that does not cause contamination of stormwater.

b. 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. Minimize storage of hazardous materials on-site. Safety Data Sheets (SDS) should be supplied for all materials stored. Chemicals should be kept in their original labeled containers. On-site fueling tanks must include secondary containment. Secondary containment means placing tanks or containers within an impervious structure capable of containing 110% of the volume of the largest tank within the containment structure. Double-walled tanks do not require additional secondary containment.

c. Conduct maintenance, fueling, and repair of heavy equipment and vehicles using spill prevention and control measures. Clean contaminated surfaces immediately following any spill incident.

d. Discharge wheel wash or tire bath wastewater to:

   - a separate on-site treatment system that prevents discharge to surface water, or
   - to the sanitary sewer, with local sewer district approval.

e. Apply fertilizers and pesticides in a manner and at application rates that will not result in loss of chemical to stormwater runoff. Follow manufacturers' label requirements for application rates and procedures.

f. Use BMPs to prevent contamination of stormwater runoff by pH-modifying sources. The sources for this contamination include, but are not limited to: bulk cement, cement kiln dust, fly ash, new concrete washing and curing waters, recycled concrete stockpiles, waste streams generated from concrete grinding and sawing, exposed aggregate processes, dewatering concrete vaults, concrete pumping and mixer washout waters.

g. Adjust the pH of stormwater if necessary to prevent violations of water quality standards.

h. Ensure that washout of concrete trucks is performed off-site or in designated concrete washout areas only. Do not wash out concrete truck drums onto the ground, or into storm drains, open ditches, streets, or streams. Washout of small concrete handling equipment may be disposed of in a formed area awaiting concrete where it will not contaminate surface or groundwater. Do not dump excess concrete on site, except in designated concrete washout areas. Concrete spillage or concrete discharge directly to groundwater or surface waters of the State is prohibited. At no time shall concrete be washed off into the footprint of an area where an infiltration BMP will be installed.

i. Obtain written approval from Ecology before using chemical treatment other than 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 prohibits 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).

The text in this box originates from one or more of the following Permits:
Appendix 1 of the Phase I / Phase II Municipal Stormwater Permits
Construction Stormwater General Permit

Additional Guidance for Element 9

- Wheel wash and/or tire bath wastewater can be combined with wastewater from concrete washout areas if the wastewaters will be properly disposed of at an offsite location or treatment facility.
- Do not use upland land applications for discharging wastewater from concrete washout areas.
- Woody debris may be chopped and spread on site.
- Conduct oil changes, hydraulic system drain down, solvent and degreasing 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 stormwater runoff using spill prevention measures, such as drip pans.
- Clean contaminated surfaces immediately following any discharge or spill incident. Emergency repairs may be performed on-site using temporary plastic placed beneath and, if raining, over the vehicle.

Suggested BMPs for Element 9

- BMP C151: Concrete Handling
- BMP C152: Sawcutting and Surfacing Pollution Prevention
- BMP C153: Material Delivery, Storage, and Containment
- BMP C154: Concrete Washout Area
- BMP C250: Construction Stormwater Chemical Treatment
- BMP C251: Construction Stormwater Filtration

- BMP C252: Treating and Disposing of High pH Water
- Also see the Source Control BMPs detailed in Chapter 8 - Source Control

7.2.10 Element 10: Control Dewatering

a. Discharge foundation, vault, and trench dewatering water, which have similar characteristics to stormwater runoff at the site, into a controlled conveyance system before discharge to:

   i. A sediment control BMP (e.g. BMP C240: Sediment Trap or BMP C241: Sediment Pond (Temporary));

   ii. Infiltration;

   iii. Transport off site in a vehicle, such as a vacuum flush truck, for legal disposal in a manner that does not pollute state waters;

   iv. Ecology-approved on-site chemical treatment or other suitable treatment technologies;

   v. Sanitary or combined sewer discharge with local sewer district approval, if there is no other option; or

   vi. Use of a sedimentation bag that discharges to a ditch or swale for small volumes of localized dewatering.

b. Discharge clean, non-turbid dewatering water, such as well-point groundwater, to systems tributary to, or directly into surface waters of the State, as specified in 7.2.8 Element 8: Stabilize Channels and Outlets, provided the dewatering flow does not cause erosion or flooding of receiving waters. Do not route clean dewatering water through stormwater sediment BMPs. Note that “surface waters of the State” may exist on a construction site as well as off site; for example, a creek running through a site.

c. Handle highly turbid or otherwise contaminated dewatering water separately from stormwater.

The text in this box originates from one or more of the following Permits:
Appendix 1 of the Phase I / Phase II Municipal Stormwater Permits
Construction Stormwater General Permit

Additional Guidance for Element 10

- Channels must be stabilized, as specified in 7.2.8 Element 8: Stabilize Channels and Outlets.
- Construction equipment operation, clamshell digging, concrete tremie pour, or work inside a cofferdam can create highly turbid or contaminated dewatering water.
- Discharging sediment-laden (muddy) water into waters of the State likely constitutes violation of water quality standards for turbidity. The easiest way to avoid discharging

muddy water is through infiltration and preserving vegetation.

- Dewatering water from contaminated sites must be handled separately from stormwater. Direct contaminated stormwater to a sanitary sewer where allowed by the local sewer authority, or to other approved treatment.

Suggested BMPs for Element 10

- BMP C203: Water Bars
- BMP C236: Vegetative Filtration

7.2.11 Element 11: Maintain BMPs

a. Maintain and repair all temporary and permanent erosion and sediment control BMPs as needed to ensure continued performance of their intended function in accordance with BMP specifications.

b. Remove all temporary erosion and sediment control BMPs within 30 days after achieving final site stabilization or after the temporary BMPs are no longer needed.

The text in this box originates from one or more of the following Permits:
Appendix 1 of the Phase I / Phase II Municipal Stormwater Permits
Construction Stormwater General Permit

Additional Guidance for Element 11

- Some temporary erosion and sediment control BMPs are biodegradable and designed to remain in place following construction. BMP C122: Nets and Blankets is an example of a BMP with biodegradable options.
- Provide protection to all BMPs installed for the permanent control of stormwater from sediment and compaction. All BMPs that are to remain in place following completion of construction shall be examined and placed in full operating conditions. If sediment enters the BMPs during construction, it shall be removed and the facility shall be returned to the conditions specified in the construction documents.
- Remove or stabilize trapped sediment on site. Permanently stabilize disturbed soil resulting from removal of BMPs or vegetation.

Suggested BMPs for Element 11

- BMP C150: Materials on Hand
- BMP C160: Certified Erosion and Sediment Control Lead

7.2.12 Element 12: Manage the Project

a. Phase development projects to the maximum degree practicable and take into account seasonal work limitations.

b. Inspect, maintain and repair all BMPs as needed to ensure continued performance of their intended function. Projects regulated under the Construction Stormwater General Permit (CSWGP) must conduct site inspections and monitoring in accordance with Special Condition S4 of the CSWGP.

c. Maintain, update, and implement the Construction SWPPP.

d. Projects that disturb one or more acres must have site inspections conducted by a Certified Erosion and Sediment Control Lead (CESCL). Project sites disturbing less than one acre may have a CESCL or a person without CESCL certification conduct inspections. By the initiation of construction, the Construction SWPPP must identify the CESCL or inspector, who must be present on site or on-call at all times.

The text in this box originates from one or more of the following Permits:
Appendix 1 of the Phase I / Phase II Municipal Stormwater Permits
Construction Stormwater General Permit

Additional Guidance for Element 12

The project manager must ensure that the project is built in such a way to comply with all Construction SWPPP Elements, as detailed in this section. Considerations for the project manager include, but are not limited to:

- construction phasing
- seasonal work limitations
- coordination with utilities and other contractors
- inspection
- monitoring
- maintaining an updated construction SWPPP

Phasing of Construction

Phase development projects where feasible in order to prevent soil erosion and transporting of sediment from the site during construction. Revegetate exposed areas and maintain that vegetation as an integral part of the clearing activities for any phase.

Clearing and grading activities for developments shall be permitted only if conducted using an approved site development plan (e.g., subdivision approval) that establishes permitted areas of clearing, grading, cutting, and filling. Minimize removing trees and disturbing or compacting native soils when establishing permitted clearing and grading areas. Show on the site plans and the development site permitted clearing and grading areas and any other areas required to preserve critical or sensitive areas, buffers, native growth protection easements, or tree retention areas as may be required by local jurisdictions.

Inspection

All BMPs must be inspected, maintained, and repaired as needed to assure continued performance of their intended function. Site inspections must be conducted by a person knowledgeable in the principles and practices of erosion and sediment control. The person must have the skills to 1) assess the site conditions and construction activities that could impact the quality of stormwater, and 2) assess the effectiveness of erosion and sediment control measures used to control the quality of stormwater discharges.

For construction sites one acre or larger, a CESCL must be identified in the construction SWPPP; this person must be on-site or on-call at all times. Certification must be obtained through an approved training program that meets the erosion and sediment control training standards established by Ecology. See BMP C160: Certified Erosion and Sediment Control Lead.

Appropriate BMPs or design changes shall be implemented as soon as possible whenever inspection and/or monitoring reveals that the BMPs identified in the Construction SWPPP are inadequate, due to the actual discharge of /or potential to discharge a significant amount of any pollutant.

The CESCL or inspector must examine stormwater visually for the presence of suspended sediment, turbidity, discoloration, and oil sheen. They must evaluate the effectiveness of BMPs and determine if it is necessary to install, maintain, or repair BMPs to improve the quality of stormwater discharges.

Based on the results of the inspection, construction site operators must correct the problems identified by:

- Reviewing the Construction SWPPP for compliance with the 13 elements and making appropriate revisions within 7 days of the inspection.
- Immediately beginning the process of fully implementing and maintaining appropriate source control and/or treatment BMPs as soon as possible, addressing the problems no later than within 10 days of the inspection. If installation of necessary treatment BMPs is not feasible within 10 days, the construction site operator may request an extension within the initial 10-day response period.
- Documenting BMP implementation and maintenance in the site log book (applies only to sites that have coverage under the Construction Stormwater General Permit).

The CESCL or inspector must inspect all areas disturbed by construction activities, all BMPs, and all stormwater discharge points at least once every calendar week and within 24 hours of any discharge from the site. (For purposes of this condition, individual discharge events that last more than one day do not require daily inspections. For example, if a stormwater pond discharges continuously over the course of a week, only one inspection is required that week.) The CESCL or inspector may reduce the inspection frequency for temporary stabilized, inactive sites to once every calendar month.

Maintaining an Updated Construction SWPPP

Retain the Construction SWPPP on-site. If it is not possible to retain the Construction SWPPP on-site, it must be located within reasonable access to the site.

Modify the Construction SWPPP whenever there is a change in the design, construction, operation, or maintenance at the construction site that has, or could have, a significant effect on the discharge of pollutants to waters of the state.

The Construction SWPPP must be modified if, during inspections or investigations conducted by the owner/operator, or the applicable local or state regulatory authority, it is determined that the Construction SWPPP is ineffective in eliminating or significantly minimizing pollutants in stormwater discharges from the site. Modify the Construction SWPPP as necessary to include additional or modified BMPs designed to correct problems identified. Complete revisions to the Construction SWPPP within 7 days following the inspection.

Suggested BMPs for Element 12

- BMP C150: Materials on Hand
- BMP C160: Certified Erosion and Sediment Control Lead
- BMP C162: Scheduling

7.2.13 Element 13: Protect Infiltration BMPs

The project proponent must protect existing and proposed infiltration BMPs during construction. The primary purpose of On-Site Stormwater Management (often referred to as Low Impact Developmet, or LID) is to reduce the disruption of the natural site hydrology through infiltration. LID BMPs are permanent facilities.

a. Protect all infiltration BMPs from sedimentation through installation and maintenance of erosion and sediment control BMPs on portions of the site that drain into the infiltration BMPs. Restore the BMPs to their fully functioning condition if they accumulate sediment during construction. Restoring the BMP must include removal of sediment and any sediment-laden soils within the BMP, 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.

c. Control erosion and avoid introducing sediment from surrounding land uses onto BMP F6.24: Permeable Pavement. Do not allow muddy construction equipment on the base material or pavement. Do not allow sediment-laden runoff onto permeable pavements.

d. Permeable pavement fouled with sediments or no longer passing an initial infiltration test must be cleaned using procedures in accordance with this manual or the manufacturer's procedures.

e. Keep all heavy equipment off existing soils under infiltration BMPs that have been excavated to final grade to retain the infiltration rate of the soils.

The text in this box originates from one or more of the following Permits:
Appendix 1 of the Phase I / Phase II Municipal Stormwater Permits
Construction Stormwater General Permit

Additional Guidance for Element 13

See Chapter 5: Precision Site Preparation, Construction & Inspection of LID Facilities in the *LID Technical Guidance Manual for Puget Sound* (Hinman and Wulkan, 2012) for more detail on protecting LID integrated management practices.

Note that the *LID Technical Guidance Manual for Puget Sound* (Hinman and Wulkan, 2012) is for additional informational purposes only. You must follow the guidance within this manual if there are any discrepancies between this manual and the *LID Technical Guidance Manual for Puget Sound* (Hinman and Wulkan, 2012).

Suggested BMPs for Element 13

- BMP C102: Buffer Zones
- BMP C103: High-Visibility Fence
- BMP C200: Interceptor Dike and Swale
- BMP C201: Grass-Lined Channels
- BMP C207: Check Dams
- BMP C208: Triangular Silt Dike (TSD)
- BMP C231: Brush Barrier
- BMP C233: Silt Fence
- BMP C234: Vegetated Strip

7.3 Construction Stormwater Pollution Prevention Plans (Construction SWPPPs)

7.3.1 What is a Construction SWPPP?

A Construction Stormwater Pollution Prevention Plan (SWPPP) is a written document (text and drawings) to implement measures to identify, prevent, and control the contamination of stormwater from construction sites. The Construction SWPPP explains and illustrates the measures, usually in the form of best management practices (BMPs), to implement on a construction site to control potential pollution problems.

While it is a good idea to include standards and specifications from the Construction SWPPP in the contract documents, the Construction SWPPP should be a separate document that can stand alone.

As site work progresses, the Construction SWPPP must be reviewed and modified routinely in prescribed time periods to reflect changing site conditions, subject to the rules for plan modification in the Construction Stormwater General Permit and/or the local permitting authority.

7.3.2 When is a Construction SWPPP Required?

A Construction Stormwater Pollution Prevention Plan (SWPPP) is required if one (or more) of the following applies:

- The construction project must have coverage under the Construction Stormwater General Permit (CSWGP). See 1.2.7 Construction Stormwater General Permit.
- The construction project is located in a municipality covered under one of the following Municipal Stormwater Permits and meets the thresholds for requiring a Construction SWPPP in the permit:
    - Phase 1
    - Western Washington Phase II
    - Eastern Washington Phase II
- The local permitting authority requires a Construction SWPPP. Check with your jurisdiction about local requirements related to construction stormwater.
- Ecology and/or the local permitting authority determined the project, site, or facility to be a significant contributor of pollutants to waters of the state.

7.3.3 Who is Responsible for the Construction SWPPP?

The owner or lessee of the land being developed is responsible for preparing the Construction SWPPP and submitting it to local authorities. The owner or lessee may designate someone (e.g. an engineer, architect, contractor, etc.) to prepare the Construction SWPPP, but the owner retains the ultimate responsibility for environmental protection at the site.

An engineer is required when proposed BMPs require design calculations, such as temporary detention ponds or ditch sizing.

The Construction SWPPP narrative must be located on the construction site or within reasonable access to the site for construction and inspection personnel. A copy of the Construction SWPPP drawings must be kept on the construction site at all times.

7.3.4 Preparing Construction SWPPPs

This section presents what you should consider when preparing a Construction SWPPP, as well as what you should include in the Construction SWPPP document. Local permitting authorities may allow small construction projects to prepare a simpler Construction SWPPP, consisting of a checklist and drawings. Designers should check with the local permitting authority about local requirements for Construction SWPPPs.

On construction sites that discharge to surface water, the primary concern in the preparation of the Construction SWPPP is compliance with Washington State Water Quality Standards. On construction sites that infiltrate all stormwater runoff, the primary concern in the preparation of the Construction SWPPP is the protection of the infiltration facilities from fine sediments during the construction phase and protection of groundwater from other pollutants. Several of the other elements are very important at these sites as well, such as marking the clearing limits, establishing the construction access, and managing the project.

Each of the thirteen elements identified in 7.2 13 Elements of Construction Stormwater Pollution Prevention must be considered and included in the Construction SWPPP unless site conditions render the element unnecessary and the exemption from that element is clearly justified in the narrative of the Construction SWPPP.

Ecology has prepared the following tools for your use as you prepare your Construction SWPPP:

- Construction SWPPP Template (available at the following web address):

  https://fortress.wa.gov/ecy/ezshare/wq/permits/CSWGP-SWPPP-Template.docx

  This customizable template presents the recommended structure and content for the Construction SWPPP.

- Construction SWPPP Checklist, available for download within the interactive online version of this manual. The interactive online version of this manual is available at the following web address:

  https://ecology.wa.gov/Regulations-Permits/Guidance-technical-assistance/Stormwater-permittee-guidance-resources/Stormwater-manuals

  This checklist is a quick reference to help determine if all the major items are included in the Construction SWPPP.

Step 1: Research Site Conditions

Consider and research the following site specific factors to understand the site specific construction stormwater pollution prevention needs.

Topography

Consider the topography of the site. The primary topographic considerations are slope steepness and length. Steeper and longer slopes have greater erosion potential than do flat and short slopes. A licensed engineer in the state of Washington, soil professional, or certified erosion control specialist should determine erosion potential.

Drainage

Identify existing drainage patterns including swales, ditches, storm drain pipe systems, etc.

Plan to convey runoff through natural drainage patterns that consist of overland flow, swales, and depressions to avoid constructing an artificial drainage system. Properly stabilize man-made ditches and waterways so they do not create erosion problems. Ensure that increased runoff from the site will not erode or flood the existing natural drainage system. Consider possible sites for temporary stormwater retention and detention.

Direct construction away from areas with saturated soil where you may encounter groundwater and away from critical areas where drainage may concentrate. Preserve natural drainage patterns on the site.

Soils

Identify soil type(s) and erodibility (low, medium, high or an index value) on the site. Evaluate soil properties such as surface and subsurface runoff characteristics, depth to impermeable layer, depth to seasonal groundwater table, permeability, shrink-swell potential, texture, settleability, potential contamination, and erodibility.

Express these qualities in averaged or nominal terms for the site. This information is often available in published literature by qualified soil professionals or engineers. For example, the *1983 Soil Survey of Snohomish County* lists the following information for each soil mapping unit or designation (e.g., a Sultan silt loam):

- A sieve analysis of the soils
- Permeability (in/hr)
- Available water-holding capacity (in/in)
- The percent of organic matter

Soils information can be obtained from a Natural Resource Conservation Service (NRCS) manual (if one has been published for the county containing the site) or the NRCS' Web Soil Survey website at http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm. If a soil survey is not available, make a request to a District NRCS.

Additionally, soil data can be obtained through site soil analysis as a part of preparation of a Stormwater Site Plan (See Chapter 3 - Preparation of Stormwater Site Plans).

Ground Cover

Identify features such as tree clusters, grassy areas, and unique or sensitive vegetation. Unique vegetation may include existing trees above a given diameter. Investigate local requirements regarding tree preservation. Note any existing denuded or exposed soil areas.

Ground cover is the most important factor in terms of preventing erosion. Saving existing vegetation will prevent erosion better than constructing BMPs. Trees and other vegetation protect the soil structure. If you cannot save the existing vegetation, consider such practices as phasing construction, temporary seeding, and mulching. Phasing construction involves stabilizing one part of the site before disturbing another. In this way, the entire site is not disturbed at once.

Critical Areas

Identify critical areas adjacent to or within the site. Critical areas may include flood hazard areas, mine hazard areas, slide hazard areas, sole source aquifers, wetlands, streambanks, fish-bearing streams, and other water bodies. Any critical areas within or adjacent to the site should exert a strong influence on land development decisions. Delineate critical areas and their buffers on the Construction SWPPP drawings and clearly flag critical areas in the field. Chain link fencing may be more useful than flagging to assure that equipment operators stay out of critical areas.

Only unavoidable work should take place within critical areas and their buffers. Such unavoidable work will require special BMPs, permit restrictions, and mitigation plans – documented routinely in the Construction SWPPP.

Adjacent Areas

Identify existing buildings, roads, and facilities adjacent to or within the site. Prepare to identify existing and proposed utility locations, construction clearing limits and erosion and sediment control BMPs on the drawings.

The analysis of adjacent properties should focus on areas both upslope and downslope from the construction project. Water bodies that will receive direct runoff from the site are a major concern. Evaluate the types, values, sensitivities of, and risks to downstream resources such as private property, stormwater facilities, public infrastructure, or aquatic systems.

Existing Encumbrances

Identify wells, existing and abandoned septic drainfields, utilities, easements, setbacks, and site constraints.

Precipitation Records

Determine the average monthly rainfall and rainfall intensity for the required design storm events. These records may be available from the local permitting agency. You may also refer to Chapter 4 - Hydrologic Analysis and Design to help determine rainfall patterns at your site.

Timing of the Project

Consider the timing and duration of the project when selecting BMPs. Projects that will proceed during the wet season and projects that will last through several seasons must take all necessary precautions to remain in compliance with the water quality standards.

Step 2: Prepare the Construction SWPPP

After collecting and analyzing the data described above to determine the site limitations, designers can then develop a Construction SWPPP. Designers must consider the 13 elements described in 7.2 13 Elements of Construction Stormwater Pollution Prevention and include them in the Construction SWPPP; unless site conditions render the element unnecessary and the exemption from that element is clearly justified in the narrative of the SWPPP.

A Construction SWPPP includes a narrative and drawings. The narrative is a written statement to explain and justify the pollution prevention decisions made for a particular project. The narrative contains concise, site specific information about existing conditions, construction schedules, and other pertinent items that are not contained on the drawings. The drawings show, on a site map, the specific BMPs that will be installed. Provide text notes on the drawings to describe the performance standards the BMPs should achieve, and actions to take if the performance goals are not achieved. See the sections below for further information on what to include in the Construction SWPPP narrative and drawings.

Prepare and retain reports summarizing the scope of inspections, the personnel conducting the inspection, the date(s) of the inspection, major observations relating to implementing the Construction SWPPP, and actions taken as a result of these inspections as part of the Construction SWPPP.

Construction SWPPPs can contain BMPs from this manual, or from other guidance documents or manuals that Ecology has approved as providing an equivalent level of pollution prevention. When BMPs from this manual (or other Ecology approved manuals) will not work for a site, experimental management practices and/or minor modifications to standard practices can be considered. However, experimental management practices and/or minor modifications to standard practices must be approved by the plan approval authority of the local jurisdiction before they may be used. All experimental management practices and/or modified standard practices are required to achieve the same or better performance than the BMPs listed in this manual.

If a Construction SWPPP uses an experimental, modified, or approved equivalent BMP, then the SWPPP must contain the following:

1. The technical basis for the selection of the experimental, modified, or approved equivalent BMP (scientific, technical studies, and/or modeling) that support the performance claims for the BMP.
2. An assessment of how the experimental, modified, or approved equivalent BMP will satisfy all known, available, and reasonable methods of prevention, control and treatment (AKART) requirements and the applicable federal technology-based treatment requirements under 40 Code of Federal Regulations (CFR) part 125.3.

Ecology has a list of manufactured BMPs that we consider Functionally Equivalent to BMPs listed in this manual. Designers can access this list of Functionally Equivalent BMPs at:

https://ecology.wa.gov/Regulations-Permits/Guidance-technical-assistance/Stormwater-permittee-guidance-resources/Emerging-stormwater-treatment-technologies

Construction SWPPP Narrative

The author of the Construction SWPPP should evaluate the following subject areas for inclusion in the Construction SWPPP narrative. The subject areas below are not an outline for the Construction SWPPP narrative. Not all items listed below are applicable to all construction projects. The author of the Construction SWPPP should ensure that the applicable sections are addressed.

- General Information on the Existing Site and Project
  - Project description: Describe the nature and purpose of the construction project. Include the total size of the area, any increase in existing impervious area; the total area expected to be disturbed by clearing, grading, excavation or other construction activities, including off-site borrow and fill areas; and the volumes of grading cut and fill that are proposed.
  - Existing site conditions: Describe the existing topography, vegetation, and drainage. Include a description of any structures or development on the parcel including the area of existing impervious surfaces.
  - Adjacent areas: Describe adjacent areas, including streams, lakes, wetlands, residential areas, and roads that the construction project might affect. Describe how upstream drainage areas may affect the site. Provide a description of the upstream drainage leading to the site and the downstream drainage leading from the site to the receiving body of water.
  - Critical areas: Describe areas on or adjacent to the site that are classified as critical areas. Critical areas that receive runoff from the site shall be described up to ¼ mile away. The local permitting authority may increase the distance. Describe special requirements for working near or within these areas.
  - Soil: Describe the soil on the site, giving such information as soil names, mapping unit, erodibility, settleability, permeability, depth, depth to groundwater, texture, and soil structure.
  - Potential erosion problem areas: Describe areas on the site that have potential erosion problems.
- 13 Elements: Describe how the Construction SWPPP addresses each of the 13 required elements (see 7.2 13 Elements of Construction Stormwater Pollution Prevention). Include the type and location of BMPs used to satisfy the required element. Often using a combination of BMPs is the best way to satisfy required elements. If an element is not applicable to a project, provide a written justification for why it is not applicable.
  - If you propose to use a permanent BMP as temporary storage, provide the plan to return the BMP to the designed condition prior to leaving the site.
- Construction Schedule and Phasing: Describe the construction schedule. If the schedule extends into the wet season, describe what activities will continue during the wet season and how the transport of sediment from the construction site to receiving waters will be prevented. Describe the intended sequence and timing of construction activities and any proposed construction phasing.
- Financial/Ownership Responsibilities: Describe ownership and obligations for the project. Include bond forms and other evidence of financial responsibility for environmental liabilities associated with construction.
- Engineering calculations: Attach any calculations made for the design of such items as sediment ponds, diversions, and waterways, as well as calculations for runoff and

stormwater detention design (if applicable). Engineering calculations must bear the signature and stamp of an engineer licensed in the state of Washington.

- Certified Erosion and Sediment Control Lead (CESCL): Identify CESCL(s) along with their contact information and expiration of their CESCL certification.

Construction SWPPP Drawings

The author of the Construction SWPPP should include the following items in the Construction SWPPP drawings. Not all items listed below are applicable to all construction projects. The author of the Construction SWPPP should ensure that the applicable sections are addressed.

- Vicinity map: Provide a vicinity map with enough detail to identify the location of the construction site, adjacent roads, and receiving waters.
- Site map: Provide a site map(s) showing the features listed below. The site map requirements may be met using multiple plan sheets for ease of legibility.
    - A legal description of the property boundaries or an illustration of property lines (including distances) in the drawings.
    - The direction of north in relation to the site.
    - Existing structures and roads, if present.
    - The boundaries of and labels indicating different soil types.
    - Areas of potential erosion problems.
    - Any on-site and adjacent surface waters, critical areas, their buffers, FEMA base flood boundaries, and Shoreline Management boundaries.
    - Existing contours and drainage basins and the direction of flow for the different drainage areas.
    - Final and interim grade contours as appropriate, drainage basins, and the direction of stormwater flow during and upon completion of construction.
    - Construction clearing limits.
    - Areas of soil disturbance, including all areas affected by clearing, grading and excavation.
    - Locations where stormwater discharges to surface waters during and upon completion of construction.
    - Existing unique or valuable vegetation and the vegetation that is to be preserved.
    - Cut and fill slopes indicating top and bottom of slope catch lines.
    - Stockpile, waste storage, and vehicle storage/maintenance areas.
    - Total cut and fill quantities and the method of disposal for excess material.

- Conveyance systems: Show on the site map the following temporary and permanent conveyance features:
    - Locations for temporary and permanent swales, interceptor trenches, or ditches.
    - Drainage pipes, ditches, or cut-off trenches associated with erosion and sediment control and stormwater management.
    - Temporary and permanent pipe inverts and minimum slopes and cover.
    - Grades, dimensions, and direction of flow in all ditches and swales, culverts, and pipes.
    - Details for bypassing off-site runoff around disturbed areas.
    - Locations and outlets of any dewatering systems.
- Location of detention BMPs: Show on the site map the locations of stormwater detention BMPs.
- Erosion and Sediment Control (ESC) BMPs: Show on the site map all major structural and nonstructural ESC BMPs including:
    - The location of sediment pond(s), pipes and structures.
    - Dimension of pond berm widths and inside and outside pond slopes.
    - The trap/pond storage required and the depth, length, and width dimensions.
    - Typical section views through pond and outlet structure.
    - Typical details of gravel cone and standpipe, and/or other filtering devices.
    - Stabilization technique details for inlets and outlets.
    - Control/restrictor device location and details.
    - Stabilization practices for berms, slopes, and disturbed areas.
    - Rock specifications and detail for rock check dam, if used.
    - Spacing for rock check dams as required.
    - Front and side sections of typical rock check dams.
    - The location, detail, and specification for silt fence.
    - The construction entrance location and a detail.
- Detailed drawings: Any structural source control practices used that are not referenced in this manual or other local manuals must be explained and illustrated with detailed drawings.
- Other pollutant BMPs: Indicate on the site map the location of BMPs to be used for the control of pollutants other than sediment such as high or low pH and hydrocarbons.

- Monitoring locations: Indicate on the site map the water quality sampling locations, if required by the local permitting authority or Ecology. Sampling stations must be located in accordance with applicable permit requirements.
- Standard notes are suggested in 7.3.5 Recommended Standard Notes for Construction SWPPP Drawings. Notes addressing construction phasing and scheduling must be included on the drawings.

7.3.5 Recommended Standard Notes for Construction SWPPP Drawings

The following standard notes are suggested for use in Construction SWPPP Drawings (also referred to as erosion/sedimentation control or ESC plans). Local jurisdictions may have other mandatory notes that are applicable. Drawings should also identify, with phone numbers, the person or firm responsible for the preparation of and maintenance of the Construction SWPPP Drawings.

Standard Notes

Approval of this erosion/sedimentation control (ESC) plan does not constitute an approval of permanent road or drainage design (e.g. size and location of roads, pipes, restrictors, channels, retention facilities, utilities).

The implementation of this ESC plan and the construction, maintenance, replacement, and upgrading of these ESC BMPs is the responsibility of the applicant until all construction is completed and approved and vegetation/landscaping is established.

Clearly flag the boundaries of the clearing limits shown on this plan in the field prior to construction. During the construction period, no disturbance beyond the flagged clearing limits shall be permitted. The flagging shall be maintained by the applicant for the duration of construction.

Construct the ESC BMPs shown on this plan in conjunction with all clearing and grading activities, and in such a manner as to ensure that sediment and sediment laden water do not enter the drainage system, roadways, or violate applicable water standards.

The ESC BMPs shown on this plan are the minimum requirements for anticipated site conditions. During the construction period, upgrade these ESC BMPs as needed for unexpected storm events and to ensure that sediment and sediment-laden water do not leave the site.

The applicant shall inspect the ESC BMPs daily and maintain them as necessary to ensure their continued functionality.

Inspect and maintain the ESC BMPs on inactive sites a minimum of once a month or within the 48 hours following a major storm event (i.e. a 24-hr storm event with a 10-yr or greater recurrence interval).

At no time shall the sediment exceed 60-percent of the sump depth or have less than 6-inches of clearance from the sediment surface to the invert of the lowest pipe. All catch basins and conveyance lines shall be cleaned prior to paving. The cleaning operation shall not flush sediment laden water into the downstream system.

Install stabilized construction entrances at the beginning of construction and maintain them for the duration of the project. Additional measures may be required to ensure that all paved areas are kept clean for the duration of the project.

7.4 Construction Stormwater BMPs

7.4.1 A Summary of Construction Stormwater BMPs

This chapter contains standards and specifications for temporary BMPs, used as appropriate during the construction phase of a project. Often using BMPs in combination is the best method to meet Construction Stormwater Pollution Prevention Plan (Construction SWPPP) requirements.

The standards and specifications in this chapter are not intended to limit innovative efforts to effectively control erosion and sedimentation. Construction SWPPPs can contain experimental BMPs or make minor modifications to standard BMPs. However, the permitting authority (state, local, or both) must approve such practices before use. Experimental and modified BMPs must achieve the same or better performance than the BMPs listed below.

None of the BMPs listed below will work successfully throughout the construction project without inspection and maintenance. Regular inspections to identify problems with the operation of each BMP, and the timely repair of any problems are essential to the continued operation of the BMPs. As site conditions change, BMPs must change to remain in compliance.

Construction Stormwater BMPs are divided into two categories: 7.4.2 Construction Source Control BMPs and 7.4.3 Construction Runoff BMPs.

Table 7.1: Construction Stormwater BMPs by SWPPP Element (continued) shows the relationship of the Construction Stormwater BMPs to the Construction SWPPP Elements described in 7.2 13 Elements of Construction Stormwater Pollution Prevention.

For more information: Information on streambank stabilization is available in the *Integrated Streambank Protection Guidelines* (WDFW, 2002).

Table 7.1: Construction Stormwater BMPs by SWPPP Element

Constructio-n Stormwater BMP	Construction SWPPP Element #												
	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12	#13
Construction Source Control BMPs													
BMP C101: Preserving Natural Vegetation	✓												
BMP C102: Buffer Zones	✓												✓

Table 7.1: Construction Stormwater BMPs by SWPPP Element (continued)

Constructio-n Stormwater BMP	Construction SWPPP Element #												
	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12	#13
BMP C103: High-Visibility Fence	✓												✓
BMP C105: Stabilized Construction Access		✓											
BMP C106: Wheel Wash		✓											
BMP C107: Construction Road / Parking Area Stabilization		✓											
BMP C120: Temporary and Permanent Seeding					✓	✓							
BMP C121: Mulching					✓	✓							
BMP C122: Nets and Blankets					✓	✓		✓					
BMP C123: Plastic Covering					✓	✓							
BMP C124: Sodding					✓	✓							
BMP C125: Topsoiling / Composting					✓								
BMP C126: Polyac-rylamide (PAM) for					✓								

Table 7.1: Construction Stormwater BMPs by SWPPP Element (continued)

Constructio-n Stormwater BMP	Construction SWPPP Element #												
	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12	#13
Soil Erosion Protection													
BMP C130: Surface Roughening					✓	✓							
BMP C131: Gradient Terraces					✓	✓							
BMP C140: Dust Control					✓								
BMP C150: Materials on Hand											✓	✓	
BMP C151: Concrete Handling									✓				
BMP C152: Sawcutting and Surfacing Pollution Prevention									✓				
BMP C153: Material Delivery, Storage, and Containment									✓				
BMP C154: Concrete Washout Area									✓				
BMP C160: Certified Erosion and Sediment Control Lead											✓	✓	

Table 7.1: Construction Stormwater BMPs by SWPPP Element (continued)

Construction Stormwater BMP	Construction SWPPP Element #												
	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12	#13
BMP C162: Scheduling												✓	
Construction Runoff BMPs													
BMP C200: Interceptor Dike and Swale						✓							✓
BMP C201: Grass-Lined Channels						✓							✓
BMP C202: Riprap Channel Lining								✓					
BMP C203: Water Bars			✓			✓				✓			
BMP C204: Pipe Slope Drains						✓							
BMP C205: Subsurface Drains						✓							
BMP C206: Level Spreader						✓				✓			
BMP C207: Check Dams			✓			✓		✓					✓
BMP C208: Triangular Silt Dike (TSD)						✓							✓
BMP C209: Outlet Protection			✓					✓					

Table 7.1: Construction Stormwater BMPs by SWPPP Element (continued)

Constructio-n Stormwater BMP	Construction SWPPP Element #												
	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12	#13
BMP C220: Inlet Protection							✓						
BMP C231: Brush Barrier				✓									✓
BMP C232: Gravel Filter Berm				✓									
BMP C233: Silt Fence				✓									✓
BMP C234: Vegetated Strip				✓									✓
BMP C235: Wattles			✓	✓									
BMP C236: Vegetative Filtration										✓			
BMP C240: Sediment Trap			✓	✓									
BMP C241: Sediment Pond (Temporary)			✓	✓									
BMP C250: Construction Stormwater Chemical Treatment				✓					✓				
BMP C251: Construction Stormwater Filtration				✓					✓				
BMP C252:									✓				

Table 7.1: Construction Stormwater BMPs by SWPPP Element (continued)

Constructio-n Stormwater BMP	Construction SWPPP Element #												
	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12	#13
Treating and Disposing of High pH Water													

Construction SWPPP Elements:

7.2.1 Element 1: Preserve Vegetation / Mark Clearing Limits
7.2.2 Element 2: Establish Construction Access
7.2.3 Element 3: Control Flow Rates
7.2.4 Element 4: Install Sediment Controls
7.2.5 Element 5: Stabilize Soils
7.2.6 Element 6: Protect Slopes
7.2.7 Element 7: Protect Storm Drain Inlets
7.2.8 Element 8: Stabilize Channels and Outlets
7.2.9 Element 9: Control Pollutants
7.2.10 Element 10: Control Dewatering
7.2.11 Element 11: Maintain BMPs
7.2.12 Element 12: Manage the Project
7.2.13 Element 13: Protect Infiltration BMPs

7.4.2 Construction Source Control BMPs

BMP C101: Preserving Natural Vegetation

Purpose

The purpose of preserving natural (or existing) vegetation is to reduce erosion wherever practicable. Limiting site disturbance is the single most effective method for reducing erosion. For example, conifers can hold up to about 50% of all rain that falls during a storm. Up to 20% to 30% of this rain may never reach the ground but is taken up by the tree or evaporates. Another benefit is that the rain held in the tree can be released slowly to the ground after the storm.

Conditions of Use

Natural vegetation should be preserved on steep slopes, near perennial and intermittent watercourses or swales, and on building sites in wooded areas.

- As required by the local jurisdiction.
- Phase construction to preserve natural vegetation on the project site for as long as possible during the construction period.

Design and Installation Specifications

Natural vegetation can be preserved in natural clumps or as individual trees, shrubs and vines.

The preservation of individual plants is more difficult because heavy equipment is generally used to remove unwanted vegetation. The points to remember when attempting to save individual plants are:

- Is the plant worth saving? Consider the location, species, size, age, vigor, and the work involved. Local jurisdictions may also have ordinances to save natural vegetation and trees.
- Fence or clearly mark areas around trees that are to be saved. It is preferable to keep ground disturbance away from the trees at least as far out as the dripline.

Plants need protection from three kinds of injuries:

- *Construction Equipment* - This injury can be above or below the ground level. Damage results from scarring, cutting of roots, and compaction of the soil. Placing a fenced buffer zone around plants to be saved prior to construction can prevent construction equipment injuries.
- *Grade Changes* - Changing the natural ground level will alter grades, which affects the plant's ability to obtain the necessary air, water, and minerals. Minor fills usually do not cause problems although sensitivity between species does vary and should be checked. Trees can typically tolerate fill of 6 inches or less. For shrubs and other plants, the fill should be less.

  When there are major changes in grade, it may become necessary to supply air to the roots of plants. This can be done by placing a layer of gravel and a tile system over the roots before the fill is made. The tile system should be laid out on the original grade leading from a drywell around the tree trunk. The system should then be covered with small stones to allow air to circulate over the root area.

  Lowering the natural ground level can seriously damage trees and shrubs. The highest percentage of the plant roots are in the upper 12 inches of the soil and cuts of only 2 to 3 inches can cause serious injury. To protect the roots it may be necessary to terrace the immediate area around the plants to be saved. If roots are exposed, construction of retaining walls may be needed to keep the soil in place. Plants can also be preserved by leaving them on an undisturbed, gently sloping mound. To increase the chances for survival, it is best to limit grade changes and other soil disturbances to areas outside the dripline of the plant.
- *Excavations* - Protect trees and other plants when excavating for drainfields and power, water, and/or sewer lines. Where possible, the trenches should be routed around trees and large shrubs. When this is not possible, it is best to tunnel under them. This can be done with hand tools or with power augers. If it is not possible to route the trench around plants to be saved, then the following should be observed:
  - Cut as few roots as possible. When you have to cut, cut clean. Paint cut root ends with a wood dressing like asphalt base paint if roots will be exposed for more than 24 hours.

    - Backfill the trench as soon as possible.
    - Tunnel beneath root systems as close to the center of the main trunk to preserve most of the important feeder roots.

Some problems that can be encountered are:

- In general, most trees native to eastern Washington do not readily adjust to changes in environment and special care should be taken to protect these trees.
- The danger of windthrow increases where dense stands of coniferous trees have been thinned. Other species (unless they are on shallow, wet soils less than 20 inches deep) have a low windthrow hazard.
- Cottonwoods, maples, and willows have water-seeking roots. These can cause trouble in sewer lines and infiltration fields. On the other hand, they thrive in high moisture conditions that other trees would not.
- Thinning operations in pure or mixed stands of grand fir, Pacific silver fir, noble fir, Sitka spruce, western red cedar, western hemlock, Pacific dogwood, and red alder can cause serious disease problems. Disease can become established through damaged limbs, trunks, roots, and freshly cut stumps. Diseased and weakened trees are also susceptible to insect attack.

Maintenance Standards

Inspect flagged and/or fenced areas regularly to make sure flagging or fencing has not been removed or damaged. If the flagging or fencing has been damaged or visibility reduced, it shall be repaired or replaced immediately and visibility restored.

If tree roots have been exposed or injured, “prune” cleanly with an appropriate pruning saw or loppers directly above the damaged roots and recover with native soils. Treatment of sap flowing trees (e.g. fir, hemlock, pine, soft maples) is not advised as sap forms a natural healing barrier.

BMP C102: Buffer Zones

Purpose

Creation of 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.

Conditions of Use

Buffer zones are used along streams, wetlands and other bodies of water that need protection from erosion and sedimentation. 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 shall remain completely undisturbed. The local permitting authority may expand the buffer widths temporarily to allow the use of the expanded area for removal of sediment.

The types of buffer zones can change the level of protection required as shown below:

- Designated Critical Area Buffers - buffers that protect Critical Areas, as defined by the Washington State Growth Management Act, and are established and managed by the local permitting authority. These should not be disturbed and must protected with sediment control BMPs to prevent impacts. The local permitting authority may expand the buffer widths temporarily to allow the use of the expanded area for removal of sediment.
- Vegetative Buffer Zones - areas that may be identified in undisturbed vegetation areas or managed vegetation areas that are outside any Designated Critical Area Buffer. They may be utilized to provide an additional sediment control area and/or reduce runoff velocities. If being used for preservation of natural vegetation, they should be arranged in clumps or strips. They can be used to protect natural swales and incorporated into the natural landscaping area.

Design and Installation Specifications

- Preserving natural vegetation or plantings in clumps, blocks, or strips is generally the easiest and most successful method.
- Leave all unstable steep slopes in natural vegetation.
- Mark clearing limits and keep all equipment and construction debris out of the natural areas and buffer zones. Steel construction fencing is the most effective method to protect sensitive areas and buffers. Alternatively, wire-backed silt fence on steel posts is marginally effective. Flagging alone is typically not effective.
- Keep all excavations outside the dripline of trees and shrubs.
- Do not push debris or extra soil into the buffer zone area because it will cause damage by burying and smothering vegetation.
- Vegetative buffer zones for streams, lakes or other waterways shall be established by the local permitting authority or other state or federal permits or approvals.

Maintenance Standards

Inspect the area frequently to make sure flagging remains in place and the area remains undisturbed. Replace all damaged flagging immediately. Remove all materials located in the buffer area that may impede the ability of the vegetation to act as a filter.

BMP C103: High-Visibility Fence

Purpose

High-visibility 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 of Use

To establish clearing limits, plastic, fabric, or metal fence may be used:

- At the boundary of sensitive areas, their buffers, and other areas required to be left uncleared.
- As necessary to control vehicle access to and on the site.

Design and Installation Specifications

High-visibility plastic fence shall be composed of a high-density polyethylene (HDPE) material and shall be at least four feet in height. Posts for the fencing shall be steel or wood and placed every 6 feet on center (maximum) or as needed to ensure rigidity. The fencing shall be fastened to the post every six inches with a polyethylene tie. On long continuous lengths of fencing, a tension wire or rope shall be used as a top stringer to prevent sagging between posts. The fence color shall be high-visibility orange. The fence tensile strength shall be 360 lbs/ft using the ASTM D4595 testing method.

If appropriate, install fabric silt fence in accordance with BMP C233: Silt Fence to act as high-visibility fence. Silt fence shall be at least 3 feet high and must be highly visible to meet the requirements of this BMP.

Metal fences shall be designed and installed according to the manufacturer's specifications.

Metal fences shall be at least 3 feet high and must be highly visible.

Fences shall not be wired or stapled to trees.

Maintenance Standards

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

BMP C105: Stabilized Construction Access

Purpose

Stabilized construction accesses are established to reduce the amount of sediment transported onto paved roads outside the project site by vehicles or equipment. This is done by constructing a stabilized pad of quarry spalls at entrances and exits for project sites.

Conditions of Use

Construction accesses shall be stabilized wherever traffic will be entering or leaving a construction site if paved roads or other paved areas are within 1,000 feet of the site.

For residential subdivision construction sites, provide a stabilized construction access for each residence, rather than only at the main subdivision entrance. Stabilized surfaces shall be of sufficient length/width to provide vehicle access/parking, based on lot size and configuration.

On large commercial, highway, and road projects, the designer should include enough extra materials in the contract to allow for additional stabilized accesses not shown in the initial

Construction SWPPP. It is difficult to determine exactly where access to these projects will take place; additional materials will enable the contractor to install them where needed.

Design and Installation Specifications

- See Figure 7.2: Stabilized Construction Access for details. Note: the 100' minimum length of the access shall be reduced to the maximum practicable size when the size or configuration of the site does not allow the full length (100').
- Construct stabilized construction accesses with a 12-inch thick pad of 4-inch to 8-inch quarry spalls, a 4-inch course of asphalt treated base (ATB), or use existing pavement. Do not use crushed concrete, cement, or calcium chloride for construction access stabilization because these products raise pH levels in stormwater and concrete discharge to waters of the State is prohibited.
- A separation geotextile shall be placed under the spalls to prevent fine sediment from pumping up into the rock pad. The geotextile shall meet the standards listed in Table 7.2: Stabilized Construction Access Geotextile Standards.

Table 7.2: Stabilized Construction Access Geotextile Standards

Geotextile Property	Required Value
Grab Tensile Strength (ASTM D4751)	200 psi min.
Grab Tensile Elongation (ASTM D4632)	30% max.
Mullen Burst Strength (ASTM D3786-80a)	400 psi min.
AOS (ASTM D4751)	No. 20 to No. 45 (U.S. standard sieve size)

- Consider early installation of the first lift of asphalt in areas that will be paved; this can be used as a stabilized access. Also consider the installation of excess concrete as a stabilized access. During large concrete pours, excess concrete is often available for this purpose.
- Fencing (see BMP C103: High-Visibility Fence) shall be installed as necessary to restrict traffic to the construction access.
- Whenever possible, the access shall be constructed on a firm, compacted subgrade. This can substantially increase the effectiveness of the pad and reduce the need for maintenance.
- Construction accesses should avoid crossing existing sidewalks and back of walk drains if at all possible. If a construction access must cross a sidewalk or back of walk drain, the full length of the sidewalk and back of walk drain must be covered and protected from sediment leaving the site.

Alternative Material Specification

WSDOT has raised safety concerns about the quarry spall rock specified above. WSDOT observes that the 4-inch to 8-inch rock sizes can become trapped between dually truck tires, and then released off-site at highway speeds. WSDOT has chosen to use a modified specification for the rock while continuously verifying that the stabilized construction access remains effective. To remain effective, the BMP must prevent sediment from migrating off site. To date, there has been no performance testing to verify operation of this new specification. Local jurisdictions may use the alternative specification, but must perform increased off-site inspection if they use, or allow others to use, it.

Stabilized construction accesses may use material that meets the requirements of WSDOT's *Standard Specifications for Road, Bridge, and Municipal Construction* Section 9-03.9(1) (WSDOT, 2016) for ballast except for the following special requirements.

The grading and quality requirements are listed in Table 7.3: Stabilized Construction Access Alternative Material Requirements.

Table 7.3: Stabilized Construction Access Alternative Material Requirements

Sieve Size	Percent Passing
2½″	99 to 100
2″	65 to 100
¾″	40 to 80
No. 4	5 max.
No. 100	0 to 2
% Fracture	75 min.

Notes:

1. All percentages are by weight.
2. The sand equivalent value and dust ratio requirements do not apply.
3. The fracture requirement shall be at least one fractured face and will apply the combined aggregate retained on the No. 4 sieve in accordance with FOP for AASHTO T 335.

Maintenance Standards

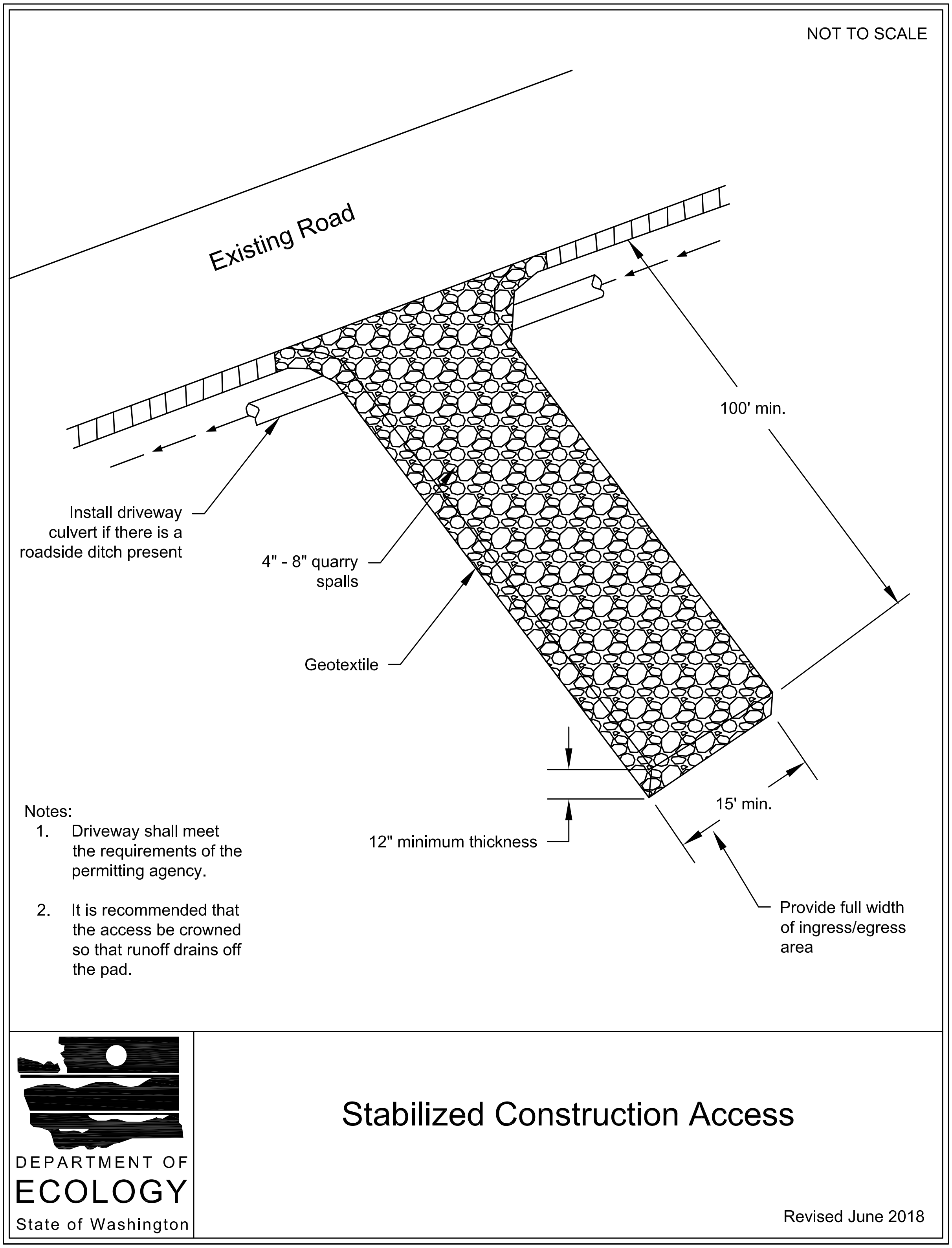
Quarry spalls shall be added if the pad is no longer in accordance with the specifications.

- If the access is not preventing sediment from being tracked onto pavement, then alternative measures to keep the streets free of sediment shall be used. This may include replacement/cleaning of the existing quarry spalls, street sweeping, an increase in the dimensions of the access, or the installation of BMP C106: Wheel Wash.
- Any sediment that is tracked onto pavement shall be removed by shoveling or street sweeping. The sediment collected by sweeping shall be removed or stabilized on site. The

pavement shall not be cleaned by washing down the street, except when sweeping is ineffective and there is a threat to public safety. If it is necessary to wash the streets, the construction of a small sump to contain the wash water shall be considered. The sediment would then be washed into the sump where it can be controlled.

- Perform street sweeping by hand or with a high efficiency sweeper. Do not use a non-high efficiency mechanical sweeper because this creates dust and throws soils into storm systems or conveyance ditches.
- Any quarry spalls that are loosened from the pad, which end up on the roadway shall be removed immediately.
- If vehicles are entering or exiting the site at points other than the construction access(es), BMP C103: High-Visibility Fence shall be installed to control traffic.
- Upon project completion and site stabilization, all construction accesses intended as permanent access for maintenance shall be permanently stabilized.

Figure 7.2: Stabilized Construction Access



Approved as Functionally Equivalent

Ecology has approved products as able to meet the requirements of this BMP. The products did not pass through the Technology Assessment Protocol – Ecology (TAPE) process. Local jurisdictions may choose not to accept these products, or may require additional testing prior to consideration for local use. Products that Ecology has approved as functionally equivalent are available for review on Ecology's website at:

https://ecology.wa.gov/Regulations-Permits/Guidance-technical-assistance/Stormwater-permittee-guidance-resources/Emerging-stormwater-treatment-technologies

BMP C106: Wheel Wash

Purpose

Wheel washes reduce the amount of sediment transported onto paved roads by washing dirt from the wheels of motor vehicles prior to the motor vehicles leaving the construction site.

Conditions of Use

- Use a wheel wash when BMP C105: Stabilized Construction Access is not preventing sediment from being tracked off site.
- Wheel washing is generally an effective BMP when installed with careful attention to topography. For example, a wheel wash can be detrimental if installed at the top of a slope abutting a right-of-way where the water from the dripping truck can run unimpeded into the street.
- Pressure washing combined with an adequately sized and surfaced pad with direct drainage to a large 10-foot x 10-foot sump can be very effective.
- Wheel wash wastewater is not stormwater. It is commonly called process water, and must be discharged to a separate on-site treatment system that prevents discharge to waters of the State, or to the sanitary sewer with local sewer district approval.
- Wheel washes may use closed-loop recirculation systems to conserve water use.
- Wheel wash wastewater shall not include wastewater from concrete washout areas.
- When practical, the wheel wash should be placed in sequence with BMP C105: Stabilized Construction Access. Locate the wheel wash such that vehicles exiting the wheel wash will enter directly onto BMP C105: Stabilized Construction Access. In order to achieve this, BMP C105: Stabilized Construction Access may need to be extended beyond the standard installation to meet the exit of the wheel wash.

Design and Installation Specifications

Suggested details are shown in Figure 7.3: Wheel Wash. The local permitting authority may allow other designs. 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 wheel wash.

Use a low clearance truck to test the wheel 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.

Wheel wash systems should be designed with a small grade change, 6- to 12-inches for a 10-foot-wide pond, to allow sediment to flow to the low side of pond to help prevent re-suspension of sediment. A drainpipe 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. Polyacrylamide (PAM) added to the wheel wash water at a rate of 0.25 to 0.5 pounds per 1,000 gallons of water increases effectiveness and reduces cleanup time. If PAM is already being used for dust or erosion control and is being applied by a water truck, the same truck can be used to change the wash water. PAM use shall be reviewed and approved by the local permitting authority. Discharge of PAM may be a basis for penalties per RCW 90.48.080.

Maintenance Standards

The wheel wash should start out each day with fresh water.

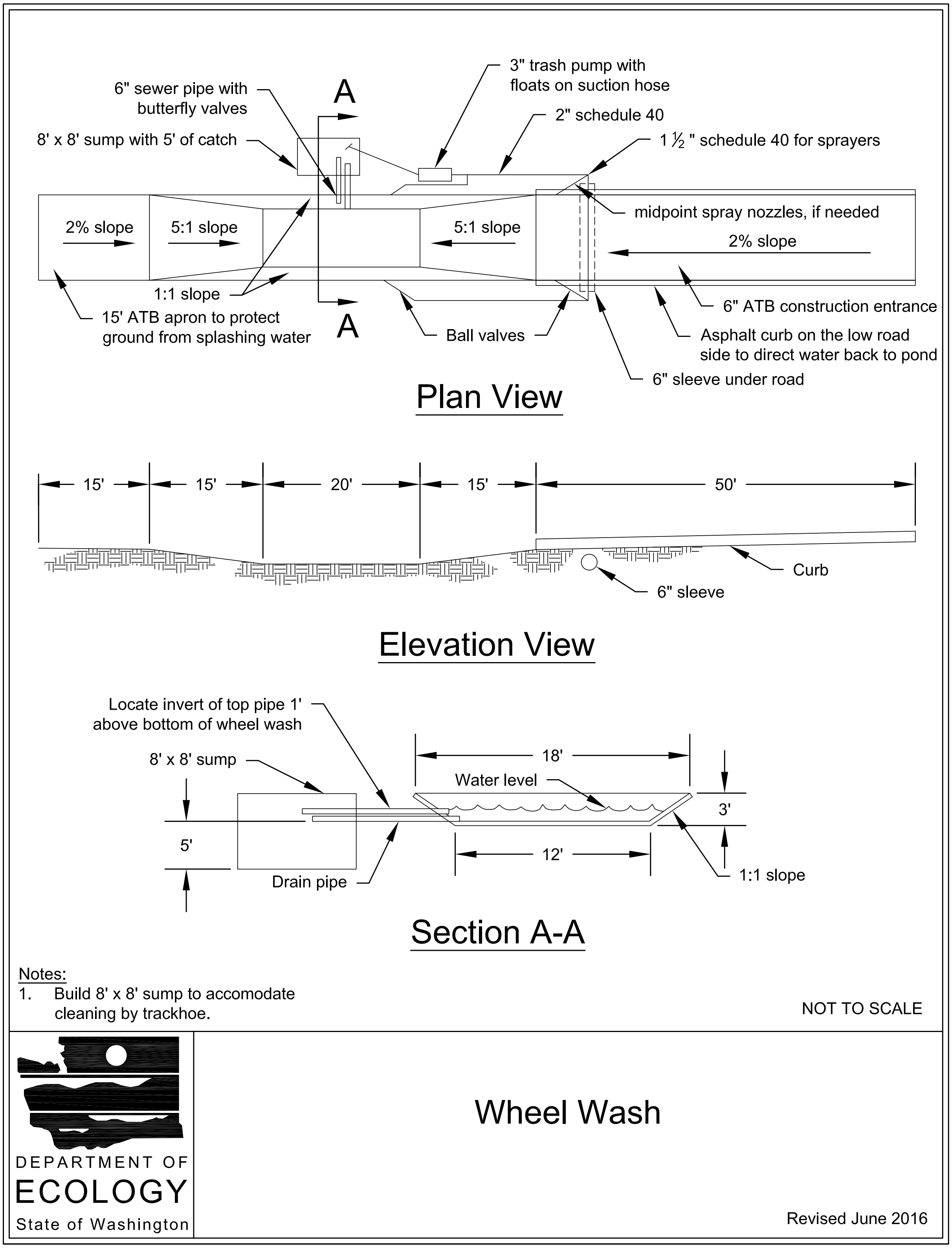
The wheel wash water should be changed a minimum of once per day. On large earthwork jobs where more than 10 to 20 trucks per hour are expected, the wheel wash water will need to be changed more often.

Approved as Functionally Equivalent

Ecology has approved products as able to meet the requirements of this BMP. The products did not pass through the Technology Assessment Protocol – Ecology (TAPE) process. Local jurisdictions may choose not to accept these products, or may require additional testing prior to consideration for local use. Products that Ecology has approved as functionally equivalent are available for review on Ecology's website at:

https://ecology.wa.gov/Regulations-Permits/Guidance-technical-assistance/Stormwater-permittee-guidance-resources/Emerging-stormwater-treatment-technologies

Figure 7.3: Wheel Wash



BMP C107: Construction Road / Parking Area Stabilization

Purpose

Stabilizing roads, parking areas, and other on-site vehicle transportation routes immediately after grading reduces erosion caused by construction traffic or stormwater runoff.

Conditions of Use

Roads and parking areas shall be stabilized wherever they are constructed, whether permanent or temporary, for use by construction traffic.

BMP C103: High-Visibility Fence shall be installed, if necessary, to limit the access of vehicles to only those roads and parking areas that are stabilized.

Design and Installation Specifications

- On areas that will receive asphalt as part of the project, install the first lift as soon as possible.
- A 6-inch depth of 2- to 4-inch crushed rock, gravel base, or crushed surfacing base course shall be applied immediately after grading or utility installation. A 4-inch course of asphalt treated base (ATB) may also be used, or the road/parking area may be paved. It may also be possible to use cement or calcium chloride for soil stabilization. If cement or cement kiln dust is used for road base stabilization, pH monitoring and BMP C252: Treating and Disposing of High pH Water is necessary to evaluate and minimize the effects on stormwater. If the area will not be used for permanent roads, parking areas, or structures, a 6-inch depth of hog fuel may also be used, but this is likely to require more maintenance. Whenever possible, construction roads and parking areas shall be placed on a firm, compacted subgrade.
- Temporary road gradients shall not exceed 15 percent. Roadways shall be carefully graded to drain. Drainage ditches shall be provided on each side of the roadway in the case of a crowned section, or on one side in the case of a super-elevated section. Drainage ditches shall be directed to a sediment control BMP.
- Rather than relying on ditches, it may also be possible to grade the road so that runoff sheet flows into a heavily vegetated area with a well-developed topsoil. Landscaped areas are not adequate. If this area has at least 50 feet of vegetation that water can flow through, then it is generally preferable to use the vegetation to treat runoff, rather than a sediment pond or trap. The 50 feet shall not include wetlands or their buffers. If runoff is allowed to sheet flow through adjacent vegetated areas, it is vital to design the roadways and parking areas so that no concentrated runoff is created.
- Storm drain inlets shall be protected to prevent sediment-laden water entering the drainage system (see BMP C220: Inlet Protection).

Maintenance Standards

Inspect stabilized areas regularly, especially after large storm events.

Crushed rock, gravel base, etc., shall be added as required to maintain a stable driving surface and to stabilize any areas that have eroded.

Following construction, these areas shall be restored to pre-construction condition or better to prevent future erosion.

Perform street cleaning at the end of each day or more often if necessary.

BMP C120: Temporary and Permanent Seeding

Purpose

Seeding reduces erosion by stabilizing exposed soils. A well-established vegetative cover is one of the most effective methods of reducing erosion.

Conditions of Use

- Use seeding throughout the project on disturbed areas that have reached final grade or that will remain unworked for more than 30 days. See 7.2.5 Element 5: Stabilize Soils for specific timelines for stabilizing exposed soils.
- See Table 7.4: Seeding Windows in Eastern Washington (continued) for appropriate seeding windows.
- Review all disturbed areas in late August to early September and complete all seeding by the end of April. Otherwise, vegetation will not establish itself enough to provide more than average protection.
- Mulch is required at all times for seeding because it protects seeds from heat, moisture loss, and transport due to runoff. Mulch can be applied on top of the seed or simultaneously by hydroseeding. See BMP C121: Mulching for specifications.
- Seed and mulch all disturbed areas not otherwise vegetated at final site stabilization. Final stabilization means the completion of all soil disturbing activities at the site and the establishment of a permanent vegetative cover, or equivalent permanent stabilization measures (such as pavement, riprap, gabions, or geotextiles) which will prevent erosion. See BMP F6.61: Post-Construction Soil Quality and Depth.

Table 7.4: Seeding Windows in Eastern Washington

Month	Seeding Recommendations
January	Acceptable seeding window
February	
March	
April	

Table 7.4: Seeding Windows in Eastern Washington (continued)

Month	Seeding Recommendations
May	Seeding permanent species is not recommended unless irrigation is conducted
June	
July	
August	
September	Acceptable seeding window
October	Optimum seeding window
November (First Half)	
November (Second Half)	Acceptable seeding window
December	

Design and Installation Specifications

General

- Install channels intended for vegetation before starting major earthwork and hydroseed with a Bonded Fiber Matrix (BFM). For vegetated channels that will have high flows, install erosion control blankets over the top of hydroseed. Before allowing water to flow in vegetated channels, establish a 50% vegetation cover. If vegetated channels cannot be established by seed before water flow, install sod or prevegetated mats in the channel bottom over top of hydromulch and erosion control blankets.
- Confirm the installation of all required stormwater control measures to prevent seed from washing away.
- Hydroseed applications shall include a minimum of 1,500 pounds per acre (lb/acre) of mulch with 3% tackifier. See BMP C121: Mulching for specifications.
- Areas that will have seeding only, and not landscaping, may need compost or meal-based mulch included in the hydroseed in order to establish vegetation. Re-install native topsoil on the disturbed soil surface before application. See BMP F6.61: Post-Construction Soil Quality and Depth.
- When installing seed via hydroseeding operations, only about 1/3 of the seed actually ends up in contact with the soil surface. This reduces the ability to establish a good stand of grass quickly. To overcome this, consider increasing seed quantities by up to 50 percent.
- Vegetation establishment can be enhanced by one of the following two approaches:
    - Approach 1: Enhance vegetation establishment by dividing the hydromulch operation into two phases:

        - Phase 1 – Install all seed and fertilizer with 25% to 30% mulch and tackifier onto the soil in the first lift.
        - Phase 2 – Install the remaining mulch and tackifier over the first lift.
    - Approach 2: Vegetation can also be enhanced by:
        - Installing the mulch, seed, fertilizer, and tackifier in one lift;
        - Spreading or blowing straw over the top of the hydromulch at a rate of about 800 to 1,000 lb/acre; or
        - Holding straw in place with a standard tackifier.

  Both of these approaches (Approach 1 and Approach 2) will increase cost moderately but will greatly improve and enhance vegetative establishment. The increased cost may be offset by the reduced need for:

    - Irrigation,
    - Reapplication of mulch, and
    - Repair of failed slope surfaces.

  Either of these approaches can use standard hydromulch (1,500 lb/acre minimum) and BFM/mechanically bonded fiber matrix (MBFM) (3,000 lb/acre minimum).

- Seed may be installed by hand if it is:
    - Temporary and covered by straw, mulch, or topsoil; or
    - Permanent in small areas (usually less than 1 acre) and covered with mulch, topsoil, or erosion blankets.
- Consult the local suppliers and/or the local conservation district for their recommendations for appropriate seed mixes and application rates. The appropriate mix depends on a variety of factors, including location, exposure, soil type, slope, and expected foot traffic.
- In addition to meeting erosion control functions and not hindering maintenance operations, selection of long-lived, successional growth native vegetation that can compete against or exclude weeds and grow with minimal maintenance after plant establishment is preferred. Provide diversity to the greatest extent possible and plan for a succession of flowering times to improve pollinator habitat.
- The seed mixes listed in Table 7.5: Temporary and Permanent Seed Mixes for Eastern Washington (continued) include recommended mixes for both temporary and permanent seeding. Alternative seed mixes approved by the local jurisdiction may also be used.

Table 7.5: Temporary and Permanent Seed Mixes for Eastern Washington

Seed Mix (percentages by weight)	Application Rate[1] (lb/acre)	Approx. Number of Seeds per Square Foot
Temporary Erosion Control Seed Mix Use for the temporary stabilization of disturbed areas until permanent vegetation or other long-term erosion control measures can be established. These annual plants will generally not survive more than one growing season.		
Mix "A" • (100%) Winter or spring wheat (I)	80	(not provided)
Mix "B" • (100%) Spring Barley (I)	80	(not provided)
Mix "C" • (100%) Regreen (I)[a] or triticale (I)	50	(not provided)
Mix "D" • (100%) Annual ryegrass (I)	15	(not provided)
Permanent Seed Mixes: Upland Areas with Less Than 12 Inches Precipitation		
Mix "A" • (70%) Crested or Siberian wheatgrass (droughty, coarse soils) (I) • (20%) Indian ricegrass (sandy soil) (N) • (10%) Big bluegrass (N) or needle and thread grass (N)	10	63
Mix "B" • (78%) Bluebunch wheatgrass (N) • (11%) Sheep fescue (I) • (11%) Big bluegrass (N) or needle and thread grass (N)	9	56
Mix "C"	9	64

Table 7.5: Temporary and Permanent Seed Mixes for Eastern Washington (continued)

Seed Mix (percentages by weight)	Application Rate[1] (lb/acre)	Approx. Number of Seeds per Square Foot
• (89%) Thickspike wheatgrass (N) • (11%) Sheep fescue (I)		
Permanent Seed Mixes: Upland Areas with 12 to 15 Inches Precipitation		
Mix "A" • (78%) Thickspike wheatgrass (N) • (22%) Indian ricegrass (sandy or sandy loam soils) (N)	9	53
Mix "B" • (80%) Bluebunch or beardless wheatgrass (N) • (10%) Sheep fescue (I) • (10%) Basin wildrye (N)	10	63
Mix "C" • (64%) Pubescent wheatgrass (I) • (18%) Thickspike wheatgrass (N) • (18%) Sheep fescue (I)	11	49
Permanent Seed Mixes: Upland Areas with 15 to 18 Inches Precipitation		
Mix "A" • (62%) Bluebunch wheatgrass (N) or beardless wheatgrass (N) • (15%) Hard fescue (I) or sheep fescue (I) • (15%) Native legume (N) • (8%) Big bluegrass (N)	13	70
Mix "B"	13	72

Table 7.5: Temporary and Permanent Seed Mixes for Eastern Washington (continued)

Seed Mix (percentages by weight)	Application Rate[1] (lb/acre)	Approx. Number of Seeds per Square Foot
• (62%) Pubescent wheatgrass (I) or intermediate wheatgrass (I) or thickspike wheatgrass (N) • (15%) Hard fescue (I) or sheep fescue (I) • (15%) Native legume (N) • (8%) Big bluegrass (N)		
Permanent Seed Mixes: Upland Areas with 18 to 24 Inches Precipitation		
Mix "A" • (58%) Slender wheatgrass (N) or sodar streambank wheatgrass • (17%) Hard fescue (I) • (17%) Native clover spp. (N) or milkvetch spp. (N) • (8%) Mountain brome (N)	12	64
Mix "B" • (66%) Blue wildrye (N) • (17%) Hard fescue (I) • (17%) Native lupine (N) or northern sweetvetch (N)	12	62
Mix "C" • (66%) Mountain brome (N) • (17%) Hard fescue (I) • (17%) White clover (I) or red clover (I)	12	76
Permanent Seed Mixes: Upland Areas with More Than 24 Inches Precipitation		
Mix "A" • (55%) Blue wildrye (N)	11	72

Table 7.5: Temporary and Permanent Seed Mixes for Eastern Washington (continued)

Seed Mix (percentages by weight)	Application Rate[1] (lb/acre)	Approx. Number of Seeds per Square Foot
• (18%) Mountain brome (N) • (18%) White clover (I) • (9%) Red fescue (I)		
Mix "B" • (33%) Mountain brome (N) • (33%) Slender wheatgrass (N) • (17%) Hard fescue (I) • (17%) Native legume (N)	12	61
Permanent Seed Mixes: Grassed Waterways with Fewer Than 15 Inches Precipitation		
Mix "A" • (78%) Thickspike wheatgrass (N) • (22%) Big bluegrass (N)	9	66
Mix "B" • (83%) Pubescent wheatgrass (I) • (17%) Sheep fescue (I)	12	48
Mix "C" • (78%) Streambank wheatgrass (N) • (22%) Sheep fescue (I)	9	56
Permanent Seed Mixes: Grassed Waterways with 15 to 18 Inches Precipitation		
Mix "A" • (83%) Tall wheatgrass (I) • (17%) Hard fescue (I) or sheep fescue (I)	12	46
Mix "B" • (83%) Pubescent wheatgrass	12	48

Table 7.5: Temporary and Permanent Seed Mixes for Eastern Washington (continued)

Seed Mix (percentages by weight)	Application Rate[1] (lb/acre)	Approx. Number of Seeds per Square Foot
(I), streambank wheatgrass (N), or intermediate wheatgrass (I) • (17%) Hard fescue (I) or sheep fescue (I)		
Mix "C" • (80%) Thickspike wheatgrass (N) • (20%) Hard fescue (I) or sheep fescue (I)	10	57
Permanent Seed Mixes: Grassed Waterways with More Than 18 Inches Precipitation		
Mix "A" • (71%) Intermediate wheatgrass (I) • (29%) Annual ryegrass (I) or perennial ryegrass (I)	14	40
Mix "B" • (83%) Mountain brome (N) or meadow brome • (17%) Hard fescue (I)	12	46
Mix "C" • (100%) Tall wheatgrass (I)	10	38
Permanent Seed Mixes: Stabilization of Ski Slopes and Subalpine Areas		
Mix "A" • (72%) Blue wildrye (N) or Idaho fescue (N) • (14%) Sheep fescue (I) • (14%) Lupine (N)	14	(not provided)
Mix "B" • (47%) Pubescent wheatgrass (I) or red fescue (I) • (29%) Hard fescue (I)	17	(not provided)

Table 7.5: Temporary and Permanent Seed Mixes for Eastern Washington (continued)

Seed Mix (percentages by weight)	Application Rate[1] (lb/acre)	Approx. Number of Seeds per Square Foot
• (12%) Sheep fescue (I) • (12%) White clover (I) or bentgrasses (I)		

Notes:

[a]Sterile wheat x wheatgrass hybrid

(N) = native plant species

(I) = introduced, nonnative plant species

1. For the permanent seed mixes, drilled seeding rates are given in lb/acre. Double the rates if the method of application is broadcast or hydroseed.
2. Consideration should be given to the traffic hazard for wildlife when selecting food species for roadside stabilization.
3. Mixtures are expressed as pure live seed (PLS).

Roughening and Rototilling

- The seedbed should be firm and rough. Roughen all soil no matter what the slope. Track walk slopes before seeding if engineering purposes require compaction. Backblading or smoothing of slopes greater than 4H:1V is not allowed if they are to be seeded.
- Restoration-based landscape practices require deeper incorporation than that provided by a simple, single-pass rototilling treatment. Wherever practical, initially rip the subgrade to improve long-term permeability, infiltration, and water inflow qualities. At a minimum, permanent areas shall receive soil amendments to achieve organic matter and permeability performance defined in engineered soil/landscape systems. For systems that are deeper than 8 inches, complete the rototilling process in multiple lifts, or prepare the soil amendments per the specifications and place to achieve the specified depth.

Fertilizers

- Conducting soil tests to determine the exact type and quantity of fertilizer needed is recommended. This will prevent the overapplication of fertilizer.
- Organic matter is the most appropriate form of fertilizer because it provides nutrients (including nitrogen, phosphorus, and potassium) in the least water-soluble form.

- Always use slow-release fertilizers because they are more efficient and have fewer environmental impacts. Do not add fertilizer to the hydromulch machine, or agitate, more than 20 minutes before use. Too much agitation destroys the slow-release coating.
- There are numerous products available to take the place of chemical fertilizers, including several with seaweed extracts that are beneficial to soil microbes and organisms. If 100% cottonseed meal is used as the mulch in hydroseed, chemical fertilizer may not be necessary. Cottonseed meal provides a good source of long-term, slow-release, available nitrogen.

Bonded Fiber Matrix and Mechanically Bonded Fiber Matrix

- On steep slopes, use Bonded Fiber Matrix (BFM) or Mechanically Bonded Fiber Matrix (MBFM) products. Apply BFM/MBFM products at a minimum rate of 3,000 pounds per acre with approximately 10% tackifier. Achieve a minimum of 95% soil coverage during application. Numerous products are available commercially. Most products require 24-36 hours to cure before rainfall, and cannot be installed on wet or saturated soils. Generally, products come in 40-50 pound bags and include all necessary ingredients except for seed and fertilizer.
- Install products per manufacturer's instructions.
- BFMs and MBFMs provide good alternatives to blankets in most areas requiring vegetation establishment. Advantages over blankets include the following:
    - BFM and MBFMs do not require surface preparation.
    - Helicopters can assist in installing BFM and MBFMs in remote areas.
    - On slopes steeper than 2.5H:1V, blanket installers may require ropes and harnesses for safety.
    - Installing BFM and MBFMs can save at least $1,000 per acre compared to blankets.

Maintenance Standards

- Reseed any seeded areas that fail to establish at least 50% cover (100% cover for areas that receive sheet or concentrated flows) of all seeded areas after 3 months of active growth following germination during the growing season. If reseeding is ineffective, use an alternate method, such as sodding, mulching, or nets/blankets. If winter weather prevents adequate grass growth, this time limit may be relaxed at the discretion of the local authority when sensitive areas would otherwise be protected.
- Reseed and protect by mulch any areas that experience erosion after achieving adequate cover. If the erosion problem is drainage related, the problem shall be fixed and the eroded area reseeded and protected by mulch.
- Supply seeded areas with adequate moisture, but do not water to the extent that it causes runoff.

Approved as Functionally Equivalent

Ecology has approved products as able to meet the requirements of this BMP. The products did not pass through the Technology Assessment Protocol – Ecology (TAPE) process. Local jurisdictions may choose not to accept these products, or may require additional testing prior to consideration for local use. Products that Ecology has approved as functionally equivalent are available for review on Ecology's website at:

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BMP C121: Mulching

Purpose

Mulching soils provides immediate temporary protection from erosion. Mulch also enhances plant establishment by conserving moisture, holding fertilizer, seed, and topsoil in place, and moderating soil temperatures. There are a variety of mulches that can be used. This section discusses only the most common types of mulch.

Conditions of Use

As a temporary cover measure, mulch should be used:

- For less than 30 days on disturbed areas that require cover.
- At all times for seeded areas, especially during the wet season and during the hot summer months.
- During the wet season on slopes steeper than 3H:1V with more than 10 feet of vertical relief.

Mulch may be applied at any time of the year and must be refreshed periodically.

For seeded areas, mulch may be made up of 100 percent:

- Cottonseed meal;
- Fibers made of wood, recycled cellulose, hemp, or kenaf;
- Compost;
- Or blends of these.

Tackifier shall be plant-based, such as guar or alpha plantago, or chemical-based such as polyacrylamide or polymers.

Generally, mulches come in 40-50 pound bags. Seed and fertilizer are added at time of application.

Recycled cellulose may contain polychlorinated biphenyl (PCBs). Ecology recommends that products should be evaluated for PCBs prior to use.

Refer to BMP C126: Polyacrylamide (PAM) for Soil Erosion Protection for conditions of use. PAM shall not be directly applied to water or allowed to enter a water body.

Any mulch or tackifier product used shall be installed per the manufacturer's instructions.

Design and Installation Specifications

For mulch materials, application rates, and specifications, see Table 7.7: Mulch Standards and Guidelines (continued). Consult with the local supplier or the local conservation district for their recommendations. Increase the application rate until the ground is 95% covered (i.e. not visible under the mulch layer). Note: Thickness may be increased for disturbed areas in or near sensitive areas or other areas highly susceptible to erosion.

Where the option of "Compost" is selected, it should be a coarse compost that meets the size gradations listed in Table 7.6: Size Gradations of Compost as Mulch Material when tested in accordance with Test Method 02.02-B found in *Test Methods for the Examination of Composting and Compost* (Thompson, 2001).

Mulch used within the ordinary high-water mark of surface waters should be selected to minimize potential flotation of organic matter. Composted organic materials have higher specific gravities (densities) than straw, wood, or chipped material. Consult the Hydraulic Permit Authority (HPA) for mulch mixes if applicable.

Table 7.6: Size Gradations of Compost as Mulch Material

Sieve Size	Percent Passing
3"	100%
1"	90% - 100%
3/4"	70% - 100%
1/4"	40% - 100%

Table 7.7: Mulch Standards and Guidelines

Mulch Material	Guideline	Description
Straw	Quality Standards	Air-dried; free from undesirable seed and coarse material.
	Application Rates	2" to 3" thick; 5 bales per 1,000 sf or 2 to 3 tons per acre
	Remarks	Cost-effective protection when applied with adequate thickness. Hand-application generally requires greater thickness than blown straw. The thickness of straw may be reduced by half when used in conjunction with seeding. In windy areas, straw must be held in place by crimping, using a tackifier, or covering with netting. Blown straw always has to be held in place with a tackifier because even light winds will blow it away. Straw, however, has several deficiencies that should be considered when selecting mulch

Table 7.7: Mulch Standards and Guidelines (continued)

Mulch Material	Guideline	Description
		materials. It often introduces and/or encourages the propagation of weed species, and it has no significant long-term benefits. Straw should only be used if mulches with long-term benefits are unavailable locally. It should also not be used within the ordinary high-water elevation of surface waters (due to flotation).
Hydromulch	Quality Standards	No growth inhibiting factors.
	Application Rates	Approx. 35-45 lbs per 1,000 sf or 1,500 - 2,000 lbs per acre
	Remarks	Shall be applied with hydromulcher. Shall not be used without seed and tackifier unless the application rate is at least doubled. Fibers longer than about 3/4 - 1 inch clog hydromulch equipment. Fibers should be kept to less than 3/4 inch.
Compost	Quality Standards	No visible water or dust during handling. Must be produced per WAC 173-350, Solid Waste Handling Standards, but may have up to 35% biosolids.
	Application Rates	2" thick minimum; approximately 100 tons per acre (approximately 750 lbs per cubic yard)
	Remarks	More effective control can be obtained by increasing thickness to 3". Compost makes an excellent mulch for protecting final grades until landscaping because it can be directly seeded or tilled into soil as an amendment. Compost used for mulch has a coarser size gradation than compost used for BMP C125: Topsoiling / Composting or BMP F6.61: Post-Construction Soil Quality and Depth. It is more stable and practical to use in wet areas and during rainy weather conditions. Do not use compost near wetlands if biosolids are included. Do not use compost near phosphorous impaired water bodies.
Chipped Site Vegetation	Quality Standards	Gradations from fines to 6 inches in length for texture, variation, and interlocking properties. Include a mix of various sizes so that the average size is between 2 and 4 inches.
	Application Rates	2" thick minimum.
	Remarks	This is a cost-effective way to dispose of debris from clearing and grubbing, and it eliminates the problems associated with burning. Generally, it should not be used on slopes above approximately 10% because of its tendency to be transported by runoff. It is not recommended within 200 feet of surface waters. If permanent seeding or planting is expected shortly after mulch, the decomposition of the chipped vegetation may tie up nutrients important to grass establishment.

Table 7.7: Mulch Standards and Guidelines (continued)

Mulch Material	Guideline	Description
		Note: Thick application of this material over existing grass, herbaceous species, and some groundcovers could smother and kill vegetation.
Wood-Based Mulch	Quality Standards	No visible water or dust during handling. Must be purchased from a supplier with a Solid Waste Handling Permit or one exempt from solid waste regulations.
	Application Rates	2" thick minimum; approximately 100 tons per acre (approximately 750 lbs. per cubic yard).
	Remarks	This material is often called "wood straw" or "hog fuel". The use of mulch ultimately improves the organic matter in the soil. Special caution is advised regarding the source and composition of wood-based mulches. Its preparation typically does not provide any weed seed control, so evidence of residual vegetation in its composition or known inclusion of weed plants or seeds should be monitored and prevented (or minimized).
Wood Strand Mulch	Quality Standards	A blend of loose, long, thin wood pieces derived from native conifer or deciduous trees with high length-to-width ratio.
	Application Rates	2" thick minimum.
	Remarks	Cost-effective protection when applied with adequate thickness. A minimum of 95% of the wood strand shall have lengths between 2 and 10 inches, with a width and thickness between 1/16 and 0.5 inches. The mulch shall not contain resin, tannin, or other compounds in quantities that would be detrimental to plant life. Sawdust or wood shavings shall not be used as mulch. See specification 9-14.4(4) from the *Standard Specifications for Road, Bridge, and Municipal Construction* (WSDOT, 2016)

Maintenance Standards

The thickness of the mulch cover must be maintained.

Any areas that experience erosion shall be remulched and/or protected with a net or blanket. If the erosion problem is drainage related, then the problem shall be fixed and the eroded area remulched.

BMP C122: Nets and Blankets

Purpose

Erosion control nets and blankets are intended to prevent erosion and hold seed and mulch in place on steep slopes and in channels so that vegetation can become well established. In addition, some nets and blankets can be used to permanently reinforce turf to protect drainage systems during high flows.

Nets (commonly called matting) are strands of material woven into an open, but high-tensile strength net (e.g. coconut fiber matting). Blankets are strands of material that are not tightly woven, but instead form a layer of interlocking fibers, typically held together by a biodegradable or photodegradable netting (for example, excelsior or straw blankets). They generally have lower tensile strength than nets, but cover the ground more completely. Coir (coconut fiber) fabric comes as both nets and blankets.

Conditions of Use

Erosion control netting and blankets shall be made of natural plant fibers unaltered by synthetic materials.

Erosion control nets and blankets should be used:

- To aid permanent vegetated stabilization of slopes 2H:1V or greater and with more than 10 feet of vertical relief.
- For drainage ditches and swales (highly recommended). The application of appropriate netting or blanket to drainage ditches and swales can protect bare soil from channelized runoff while vegetation is established. Nets and blankets also can capture a great deal of sediment due to their open, porous structure. Nets and blankets can be used to permanently stabilize channels and may provide a cost-effective, environmentally preferable alternative to riprap.

Disadvantages of nets and blankets include:

- Surface preparation is required.
- On slopes steeper than 2.5H:1V, net and blanket installers may need to be roped and harnessed for safety.
- They cost at least $4,000 - $6,000 per acre installed.

Advantages of nets and blankets include:

- Installation without mobilizing special equipment.
- Installation by anyone with minimal training
- Installation in stages or phases as the project progresses.
- Installers can hand place seed and fertilizer as they progress down the slope.
- Installation in any weather.
- There are numerous types of nets and blankets that can be designed with various parameters in mind. Those parameters include: fiber blend, mesh strength, longevity, biodegradability, cost, and availability.

An alternative to nets and blankets in some limited conditions is BMP C202: Riprap Channel Lining. Ensure that BMP C202: Riprap Channel Lining is appropriate before using it as a substitute for nets and blankets.

Design and Installation Specifications

- See Figure 7.4: Channel Installation (Clackamas County et al., 2008) and Figure 7.5: Slope Installation for typical orientation and installation of nets and blankets used in channels and as slope protection. Note: these are typical only; all nets and blankets must be installed per manufacturer's installation instructions.
- Installation is critical to the effectiveness of these products. If good ground contact is not achieved, runoff can concentrate under the product, resulting in significant erosion.
- Install nets and blankets on slopes per the following steps:
    1. Complete final grade and track walk up and down the slope. Soils should be raked and uniform prior to installing nets or blankets. To be effective, nets and blankets must have good adhesion to the soil.
    2. Install hydromulch with seed and fertilizer.
    3. Dig a small trench, approximately 12 inches wide by 6 inches deep along the top of the slope.
    4. Install the leading edge of the net/blanket into the small trench and staple approximately every 18 inches.

       NOTE: Staples are metal, "U"-shaped, and a minimum of 6 inches long. Longer staples are used in sandy soils. Biodegradable stakes are also available.
    5. Roll the net/blanket slowly down the slope as the installer walks backward.

       NOTE: The net/blanket rests against the installer's legs. Staples are installed as the net/blanket is unrolled. It is critical that the proper staple pattern is used for the net/blanket being installed. The net/blanket is not to be allowed to roll down the slope on its own as this stretches the net/blanket, making it impossible to maintain soil contact. In addition, no one is allowed to walk on the net/blanket after it is in place.
    6. If the net/blanket is not long enough to cover the entire slope length, the trailing edge of the upper net/blanket should overlap the leading edge of the lower net/blanket and be stapled. On steeper slopes, this overlap should be installed in a small trench, stapled, and covered with soil.
- With the variety of products available, it is impossible to cover all the details of appropriate use and installation. Therefore, it is critical that the designer consult the manufacturer's information and that a site visit takes place in order to ensure that the product specified is appropriate. Information is also available in WSDOT's *Standard Specifications for Road, Bridge, and Municipal Construction* Division 8-01 and Division 9-14 (WSDOT, 2016).
- Use jute matting in conjunction with mulch (BMP C121: Mulching). Excelsior, woven straw blankets and coir (coconut fiber) blankets may be installed without mulch. There are many

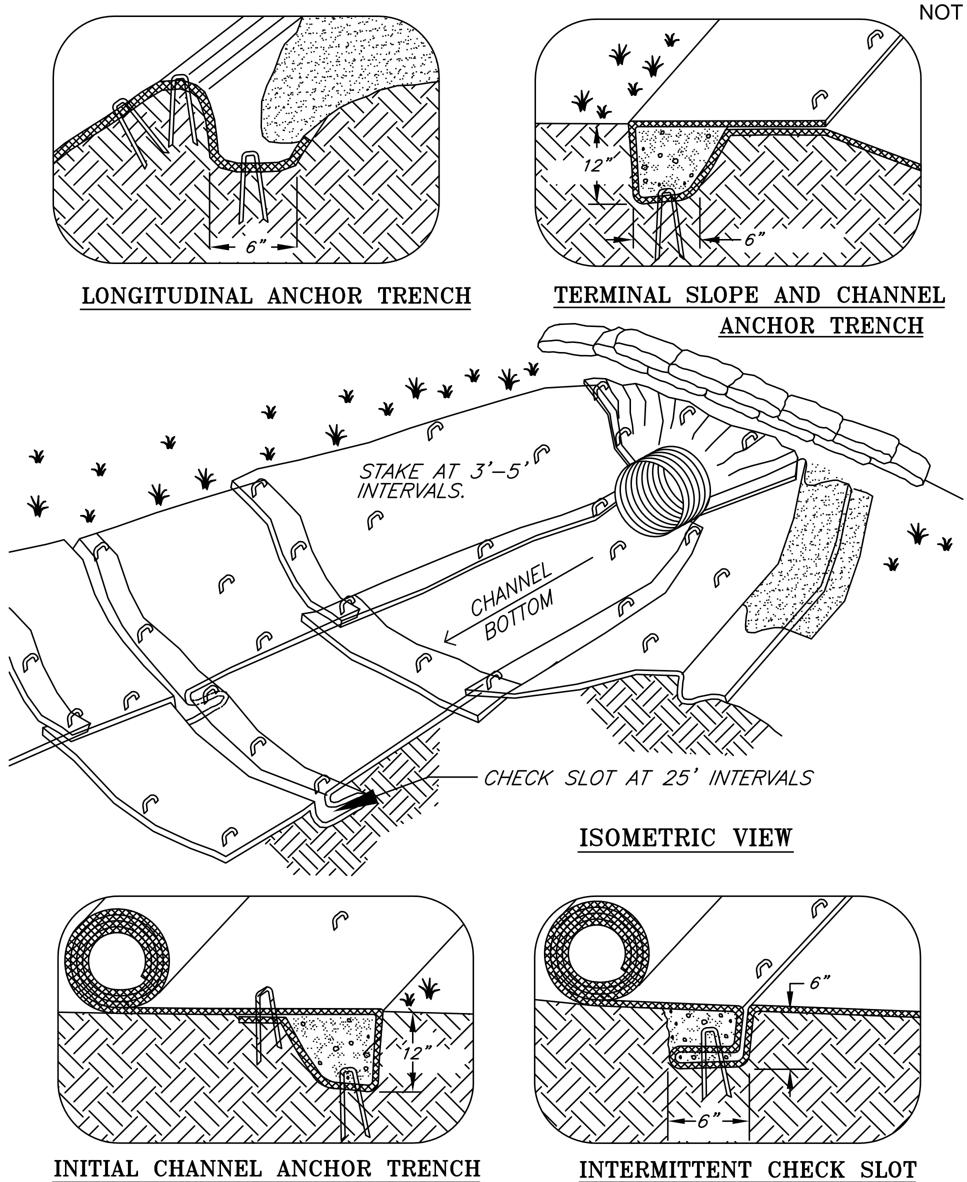
other types of erosion control nets and blankets on the market that may be appropriate in certain circumstances.

- In general, most nets (e.g., jute matting) require mulch in order to prevent erosion because they have a fairly open structure. Blankets typically do not require mulch because they usually provide complete protection of the surface.
- Extremely steep, unstable, wet, or rocky slopes are often appropriate candidates for use of synthetic blankets, as are riverbanks, beaches and other high-energy environments. If synthetic blankets are used, the soil should be hydromulched first.
- 100 percent biodegradable blankets are available for use in sensitive areas. These organic blankets are usually held together with a paper or fiber mesh and stitching which may last up to a year.
- Most netting used with blankets is photodegradable, meaning it breaks down under sunlight (not UV stabilized). However, this process can take months or years even under bright sun. Once vegetation is established, sunlight does not reach the mesh. It is not uncommon to find non-degraded netting still in place several years after installation. This can be a problem if maintenance requires the use of mowers or ditch cleaning equipment. In addition, birds and small animals can become trapped in the netting.

Maintenance Standards

- Maintain good contact with the ground. Erosion must not occur beneath the net or blanket.
- Repair and staple any areas of the net or blanket that are damaged or not in close contact with the ground.
- Fix and protect eroded areas if erosion occurs due to poorly controlled drainage.

Figure 7.4: Channel Installation



Notes:
1. Check slots to be constructed per manufacturers specifications.
2. Staking or stapling layout per manufacturers specifications.

(Clackamas County et al., 2008)

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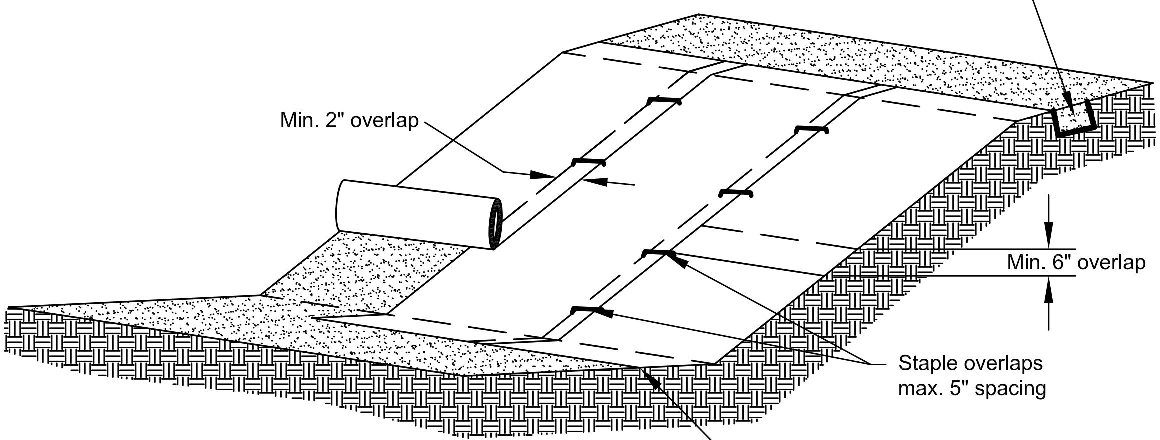
State of Washington

Channel Installation

Revised July 2016

Figure 7.5: Slope Installation



Notes:

1. Slope surface shall be smooth before placement for proper soil contact.
2. Stapling pattern as per manufacturer's recommendations.
3. Do not stretch blankets/mattings tight - allow the rolls to mold to any irregularities.
4. For slopes less than 3H:1V, rolls may be placed in horizontal strips.
5. If there is a berm at the top of the slope, anchor upslope of the berm.
6. Lime, fertilize, and seed before installation. Planting of shrubs, trees, etc. should occur after installation.

NOT TO SCALE

DEPARTMENT OF ECOLOGY State of Washington

Slope Installation

Revised June 2016

BMP C123: Plastic Covering

Purpose

Plastic covering provides immediate, short-term erosion protection to slopes and disturbed areas.

Conditions of Use

Plastic covering may be used on disturbed areas that require cover measures for less than 30 days, except as stated below.

- Plastic is particularly useful for protecting cut and fill slopes and stockpiles. However, the relatively rapid breakdown of most polyethylene sheeting makes it unsuitable for applications greater than six months.
- Due to rapid runoff caused by plastic covering, do not use this method upslope of areas that might be adversely impacted by concentrated runoff. Such areas include steep and/or unstable slopes.
- Plastic sheeting may result in increased runoff volumes and velocities, requiring additional on-site measures to counteract the increases. Creating a trough with wattles or other material can convey clean water away from these areas.
- To prevent undercutting, trench and backfill rolled plastic covering products.
- Although the plastic material is inexpensive to purchase, the cost of installation, maintenance, removal, and disposal add to the total costs of this BMP.
- Whenever plastic is used to protect slopes, install water collection measures at the base of the slope. These measures include plastic-covered berms, channels, and pipes used to convey clean rainwater away from bare soil and disturbed areas. Do not mix clean runoff from a plastic covered slope with dirty runoff from a project.
- Other uses for plastic include:
    - Temporary ditch liner.
    - Pond liner in temporary sediment pond.
    - Liner for bermed temporary fuel storage area if plastic is not reactive to the type of fuel being stored.
    - Emergency slope protection during heavy rains.
    - Temporary drainpipe (“elephant trunk”) used to direct water.

Design and Installation Specifications

- Plastic slope cover must be installed as follows:
    1. Run plastic up and down the slope, not across the slope.
    2. Plastic may be installed perpendicular to a slope if the slope length is less than 10 feet.

3. Provide a minimum of 8-inch overlap at the seams.
4. On long or wide slopes, or slopes subject to wind, tape all seams.
5. Place 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.
6. Place sand filled burlap or geotextile bags every 3 to 6 feet along seams and tie them together with twine to hold them in place.
7. Inspect plastic for rips, tears, and open seams regularly and repair immediately. This prevents high velocity runoff from contacting bare soil, which causes extreme erosion.
8. Sandbags may be lowered into place tied to ropes. However, all sandbags must be staked in place.

- Plastic sheeting shall have a minimum thickness of 6 mil.
- If erosion at the toe of a slope is likely, a gravel berm, riprap, or other suitable protection shall be installed at the toe of the slope in order to reduce the velocity of runoff.

Maintenance Standards

- Torn sheets must be replaced and open seams repaired.
- Completely remove and replace the plastic if it begins to deteriorate due to ultraviolet radiation.
- Completely remove plastic when no longer needed.
- Dispose of old tires used to weight down plastic sheeting appropriately.

Approved as Functionally Equivalent

Ecology has approved products as able to meet the requirements of this BMP. The products did not pass through the Technology Assessment Protocol – Ecology (TAPE) process. Local jurisdictions may choose not to accept these products, or may require additional testing prior to consideration for local use. Products that Ecology has approved as functionally equivalent are available for review on Ecology's website at:

https://ecology.wa.gov/Regulations-Permits/Guidance-technical-assistance/Stormwater-permittee-guidance-resources/Emerging-stormwater-treatment-technologies

BMP C124: Sodding

Purpose

The purpose of sodding is to establish turf for immediate erosion protection and to stabilize drainage paths where concentrated overland flow will occur.

Conditions of Use

Sodding may be used in the following areas:

- Disturbed areas that require short-term or long-term cover.
- Disturbed areas that require immediate vegetative cover.
- All waterways that require vegetative lining. Waterways may also be seeded rather than sodded, and protected with a net or blanket.

Design and Installation Specifications

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

The following steps are recommended for sod installation:

1. Shape and smooth the surface to final grade in accordance with the approved grading plan. Consider any areas (such as swales) that need to be overexcavated below design elevation to allow room for placing soil amendment and sod.
2. Amend 4 inches (minimum) of compost into the top 8 inches of the soil if the organic content of the soil is less than ten percent or the permeability is less than 0.6 inches per hour. See Ecology's Compost web page for further information:

   https://ecology.wa.gov/Waste-Toxics/Reducing-recycling-waste/Organic-materials/Managing-organics-compost
3. Fertilize according to the sod supplier's recommendations.
4. Work lime and fertilizer 1 to 2 inches into the soil, and smooth the surface.
5. Lay strips of sod beginning at the lowest area to be sodded and perpendicular to the direction of water flow. Wedge strips securely into place. Square the ends of each strip to provide for a close, tight fit. Stagger joints at least 12 inches. Staple on slopes steeper than 3H:1V. Staple the upstream edge of each sod strip.
6. Roll the sodded area and irrigate.
7. When sodding is carried out in alternating strips or other patterns, seed the areas between the sod immediately after sodding.

Maintenance Standards

If the grass is unhealthy, the cause shall be determined and appropriate action taken to reestablish a healthy ground cover. If it is impossible to establish a healthy ground cover due to frequent saturation, instability, or some other cause, the sod shall be removed, the area seeded with an appropriate mix, and protected with a net or blanket (BMP C122: Nets and Blankets).

BMP C125: Topsoiling / Composting

Purpose

Topsoiling and composting provide a suitable growth medium for final site stabilization with vegetation. While not a permanent cover practice in itself, topsoiling and composting are an integral component of providing permanent cover in those areas where there is an unsuitable soil surface for plant growth. Use this BMP in conjunction with other BMPs such as BMP C120: Temporary and Permanent Seeding, BMP C121: Mulching, or BMP C124: Sodding.

Implementation of this BMP may meet the post-construction requirements of BMP F6.61: Post-Construction Soil Quality and Depth.

Native soils and disturbed soils that have been organically amended not only retain much more stormwater, but also serve as effective biofilters for urban pollutants and, by supporting more vigorous plant growth, reduce the water, fertilizer, and/or pesticides needed to support installed landscapes. Topsoil does not include any subsoils but only the material from the top several inches including organic debris.

Conditions of Use

- Permanent landscaped areas shall contain healthy topsoil that reduces the need for fertilizers, improves overall topsoil quality, provides for better vegetative health and vitality, improves hydrologic characteristics, and reduces the need for irrigation.
- Leave native soils and the duff layer undisturbed to the maximum extent practicable. Stripping of existing, properly functioning soil system and vegetation for the purpose of topsoiling during construction is not acceptable. Preserve existing soil systems in undisturbed and uncompacted conditions if functioning properly.
- Areas that already have good topsoil, such as undisturbed areas, do not require soil amendments.
- Restore, to the maximum extent practical, native soils disturbed during clearing and grading to a condition equal to or better than the original site condition’s moisture-holding capacity. Use on-site native topsoil, incorporate amendments into on-site soil, or import blended topsoil to meet this requirement.
- Topsoiling is a required procedure when establishing vegetation on shallow soils, and soils of critically low pH (high acid) levels.
- Beware of where the topsoil comes from, and what vegetation was on site before disturbance. Invasive plant seeds may be included and could cause problems for establishing native plants, landscaped areas, or grasses.
- Topsoil from the site will contain mycorrhizal bacteria that are necessary for healthy root growth and nutrient transfer. These native mycorrhizae are acclimated to the site and will provide optimum conditions for establishing grasses. Use commercially available mycorrhizae products when using off-site topsoil.

Design and Installation Specifications

Meet the following requirements for disturbed areas where topsoil will be applied (e.g. for disturbed areas that will be developed as lawn or other landscape):

- Maximize the depth of the topsoil wherever possible to provide the maximum possible infiltration capacity and beneficial growth medium. Topsoil shall have:
  - A minimum depth of 8 inches. Scarify subsoils below the topsoil layer at least 4 inches with some incorporation of the upper material to avoid stratified layers, where

feasible. Ripping or re-structuring the subgrade may also provide additional benefits regarding the overall infiltration and interflow dynamics of the soil system. The decision to either layer topsoil over a subgrade or incorporate topsoil into the underlying layer may vary depending on the planting specified.

  - A minimum organic content of 10% dry weight in planting beds, and 5% organic matter content in turf areas. Incorporate organic amendments to a minimum 8 inch depth except where tree roots or other natural features limit the depth of incorporation.
  - A pH between 6.0 and 8.0 or matching the pH of the undisturbed soil.
  - If blended topsoil is imported, then fines should be limited to 25% passing through a 200 sieve.

- Mulch planting beds with 2 inches of organic material
- Accomplish the required organic content, depth, and pH by returning native topsoil to the site, importing topsoil of sufficient organic content, and/or incorporating organic amendments. When using the option of incorporating amendments to meet the organic content requirement, use compost that meets the compost specification for Bioretention (See BMP F6.23: Bioretention), with the exception that the compost may have up to 35% biosolids or manure.
- The final composition and construction of the soil system will result in a natural selection or favoring of certain plant species over time. For example, incorporation of topsoil may favor grasses, while layering with mildly acidic, high-carbon amendments may favor more woody vegetation.
- Allow sufficient time in scheduling for topsoil spreading prior to seeding, sodding, or planting.
- Take care when applying topsoil to subsoils with contrasting textures. Sandy topsoil over clayey subsoil is a particularly poor combination, as water creeps along the junction between the soil layers and causes the topsoil to slough. If topsoil and subsoil are not properly bonded, water will not infiltrate the soil profile evenly and it will be difficult to establish vegetation. The best method to promote bonding is to actually work the topsoil into the layer below for a depth of at least 6 inches.
- Field exploration of the site shall be made to determine if there is surface soil of sufficient quantity and quality to justify stripping. Topsoil shall be friable and loamy (loam, sandy loam, silt loam, sandy clay loam, and/or clay loam). Avoid areas of natural groundwater recharge.
- Stripping shall be confined to the immediate construction area. A 4 to 6 inch stripping depth is common, but depth may vary depending on the particular soil. All surface runoff control structures shall be in place prior to stripping.
- Do not place topsoil while in a frozen or muddy condition, when the subgrade is excessively wet, or when conditions exist that may otherwise be detrimental to proper grading or proposed sodding or seeding.

- In any areas requiring grading, remove and stockpile the duff layer and topsoil on site in a designated, controlled area, not adjacent to public resources and critical areas. Reapply stockpiled topsoil to other portions of the site where feasible.
- Locate the topsoil stockpile so that it meets specifications and does not interfere with work on the site. It may be possible to locate more than one pile in proximity to areas where topsoil will be used.
- Stockpiling of topsoil shall occur in the following manner:
    - Side slopes of the stockpile shall not exceed 2H:1V.
    - Between October 1 and June 30:
        - An interceptor dike with gravel outlet and silt fence shall surround all topsoil stockpiles.
        - Within 5 days complete erosion control seeding, or covering stockpiles with clear plastic, or other mulching materials.
    - Between July 1 and September 30:
        - An interceptor dike with gravel outlet and silt fence shall surround all topsoil stockpiles if the stockpile will remain in place for a longer period of time than active construction grading.
        - Within 10 days complete erosion control seeding, or covering stockpiles with clear plastic, or other mulching materials.
- When native topsoil is to be stockpiled and reused, the following should apply to ensure that the mycorrhizal bacteria, earthworms, and other beneficial organisms will not be destroyed:
    - Reinstall topsoil within 4 to 6 weeks.
    - Do not allow the saturation of topsoil with water.
    - Do not use plastic covering.

Maintenance Standards

- Inspect stockpiles regularly, especially after large storm events. Stabilize any areas that have eroded.
- Establish soil quality and depth toward the end of construction and once established, protect from compaction, such as from large machinery use, and from erosion.
- Plant and mulch soil after installation.
- Leave plant debris or its equivalent on the soil surface to replenish organic matter.
- Reduce and adjust, where possible, the use of irrigation, fertilizers, herbicides and pesticides, rather than continuing to implement formerly established practices.

BMP C126: Polyacrylamide (PAM) for Soil Erosion Protection

Purpose

Polyacrylamide (PAM) is used on construction sites to prevent soil erosion.

Applying PAM to bare soil in advance of a rain event significantly reduces erosion and controls sediment in two ways. First, PAM increases the soil's available pore volume, thus increasing infiltration and reducing the quantity of stormwater runoff. Second, it increases flocculation of suspended particles and aids in their deposition, thus reducing stormwater runoff turbidity and improving water quality.

Conditions of Use

PAM shall not be directly applied to water or allowed to enter a water body. Stormwater runoff from areas where PAM has been applied shall pass through BMP C240: Sediment Trap or BMP C241: Sediment Pond (Temporary) (depending on the size of the drainage area) prior to discharging to surface waters.

PAM use shall be reviewed and approved by the local jurisdiction.

Loss of sediment and PAM may be a basis for penalties per RCW 90.48.080.

PAM can be applied to bare soil under the following conditions:

- During rough grading operations.
- In staging areas.
- In balanced cut and fill earthwork.
- On haul roads prior to placement of crushed rock surfacing.
- On compacted soil roadbase.
- At stockpiles.
- After final grade and before paving or final seeding and planting.
- At pit sites.
- At sites having a winter shut down. In the case of winter shut down, or where soil will remain unworked for several months, PAM should be used together with mulch.

Design and Installation Specifications

- Do not use PAM on a slope that flows directly into a stream or wetland.
- Do not add PAM to water discharging from the site.
- The total number of sediment control BMPs used shall be maximized to achieve the greatest amount of settlement of sediment prior to discharging from the site. Check dam(s) may be used in a drainage channel to form the sediment trap(s).

- Maximize the use of silt fence to limit the discharge of sediment from the site.
- All areas not being actively worked shall be covered and protected from rainfall. PAM shall not be the only cover BMP used.
- PAM can be applied to wet soil, but dry soil is preferred due to less sediment loss.
- PAM will work when applied to saturated soil, but is not as effective as applications to dry or damp soil.

The Preferred Application Method

PAM may be applied with water in dissolved form, or it may be applied in dry, granular, or powdered form. The preferred application method is with water in dissolved form.

PAM is to be applied at a maximum rate of 2/3 pound PAM per 1,000 gallons water (80 mg/L) per 1 acre of bare soil. See Table 7.8: PAM and Water Application Rates to determine the PAM and water application rate for a disturbed soil area. Higher concentrations of PAM **do not** provide any additional effectiveness.

Table 7.8: PAM and Water Application Rates

Disturbed Area (ac)	PAM (lbs)	Water (gal)
0.50	0.33	500
1.00	0.66	1,000
1.50	1.00	1,500
2.00	1.32	2,000
2.50	1.65	2,500
3.00	2.00	3,000
3.50	2.33	3,500
4.00	2.65	4,000
4.50	3.00	4,500
5.00	3.33	5,000

Follow the steps below to apply PAM using the preferred method:

1. Pre-measure the area where PAM is to be applied and calculate the amount of product and water necessary to provide coverage at the specified application rate (2/3 pound PAM/1000 gallons/acre).
2. PAM has infinite solubility in water, but dissolves very slowly. Dissolve pre-measured dry granular PAM with a known quantity of clean water in a bucket several hours or overnight. Mechanical mixing will help dissolve the PAM. Always add PAM to water - not water to

PAM.

3. Pre-fill the water truck about 1/8 full with water. The water does not have to be potable, but it must have relatively low turbidity (in the range of 20 NTU or less).
4. Add the PAM/water mixture to the truck.
5. Completely fill the water truck to the specified volume.
6. Spray the PAM/water mixture onto dry soil, until the soil surface is uniformly and completely wetted.

An Alternate Application Method

PAM may also be applied as a powder at the rate of 5 lbs per acre. This must be applied on a day that is dry.

For areas less than 10 acres, a hand-held “organ grinder” fertilizer spreader set to the smallest setting will work. For efficiency, tractor-mounted spreaders will work for larger areas.

The following shall be used for application of powdered PAM:

- Powdered PAM shall be used in conjunction with other BMPs and not in place of other BMPs.
- Keep the granular PAM supply out of the sun. Granular PAM loses its effectiveness in three months after exposure to sunlight and air.
- Proper application and re-application plans are necessary to ensure total effectiveness of PAM usage.

Safety and Toxicity

PAM, combined with water, is very slippery and can be a safety hazard. Care must be taken to prevent spills of PAM powder onto paved surfaces. During an application of PAM, prevent over-spray from reaching pavement to avoid the pavement becoming slippery. If PAM powder gets on skin or clothing, wipe it off with a rough towel rather than washing with water. Washing with water will make cleanup messier and take longer.

Some PAMs are more toxic and carcinogenic than others. Only the most environmentally safe PAM products should be used.

The specific PAM copolymer formulation must be anionic. **Cationic PAM shall not be used in any application because of known aquatic toxicity problems.** Use only the highest drinking water grade PAM, certified for compliance with NSF International (NSF)/American National Standards Institute (ANSI) Standard 60 for drinking water treatment, for soil applications. Recent media attention and high interest in PAM has resulted in some entrepreneurial exploitation of the term "polymer." All PAMs are polymers, but not all polymers are PAMs, and not all PAM products comply with ANSI/NSF Standard 60.

- PAM designated for these uses should be "water soluble" or "linear" or "non-crosslinked". Cross-linked or water absorbent PAMs, polymerized in highly acidic (pH<2) conditions, are used to maintain soil moisture content.

- The PAM anionic charge density may vary from 2% to 30%; a value of 18% is typical. Studies conducted by the United States Department of Agriculture (USDA)/ARS demonstrated that soil stabilization was optimized by using very high molecular weight (12-15 mg/mole), highly anionic (>20% hydrolysis) PAM.
- PAM tackifiers are available and being used in place of guar and alpha plantago. Typically, PAM tackifiers should be used at a mixing rate of no more than 0.5 to 1 lb. per 1,000 gallons of water in a hydromulch machine. Some tackifier product instructions say to use at an application rate of 3 to 5 lbs per acre, which can be too much. In addition, pump problems can occur at higher application rates due to increased viscosity.

Maintenance Standards

- PAM may be reapplied on actively worked areas after a 48-hour period.
- Reapplication is not required unless PAM treated soil is disturbed or unless turbidity levels show the need for an additional application. If PAM treated soil is left undisturbed, a reapplication may be necessary after 2 months. More PAM applications may be required for steep slopes, silty and clayey soils (USDA Classification Type "C" and "D" soils), long grades, and high precipitation areas. When PAM is applied first to bare soil and then covered with straw, a reapplication may not be necessary for several months.
- PAM may affect the treatment efficiency of chitosan flocculent systems.

BMP C130: Surface Roughening

Purpose

Surface roughening aids in the establishment of vegetative cover, reduces runoff velocity, increases infiltration, and provides for sediment trapping through the provision of a rough soil surface. Horizontal depressions are created by operating a tiller or other suitable equipment on the contour or by leaving slopes in a roughened condition by not fine grading them.

Use this BMP in conjunction with other BMPs such as BMP C120: Temporary and Permanent Seeding, BMP C121: Mulching, or BMP C124: Sodding.

Conditions for Use

- All slopes steeper than 3H:1V and greater than 5 vertical feet require surface roughening to a depth of 2 to 4 inches prior to seeding.
- Areas that will not be stabilized immediately may be roughened to reduce runoff velocity until seeding takes place.
- Slopes with a stable rock face do not require roughening.
- Slopes where mowing is planned should not be excessively roughened.

Design and Installation Specifications

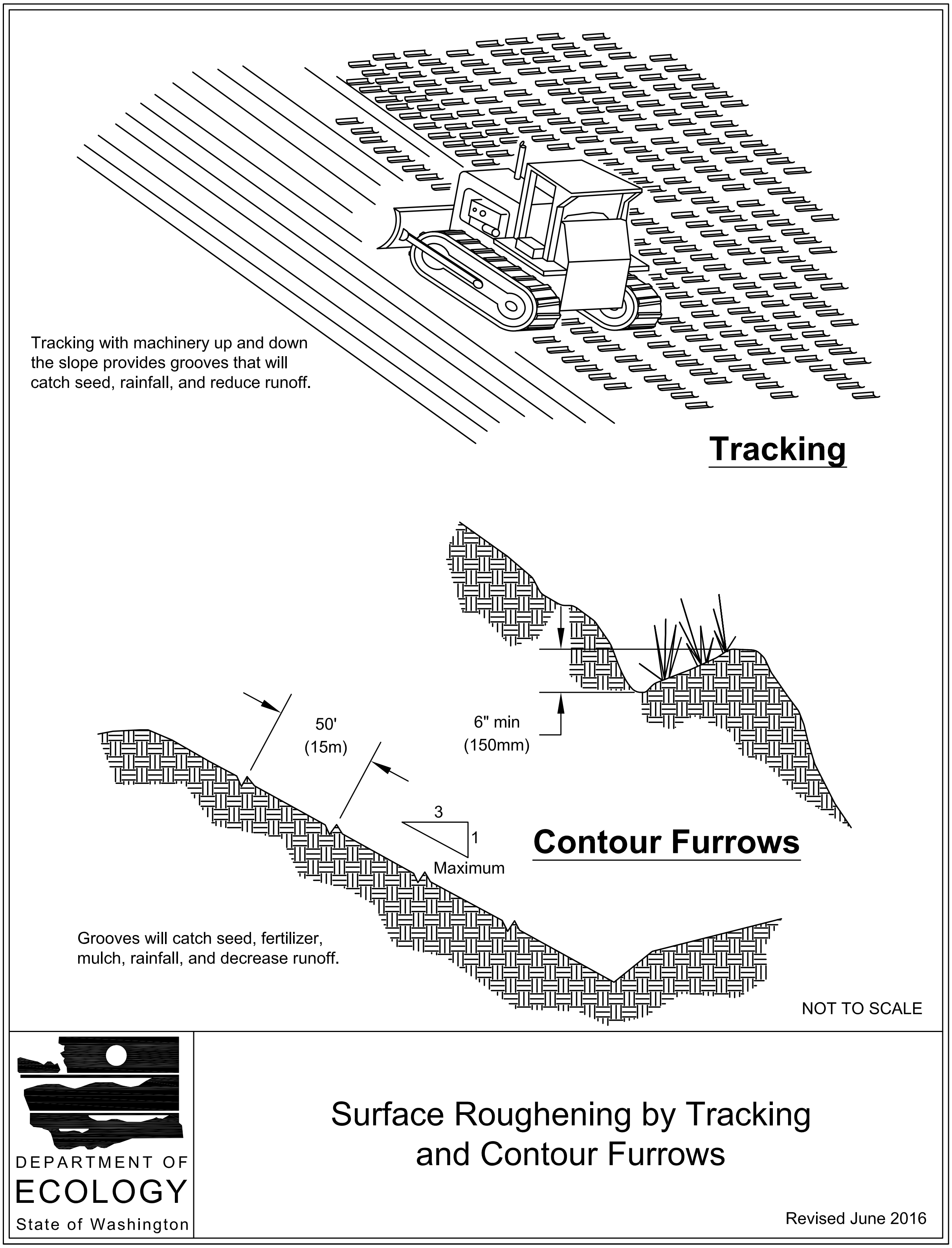
There are different methods for achieving a roughened soil surface on a slope, and the selection of an appropriate method depends on the type of slope. Roughening methods include stair-step grading, grooving, contour furrows, and tracking. See Figure 7.6: Surface Roughening by Tracking and Contour Furrows. Factors to be considered in choosing a roughening method are slope steepness, mowing requirements, and whether the slope is formed by cutting or filling.

- Disturbed areas that will not require mowing may be stair-step graded, grooved, or left rough after filling.
- Stair-step grading is particularly appropriate in soils containing large amounts of soft rock. Each "step" catches material that sloughs from above, and provides a level site where vegetation can become established. Stairs should be wide enough to work with standard earth moving equipment. Stair steps must be on contour or gullies will form on the slope.
- Areas that will be mowed (these areas should have slopes less steep than 3H:1V) may have small furrows left by disking, harrowing, raking, or seed-planting machinery operated on the contour.
- Graded areas with slopes steeper than 3H:1V but less than 2H:1V should be roughened before seeding. This can be accomplished in a variety of ways, including "track walking", or driving a crawler tractor up and down the slope, leaving a pattern of cleat imprints parallel to slope contours.
- Tracking is done by operating equipment up and down the slope to leave horizontal depressions in the soil.

Maintenance Standards

- Areas that are surface roughened should be seeded as quickly as possible.
- Regular inspections should be made of the area. If rills appear, they should be re-roughened and re-seeded immediately.

Figure 7.6: Surface Roughening by Tracking and Contour Furrows



BMP C131: Gradient Terraces

Purpose

Gradient terraces reduce erosion damage by intercepting surface runoff and conveying it to a stable outlet at a non-erosive velocity.

Conditions of Use

Gradient terraces are normally limited to bare land having a water erosion problem. They should not be constructed on deep sands or on soils that are too stony, steep, or shallow to permit practical and economical installation and maintenance. Gradient terraces may only be used where suitable outlets are or will be made available.

Design and Installation Specifications

- The maximum vertical spacing of gradient terraces should be determined by the following method:

  $$VI = (0.8)s + y$$

  Where:

  VI = vertical interval in feet

  s = land rise per 100 feet, expressed in feet

  y = a soil and cover variable with values from 1.0 to 4.0

  Values of “y” are influenced by soil erodibility and cover practices. The lower values are applicable to erosive soils where little to no residue is left on the surface. The higher value is applicable only to erosion-resistant soils where a large amount of residue (1.5 tons of straw per acre equivalent) is on the surface.

- The minimum constructed cross-section should meet the design dimensions.

- The top of the constructed ridge should not be lower at any point than the design elevation plus the specified overfill for settlement. The opening at the outlet end of the terrace should have a cross section equal to that specified for the terrace channel.

- Channel grades may be either uniform or variable with a maximum grade of 0.6 feet per 100 feet length (0.6%). For short distances, terrace grades may be increased to improve alignment. The channel velocity should not exceed that which is nonerosive for the soil type.

- All gradient terraces should have adequate outlets. Such an outlet may be a grassed waterway, vegetated area, or tile outlet. In all cases the outlet must convey runoff from the terrace or terrace system to a point where the outflow will not cause damage. Vegetative cover and energy dissipators should be used in the outlet channel.

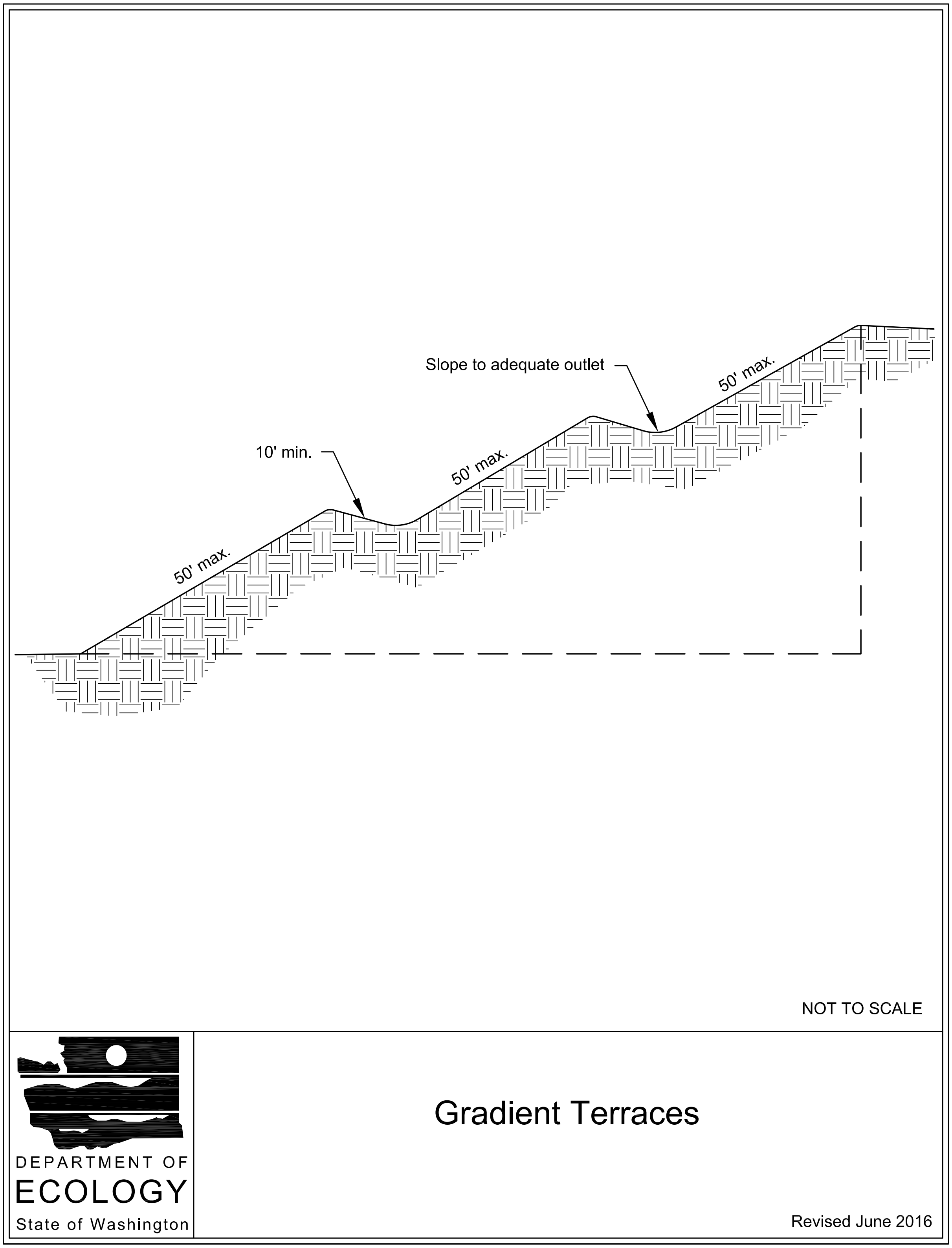
- The design elevation of the water surface of the terrace should not be lower than the design elevation of the water surface in the outlet at their junction, when both are operating at design flow.

- Vertical spacing determined by the above methods may be increased as much as 0.5 feet or 10 percent, whichever is greater, to provide better alignment or location, to avoid obstacles, to adjust for equipment size, or to reach a satisfactory outlet. The contributing drainage area above the terrace should not exceed the area that would be drained by a terrace with normal spacing.
- The terrace should have enough capacity to handle the peak runoff expected from a 2-year, 24-hour design storm without overtopping.
- The terrace cross-section should be proportioned to fit the land slope.
- The ridge height should include a reasonable settlement factor.
- The ridge should have a minimum top width of 3 feet at the design height.
- The minimum cross-sectional area of the terrace channel should be 8 square feet for land slopes of 5 percent or less, 7 square feet for slopes from 5 to 8 percent, and 6 square feet for slopes steeper than 8 percent. The terrace can be constructed wide enough to be maintained using a small vehicle.

Maintenance Standards

Maintenance should be performed as needed. Terraces should be inspected regularly; at least once per year, and after large storm events.

Figure 7.7: Gradient Terraces



BMP C140: Dust Control

Purpose

Dust control prevents wind transport of dust from disturbed soil surfaces onto roadways, into drainage systems, and into surface waters.

Wind erosion is a significant cause of soil movement from construction sites in eastern Washington. Although wind erosion can contribute to water quality impacts, dust control is regulated in some areas of eastern Washington primarily through local air quality authorities. Where such an entity exists, contact the local air quality authority for appropriate and required BMPs for dust control to implement at your project site.

Conditions of Use

Use dust control in areas (including roadways) subject to surface and air movement of dust where on-site or off-site impacts to roadways, drainage systems, or surface waters are likely.

Design and Installation Specifications

- Vegetate or mulch areas that will not receive vehicle traffic. In areas where planting, mulching, or paving is impractical, apply gravel or landscaping rock.
- Limit dust generation by clearing only those areas where immediate activity will take place, leaving the remaining area(s) in the original condition. Maintain the original ground cover as long as practical.
- Construct natural or artificial windbreaks or windscreens. These may be designed as enclosures for small dust sources.
- Sprinkle the site with water until the surface is wet. Repeat as needed. To prevent carryout of mud onto the street, refer to BMP C105: Stabilized Construction Access and BMP C106: Wheel Wash.
- Irrigation water can be used for dust control. Irrigation systems should be installed as a first step on sites where dust control is a concern.
- Spray exposed soil areas with a dust palliative, following the manufacturer's instructions and cautions regarding handling and application. Used oil is prohibited from use as a dust suppressant. Local jurisdictions may approve other dust palliatives such as calcium chloride or PAM.
- PAM (BMP C126: Polyacrylamide (PAM) for Soil Erosion Protection) added to water at a rate of 0.5 pounds per 1,000 gallons of water per acre and applied from a water truck is more effective than water alone. This is due to the increased infiltration of water into the soil and reduced evaporation. In addition, small soil particles are bonded together and are not as easily transported by wind. Adding PAM may reduce the quantity of water needed for dust control.

Note that the application rate specified here applies to this BMP, and is not the same application rate that is specified in BMP C126: Polyacrylamide (PAM) for Soil Erosion Protection, but the downstream protections still apply.

Refer to BMP C126: Polyacrylamide (PAM) for Soil Erosion Protection for conditions of use. PAM shall not be directly applied to water or allowed to enter a water body. PAM use shall be reviewed and approved by the local permitting authority and discharge of PAM may be a basis for penalties per RCW 90.48.080.

- Contact your local Air Pollution Control Authority for guidance and training on other dust control measures. Compliance with the local Air Pollution Control Authority constitutes compliance with this BMP. See the following website for more information:

  https://ecology.wa.gov/About-us/Our-role-in-the-community/Partnerships-committees/Clean-air-agencies

- Use vacuum street sweepers.
- Remove mud and other dirt promptly so it does not dry and then turn into dust.
- Techniques that can be used for unpaved roads and lots include:
  - Lower speed limits. High vehicle speed increases the amount of dust stirred up from unpaved roads and lots.
  - Upgrade the road surface strength by improving particle size, shape, and mineral types that make up the surface and base materials.
  - Add surface gravel to reduce the source of dust emission. Limit the amount of fine particles (those smaller than .075 mm) to 10 to 20 percent.
  - Use geotextile fabrics to increase the strength of new roads or roads undergoing reconstruction.
  - Encourage the use of alternate, paved routes, if available.
  - Apply chemical dust suppressants using the admix method, blending the product with the top few inches of surface material. Suppressants may also be applied as surface treatments.
  - Limit dust-generating work on windy days.
  - Pave unpaved permanent roads and other trafficked areas.

Maintenance Standards

Respray area as necessary to keep dust to a minimum.

BMP C150: Materials on Hand

Purpose

Keep quantities of erosion prevention and sediment control materials on the project site at all times to be used for regular maintenance and emergency situations such as unexpected heavy rains. Having these materials on-site reduces the time needed to replace existing or implement new BMPs when inspections indicate that existing BMPs are not meeting the Construction SWPPP requirements. In addition, contractors can save money by buying some materials in bulk and storing them at their office or yard.

Conditions of Use

- Construction projects of any size or type can benefit from having materials on hand. A small commercial development project could have a roll of plastic and some gravel available for immediate protection of bare soil and temporary berm construction. A large earthwork project, such as highway construction, might have several tons of straw, several rolls of plastic, flexible pipe, sandbags, geotextile fabric and steel “T” posts.
- Materials should be stockpiled and readily available before any site clearing, grubbing, or earthwork begins. A large contractor or project proponent could keep a stockpile of materials that are available for use on several projects.
- If storage space at the project site is at a premium, the contractor could maintain the materials at their office or yard. The office or yard must be less than an hour from the project site.

Design and Installation Specifications

Depending on project type, size, complexity, and length, materials and quantities will vary. A good minimum list of items that will cover numerous situations includes:

- Clear plastic, 6 mil
- Drainpipe, 6 or 8 inch diameter
- Sandbags, filled
- Straw bales for mulching
- Quarry spalls
- Washed gravel
- Geotextile fabric
- Catch basin inserts
- Steel "T" posts
- Silt fence material
- Straw wattles

Maintenance Standards

- All materials with the exception of the quarry spalls, steel "T" posts, and gravel should be kept covered and out of both sun and rain.
- Re-stock materials as needed.

BMP C151: Concrete Handling

Purpose

Concrete work can generate process water and slurry that contain fine particles and high pH, both of which can violate water quality standards in the receiving water. Concrete spillage or concrete discharge to waters of the State is prohibited. Use this BMP to minimize and eliminate concrete, concrete process water, and concrete slurry from entering waters of the State.

Conditions of Use

Any time concrete is used, utilize these management practices. Concrete construction project components include, but are not limited to:

- Curbs
- Sidewalks
- Roads
- Bridges
- Foundations
- Floors
- Runways

Disposal options for concrete, in order of preference are:

1. Off-site disposal
2. Concrete wash-out areas (see BMP C154: Concrete Washout Area)
3. De minimus washout to formed areas awaiting concrete

Design and Installation Specifications

- Wash concrete truck drums at an approved off-site location or in designated concrete washout areas only. Do not wash out concrete trucks onto the ground (including formed areas awaiting concrete), or into storm drains, open ditches, streets, or streams. Refer to BMP C154: Concrete Washout Area for information on concrete washout areas.
  - Return unused concrete remaining in the truck and pump to the originating batch plant for recycling. Do not dump excess concrete on site, except in designated concrete washout areas as allowed in BMP C154: Concrete Washout Area.

- Wash small concrete handling equipment (e.g. hand tools, screeds, shovels, rakes, floats, trowels, and wheelbarrows) into designated concrete washout areas or into formed areas awaiting concrete pour.
- At no time shall concrete be washed off into the footprint of an area where an infiltration feature will be installed.
- Wash equipment difficult to move, such as concrete paving machines, in areas that do not directly drain to natural or constructed stormwater conveyance or potential infiltration areas.
- Do not allow washwater from areas, such as concrete aggregate driveways, to drain directly (without detention or treatment) to natural or constructed stormwater conveyances.
- Contain washwater and leftover product in a lined container when no designated concrete washout areas (or formed areas, allowed as described above) are available. Dispose of contained concrete and concrete washwater (process water) properly.
- Always use forms or solid barriers for concrete pours, such as pilings, within 15-feet of surface waters.
- Refer to BMP C252: Treating and Disposing of High pH Water for pH adjustment requirements.
- Refer to the Construction Stormwater General Permit (CSWGP) for pH monitoring requirements if the project involves one of the following activities:
    - Significant concrete work (as defined in the CSWGP).
    - The use of soils amended with (but not limited to) Portland cement-treated base, cement kiln dust or fly ash.
    - Discharging stormwater to segments of water bodies on the 303(d) list (Category 5) for high pH.

Maintenance Standards

Check containers for holes in the liner daily during concrete pours and repair the same day.

BMP C152: Sawcutting and Surfacing Pollution Prevention

Purpose

Sawcutting and surfacing operations generate slurry and process water that contain fine particles and have a high pH (concrete cutting), both of which can violate the water quality standards in the receiving water. Concrete spillage or concrete discharge to waters of the State is prohibited. Use this BMP to minimize and eliminate process water and slurry created by sawcutting or surfacing from entering waters of the State.

Conditions of Use

Utilize these management practices anytime sawcutting or surfacing operations take place. Sawcutting and surfacing operations include, but are not limited to:

- Sawing
- Coring
- Grinding
- Roughening
- Hydro-demolition
- Bridge and road surfacing

Design and Installation Specifications

- Vacuum slurry and cuttings during cutting and surfacing operations.
- Slurry and cuttings shall not remain on permanent concrete or asphalt pavement overnight.
- Slurry and cuttings shall not drain to any natural or constructed drainage conveyance including stormwater systems. This may require temporarily blocking catch basins.
- Dispose of collected slurry and cuttings in a manner that does not violate groundwater or surface water quality standards.
- 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.
- 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.

Maintenance Standards

Continually monitor operations to determine whether slurry, cuttings, or process water could enter waters of the state. 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/or vacuum trucks.

BMP C153: Material Delivery, Storage, and Containment

Purpose

Prevent, reduce, or eliminate the discharge of pollutants to the stormwater system or watercourses from material delivery and storage. Minimize the storage of hazardous materials on-site, store materials in a designated area, and install secondary containment.

Conditions of Use

Use at construction 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

Design and Installation Specifications

- The temporary storage area should be located away from vehicular traffic, near the construction entrance(s), and away from waterways or storm drains.
- Safety Data Sheets (SDS) should be supplied for all materials stored. Chemicals should be kept in their original labeled containers.
- Hazardous material storage on-site should be minimized.
- Hazardous materials should be handled as infrequently as possible.
- During the wet weather season (October 1 – June 30), consider storing materials in a covered area.
- Materials should be stored in secondary containments, such as an earthen dike, horse trough, 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 "bus boy" trays or concrete mixing trays.
- Do not store chemicals, drums, or bagged materials directly on the ground. Place these items on a pallet and, when possible, within 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.
- Liquids, petroleum products, and substances listed in 40 CFR Parts 110, 117, or 302 shall be stored in approved containers and drums and shall not be overfilled. Containers and drums shall be stored in temporary secondary containment facilities.
- Temporary secondary containment facilities shall provide for a spill containment volume able to contain 10% of the total enclosed container volume of all containers, or 110% of the capacity of the largest container within its boundary, whichever is greater.
- Secondary containment facilities shall be impervious to the materials stored therein for a minimum contact time of 72 hours.

- Sufficient separation should be provided between stored containers to allow for spill cleanup and emergency response access.
- During the wet weather season (Oct 1 – June 30), each secondary containment facility shall be covered during non-working days.
- Secondary containment facilities shall be covered at all times, except when in active use.
- Keep material storage areas clean, organized, and equipped with an ample supply of appropriate spill clean-up material (spill kit).
- The spill kit should include, at a minimum:
  - 1 - Water resistant nylon bag
  - 3 - Oil absorbent socks 3”x 4’
  - 2 - Oil absorbent socks 3”x 10’
  - 12 - Oil absorbent pads 17”x19”
  - 1 - Pair splash resistant goggles
  - 3 - Pairs nitrile gloves
  - 10 - Disposable bags with ties
  - Instructions

Maintenance Standards

- Secondary containment facilities shall be maintained free of accumulated rainwater and spills. In the event of spills or leaks, accumulated rainwater and spills shall be collected and placed into drums. These liquids shall be handled as hazardous waste unless testing determines them to be non-hazardous.
- Re-stock spill kit materials as needed.

BMP C154: Concrete Washout Area

Purpose

Prevent or reduce the discharge of pollutants from concrete waste to stormwater by conducting washout off-site, or performing on-site washout in a designated area.

Conditions of Use

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 into formed areas awaiting concrete pour.

At no time shall concrete be washed off into the footprint of an area where an infiltration feature will be installed.

Design and Installation Specifications

Implementation

- Perform washout of concrete truck drums at an approved off-site location or in designated concrete washout areas only.
- Do not wash out concrete onto non-formed areas, or into storm drains, open ditches, streets, or streams.
- Wash equipment difficult to move, such as concrete paving machines, in areas that do not directly drain to natural or constructed stormwater conveyance or potential infiltration areas.
- Do not allow excess concrete to be dumped on-site, except in designated concrete washout areas as allowed above.
- Concrete washout areas may be prefabricated concrete washout containers, or self-installed structures (above-grade or below-grade).
- 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.
- 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.
- Concrete washout areas shall be constructed and maintained in sufficient quantity and size to contain all liquid and concrete waste generated by washout operations.

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 the contractor’s superintendent or Certified Erosion and Sediment Control Lead (CESCL) to oversee and enforce concrete waste management procedures.
- A sign should be installed adjacent to each concrete washout area to inform concrete equipment operators to utilize the proper facilities.

Contracts

Incorporate requirements for concrete waste management into concrete supplier and subcontractor agreements.

Location and Placement

- Locate concrete washout areas at least 50 feet from sensitive areas such as storm drains, open ditches, water bodies, or wetlands.
- Allow convenient access to the concrete washout area for concrete trucks, preferably near the area where the concrete is being poured.
- If trucks need to leave a paved area to access the concrete washout area, prevent track-out with a pad of rock or quarry spalls (see BMP C105: Stabilized Construction Access). These areas should be far enough away from other construction traffic to reduce the likelihood of accidental damage and spills.
- The number of concrete washout areas you install should depend on the expected demand for storage capacity.
- On large sites with extensive concrete work, concrete washout areas should be placed in multiple locations for ease of use by concrete truck drivers.

Concrete Truck Washout Procedures

- Washout of concrete truck drums shall be performed in designated concrete washout areas only.
- Concrete washout from concrete pumper bins can be washed into concrete pumper trucks and discharged into designated concrete washout areas or properly disposed of off-site.

Concrete Washout Area Installation

- Concrete washout areas should be constructed as shown in the figures below, with a recommended minimum length and minimum width of 10 ft, but with sufficient quantity and volume to contain all liquid and concrete waste generated by washout operations.
- Plastic lining material should be a minimum of 10 mil polyethylene sheeting and should be free of holes, tears, or other defects that compromise the impermeability of the material.
- Lath and flagging should be commercial type.
- Liner seams shall be installed in accordance with manufacturers’ recommendations.
- Soil base shall be prepared free of rocks or other debris that may cause tears or holes in the plastic lining material.

Maintenance Standards

Inspection and Maintenance

- Inspect and verify that concrete washout areas are in place prior to the commencement of concrete work.
- Once concrete wastes are washed into the designated washout area and allowed to harden, the concrete should be broken up, removed, and disposed of per applicable solid waste regulations. Dispose of hardened concrete on a regular basis.
- During periods of concrete work, inspect the concrete washout areas daily to verify continued performance.
    - Check overall condition and performance.
    - Check remaining capacity (% full).
    - If using self-installed concrete washout areas, verify plastic liners are intact and sidewalls are not damaged.
    - If using prefabricated containers, check for leaks.
- Maintain the concrete washout areas to provide adequate holding capacity with a minimum freeboard of 12 inches.
- Concrete washout areas must be cleaned, or new concrete washout areas must be constructed and ready for use once the concrete washout area is 75% full.
- If the concrete washout area is nearing capacity, vacuum and dispose of the waste material in an approved manner.
    - Do not discharge liquid or slurry to waterways, storm drains or directly onto ground.
    - Do not discharge to the sanitary sewer without local approval.
    - Place a secure, non-collapsing, non-water collecting cover over the concrete washout area prior to predicted wet weather 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 you remove materials from a self-installed concrete washout area, build a new structure; or, 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 Concrete Washout Areas

- When concrete washout areas are no longer required for the work, the hardened concrete, slurries and liquids shall be removed and properly disposed of.

- Materials used to construct concrete washout areas shall be removed from the site of the work and disposed of or recycled.
- Holes, depressions or other ground disturbance caused by the removal of the concrete washout areas shall be backfilled, repaired, and stabilized to prevent erosion.

Figure 7.8: Concrete Washout Area with Wood Planks

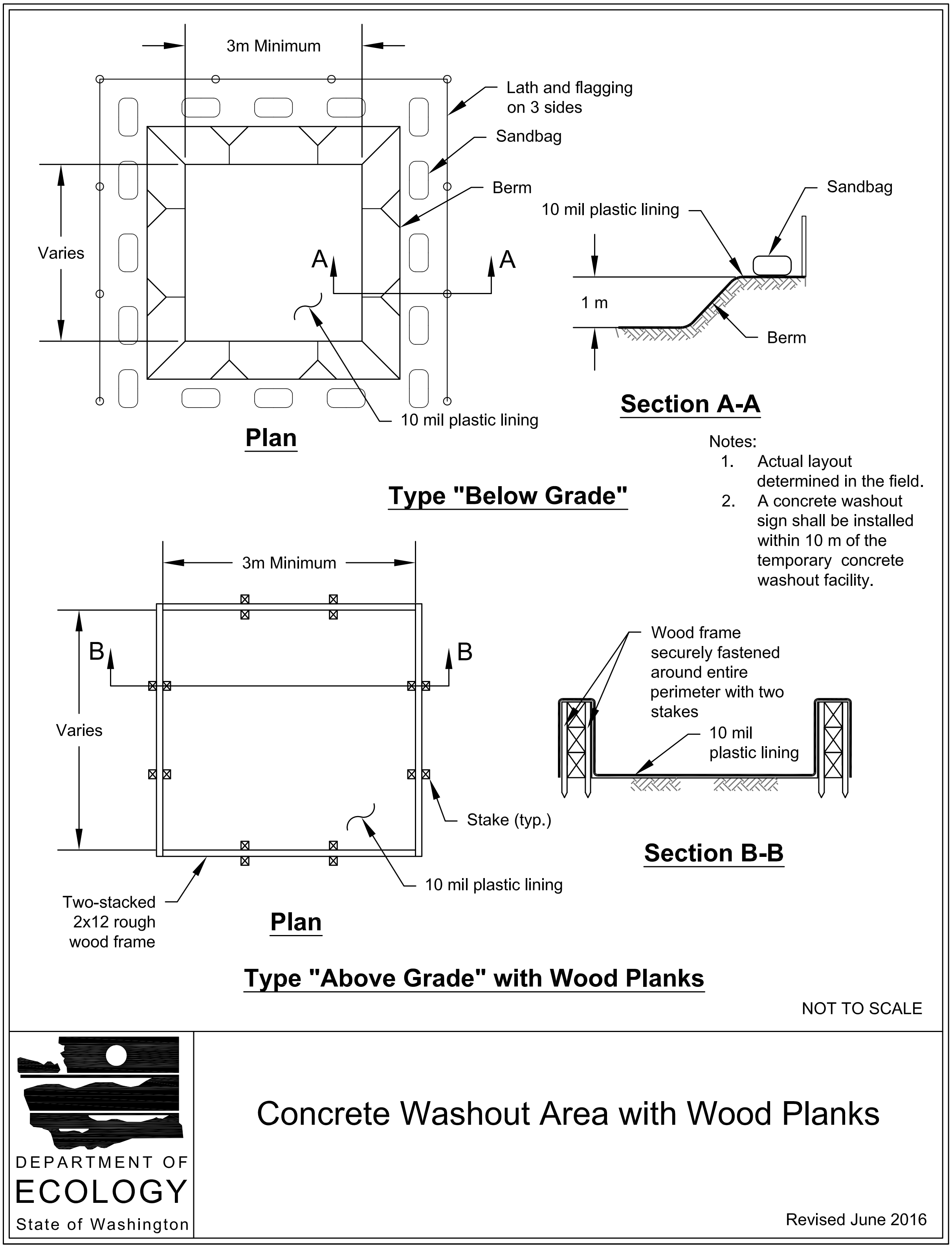


Figure 7.9: Concrete Washout Area with Straw Bales

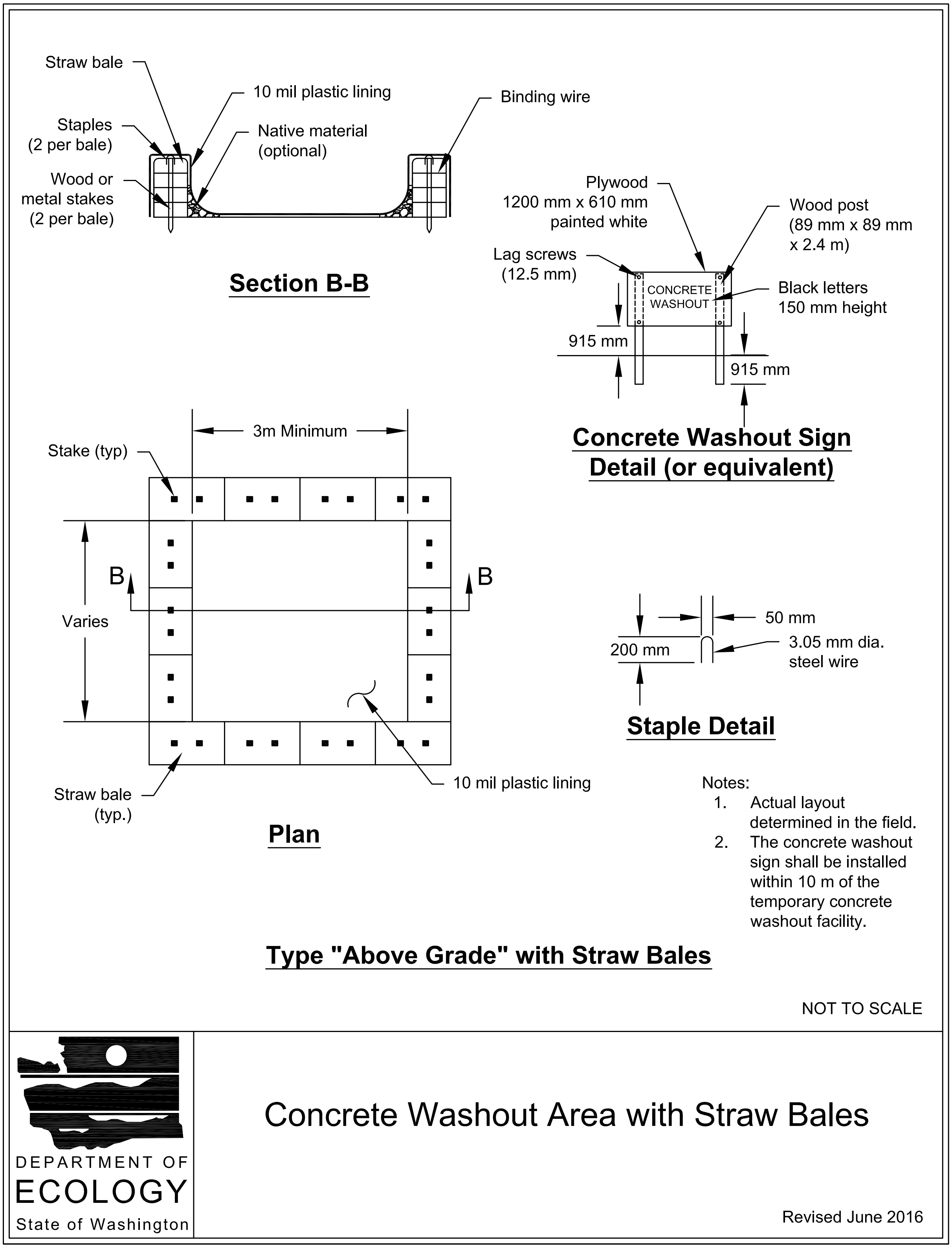
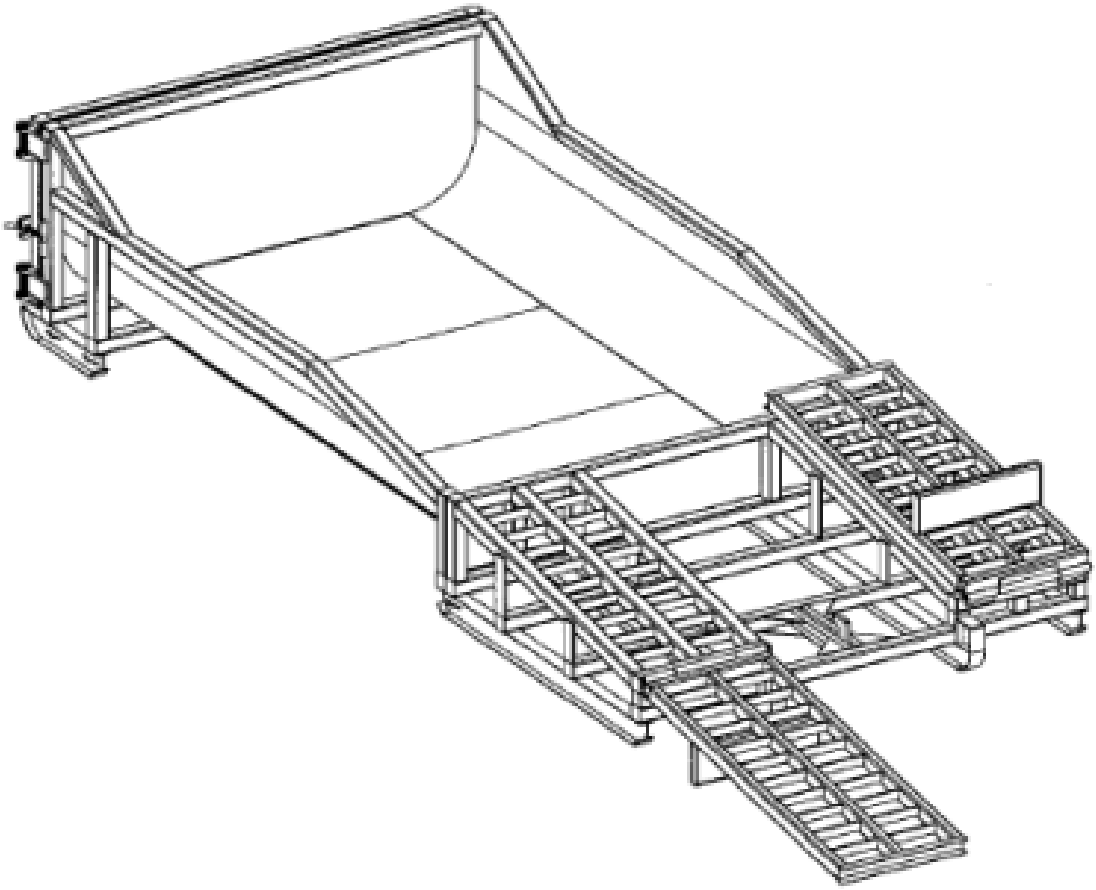


Figure 7.10: Prefabricated Concrete Washout Container with Ramp



NOT TO SCALE

DEPARTMENT OF ECOLOGY State of Washington

Prefabricated Concrete Washout Container with Ramp

Revised June 2016

BMP C160: Certified Erosion and Sediment Control Lead

Purpose

The project proponent designates at least one person as the responsible representative in charge of erosion and sediment control (ESC) and water quality protection. The designated person shall be responsible for ensuring compliance with all local, state, and federal erosion and sediment control and water quality requirements. Construction sites one acre or larger that discharge to waters of the State must designate a Certified Erosion and Sediment Control Lead (CESCL) as the responsible representative.

Conditions of Use

A CESCL shall be made available on projects one acre or larger that discharge stormwater to surface waters of the state. Sites less than one acre may have a person without CESCL certification conduct inspections.

The CESCL shall:

- Have a current certificate proving attendance in an ESC training course that meets the minimum ESC training and certification requirements established by Ecology.

  Ecology has provided the minimum requirements for CESCL course training, as well as a list of ESC training and certification providers at:

  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 go to:

  http://www.envirocertintl.org/cpesc/

Specifications

- CESCL certification shall remain valid for three years.
- The CESCL shall have authority to act on behalf of the contractor or project proponent and shall be available, or on-call, 24 hours per day throughout the period of construction.
- The Construction SWPPP shall include the name, telephone number, fax number, and address of the designated CESCL. See 7.3 Construction Stormwater Pollution Prevention Plans (Construction SWPPPs).
- A CESCL may provide inspection and compliance services for multiple construction projects in the same geographic region, but must be on site whenever earthwork activities are occurring that could generate release of turbid water.
- Duties and responsibilities of the CESCL shall include, but are not limited to, the following:

- Maintaining a permit file on site at all times which includes the Construction SWPPP and any associated permits and plans.
- Directing BMP installation, inspection, maintenance, modification, and removal.
- Updating all project drawings and the Construction SWPPP with changes made.
- Completing any sampling requirements including reporting results using electronic Discharge Monitoring Reports (WebDMR).
- Facilitating, participating in, and taking corrective actions resulting from inspections performed by outside agencies or the owner.
- Keeping daily logs and inspection reports. Inspection reports should include:
  - Inspection date/time.
  - Weather information; general conditions during inspection and approximate amount of precipitation since the last inspection.
  - Visual monitoring results, including a description of discharged stormwater. The presence of suspended sediment, turbid water, discoloration, and oil sheen shall 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.
  - A summary or list of all BMPs implemented, including observations of all ESC structures or practices. The following shall be noted:
    1. Locations of BMPs inspected.
    2. Locations of BMPs that need maintenance.
    3. Locations of BMPs that failed to operate as designed or intended.
    4. Locations of where additional or different BMPs are required.

BMP C162: Scheduling

Purpose

Sequencing a construction project can reduce the amount and duration of soil exposed to erosion by wind, rain, runoff, and vehicle tracking.

Conditions of Use

The construction sequence schedule is an orderly listing of all major land-disturbing activities together with the necessary erosion and sediment control (ESC) measures planned for the project. This type of schedule guides the contractor on work to be done before other work is started so that serious erosion and sedimentation problems can be avoided.

Following a specified work schedule that coordinates the timing of land-disturbing activities and the installation of control measures is perhaps the most cost-effective way of controlling erosion during construction. The removal of ground cover leaves a site vulnerable to erosion. Construction sequencing that limits land clearing, provides timely installation of ESC BMPs, and restores protective cover quickly can significantly reduce the erosion potential of a site.

Design Considerations

- Minimize construction during rainy periods.
- Schedule projects to disturb only small portions of the site at any one time. Complete grading as soon as possible. Immediately stabilize the disturbed portion before grading the next portion. Practice staged seeding in order to revegetate cut and fill slopes as the work progresses.

7.4.3 Construction Runoff BMPs

BMP C200: Interceptor Dike and Swale

Purpose

Provide a dike of compacted soil or a swale at the top or base of a disturbed slope or along the perimeter of a disturbed construction area to convey stormwater. Use the dike and/or swale to intercept the runoff from unprotected areas and direct it to areas where erosion can be controlled. This can prevent storm runoff from entering the work area or sediment-laden runoff from leaving the construction site.

Conditions of Use

Use an interceptor dike or swale where runoff from an exposed site or disturbed slope must be conveyed to an erosion control BMP that can safely convey the stormwater.

- Locate upslope of a construction site to prevent runoff from entering the disturbed area.
- When placed horizontally across a disturbed slope, it reduces the amount and velocity of runoff flowing down the slope.
- Locate downslope to collect runoff from a disturbed area and direct it to a sediment trapping BMP (e.g. BMP C240: Sediment Trap or BMP C241: Sediment Pond (Temporary)).

Design and Installation Specifications

- Dike and/or swale and channel must be stabilized with temporary or permanent vegetation or other channel protection during construction.
- Steep grades require channel protection and check dams.
- Review construction for areas where overtopping may occur.
- Can be used at the top of new fill before vegetation is established.
- May be used as a permanent diversion channel to carry the runoff.

- Contributing area for an individual dike or swale should be one acre or less.
- Design the dike and/or swale to contain flows calculated by one of the following methods:
    - Temporary interceptor dikes: Sized to handle the expected peak flow rate from a 6-month, 3-hour storm (referred to as the short-duration storm) for the worst-case land cover condition.
    - Permanent interceptor dikes: The peak volumetric flow rate is calculated using a 10-minute time step for a 25-year, 24-hour frequency storm for the developed condition.

  Worst-case land cover conditions (i.e. producing the most runoff) should be used for temporary interceptor dike analysis. In most cases, this would be the land cover conditions just prior to final landscaping.

Interceptor Dikes

Interceptor dikes shall meet the following criteria:

- Top Width: 2 feet minimum.
- Height: 1.5 feet minimum on berm.
- Side Slope: 2H:1V or flatter.
- Grade: Depends on topography; however, dike system minimum is 0.5%, and maximum is 1%.
- Compaction: Minimum of 90% ASTM D698 standard proctor.
- Stabilization: Depends on velocity and reach. Inspect regularly to ensure stability.
- Ground Slopes less than 5%: Seed and mulch applied within 5 days of dike construction (see BMP C121: Mulching).
- Ground Slopes from 5% to 40%: Dependent on runoff velocities and dike materials. Stabilization should be done immediately using either sod or riprap, or other measures to avoid erosion.
- The upslope side of the dike shall provide positive drainage to the dike outlet. No erosion shall occur at the outlet. Provide energy dissipation measures as necessary. Sediment-laden runoff must be released through a sediment trapping BMP.
- Minimize construction traffic over temporary dikes. Use temporary cross culverts for channel crossing.
- See Table 7.9: Horizontal Spacing of Interceptor Dikes Along Ground Slope for recommended horizontal spacing between dikes.

Table 7.9: Horizontal Spacing of Interceptor Dikes Along Ground Slope

Average Slope	Slope Percent	Flowpath Length
20H:1V or less	3 - 5%	300 feet
(10 to 20)H:1V	5 - 10%	200 feet
(4 to 10)H:1V	10 - 25%	100 feet
(2 to 4)H:1V	25 - 50%	50 feet

Interceptor Swales

Interceptor swales shall meet the following criteria:

- Bottom Width: 2 feet minimum; the cross-section bottom shall be level.
- Depth: 1 foot minimum.
- Side Slope: 2H:1V or flatter.
- Grade: Maximum 5%, with positive drainage to a suitable outlet (such as BMP C241: Sediment Pond (Temporary)).
- Stabilization: Seed per BMP C120: Temporary and Permanent Seeding, or BMP C202: Riprap Channel Lining, 12 inches thick riprap pressed into the bank and extending at least 8 inches vertical from the bottom.

Maintenance Standards

- Inspect diversion dikes and interceptor swales once a week and after every rainfall. Immediately remove sediment from the flow area.
- Damage caused by construction traffic or other activity must be repaired before the end of each working day.
- Check outlets and make timely repairs as needed to avoid gully formation. When the area below the temporary diversion dike is permanently stabilized, remove the dike and fill and stabilize the channel to blend with the natural surface.

BMP C201: Grass-Lined Channels

Purpose

To provide a channel with a vegetative lining for conveyance of runoff. The purpose of the vegetative lining is to prevent transport of sediment and erosion.

Conditions of Use

This practice applies to construction sites where concentrated runoff needs to be directed to prevent erosion or flooding.

- Use this BMP when a vegetative lining can provide sufficient stability for the channel cross section and at lower velocities of water (normally dependent on grade). This means that the channel slopes are generally less than 5% and space is available for a relatively large cross section.

- Typical uses include roadside ditches, channels at property boundaries, outlets for diversions, and other channels and drainage ditches in low areas.

- Channels that will be vegetated should be installed before major earthwork and hydroseeded with a bonded fiber matrix (BFM). The vegetation should be well established (i.e. 50% cover of all seeded areas after 3 months of active growth following germination during the growing season) before water is allowed to flow in the ditch unless BMP C122: Nets and Blankets is used to protect the channel. With channels that will have high flows, erosion control blankets should be installed over the hydroseed. If vegetation cannot be established from seed before water is allowed in the ditch, sod should be installed in the bottom of the ditch in lieu of hydromulch and blankets.

Design and Installation Specifications

See Figure 7.11: Typical Grass-Lined Channels

Locate channels where they can conform to the topography and other features such as roads. Use natural drainage systems to the greatest extent possible

- Avoid sharp changes in alignment or bends and changes in grade.

- Do not reshape the landscape to fit the drainage channel.

- The maximum design velocity shall be based on soil conditions, type of vegetation, and method of revegetation, but at no time shall velocity exceed 5 feet/second. The channel shall not be overtopped by the peak volumetric flow rate calculated using the expected peak flow rate from a 6-month, 3-hour storm (referred to as the short-duration storm) for the worst-case land cover condition.

  Worst-case land cover conditions (i.e. producing the most runoff) should be used for analysis (in most cases, this would be the land cover conditions just prior to final landscaping).

- Where the grass-lined channel will also function as a permanent stormwater conveyance facility, consult the drainage conveyance requirements of the local jurisdiction.

- An established grass or vegetated lining is required before the channel can be used to convey stormwater, unless stabilized with nets or blankets (see BMP C122: Nets and Blankets).

- If design velocity of a channel to be vegetated by seeding exceeds 2 ft/sec, a temporary channel liner is required. Geotextile or special mulch protection such as fiberglass roving or straw and netting provides stability until the vegetation is fully established. See Figure 7.12: Temporary Channel Liners.

- Check dams shall be removed when the grass has matured sufficiently to protect the ditch or swale unless the slope of the swale is greater than 4%. The area beneath the check dams shall be seeded and mulched immediately after dam removal.

- If vegetation is established by sodding, the permissible velocity for established vegetation may be used and no temporary liner is needed.
- Do not subject the grass-lined channel to sedimentation from disturbed areas. Use sediment-trapping BMPs upstream of the channel.
- V-shaped grass channels generally apply where the quantity of water is small, such as in short reaches along roadsides. The V-shaped cross section is least desirable because it is difficult to stabilize the bottom where velocities may be high.
- Trapezoidal grass channels are used where runoff volumes are large and slope is low so that velocities are nonerosive to vegetated linings.

  Note: it is difficult to construct small parabolic shaped channels.
- Subsurface drainage or riprap channel bottoms may be necessary on sites that are subject to prolonged wet conditions due to long duration flows or a high water table.
- Provide outlet protection at culvert ends and at channel intersections.
- Grass channels, at a minimum, should carry peak runoff for temporary construction drainage facilities from the 6-month, 3-hour storm (referred to as the short-duration storm) for the worst case land cover condition without eroding. Where flood hazard exists, increase the capacity according to the potential damage.
- Grassed channel side slopes generally are constructed 3H:1V or flatter to aid in the establishment of vegetation and for maintenance.
- Construct channels a minimum of 0.2 foot larger around the periphery to allow for soil bulking during seedbed preparations and sod buildup.

Maintenance Standards

During the establishment period, check grass-lined channels after every rainfall.

- After grass is established, periodically check the channel; check it after every heavy rainfall event. Immediately make repairs.
- Check the channel outlet and all road crossings for bank stability and evidence of piping or scour holes.
- Remove all significant sediment accumulations to maintain the designed carrying capacity. Keep the grass in a healthy, vigorous condition at all times, since it is the primary erosion protection for the channel.

Figure 7.11: Typical Grass-Lined Channels

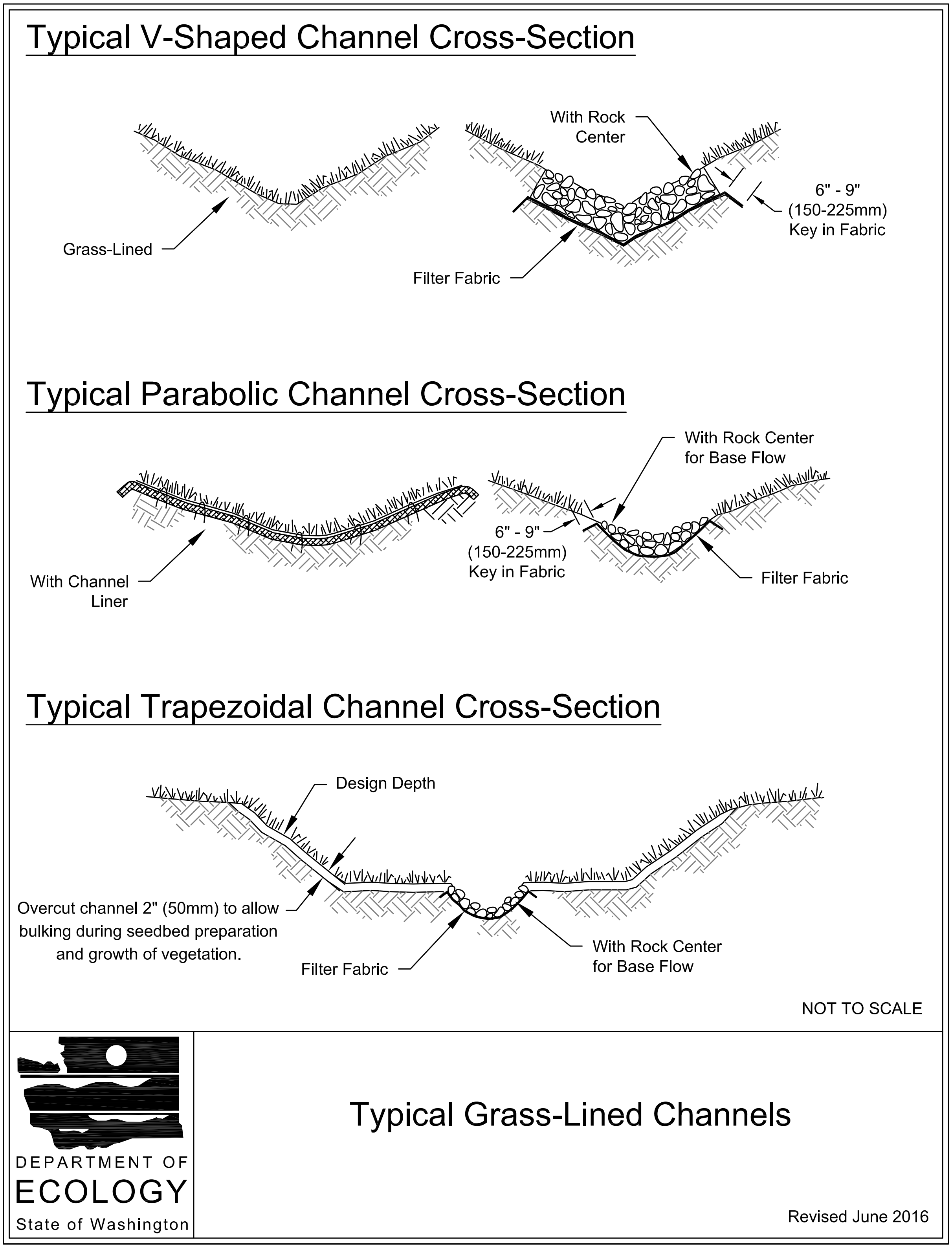
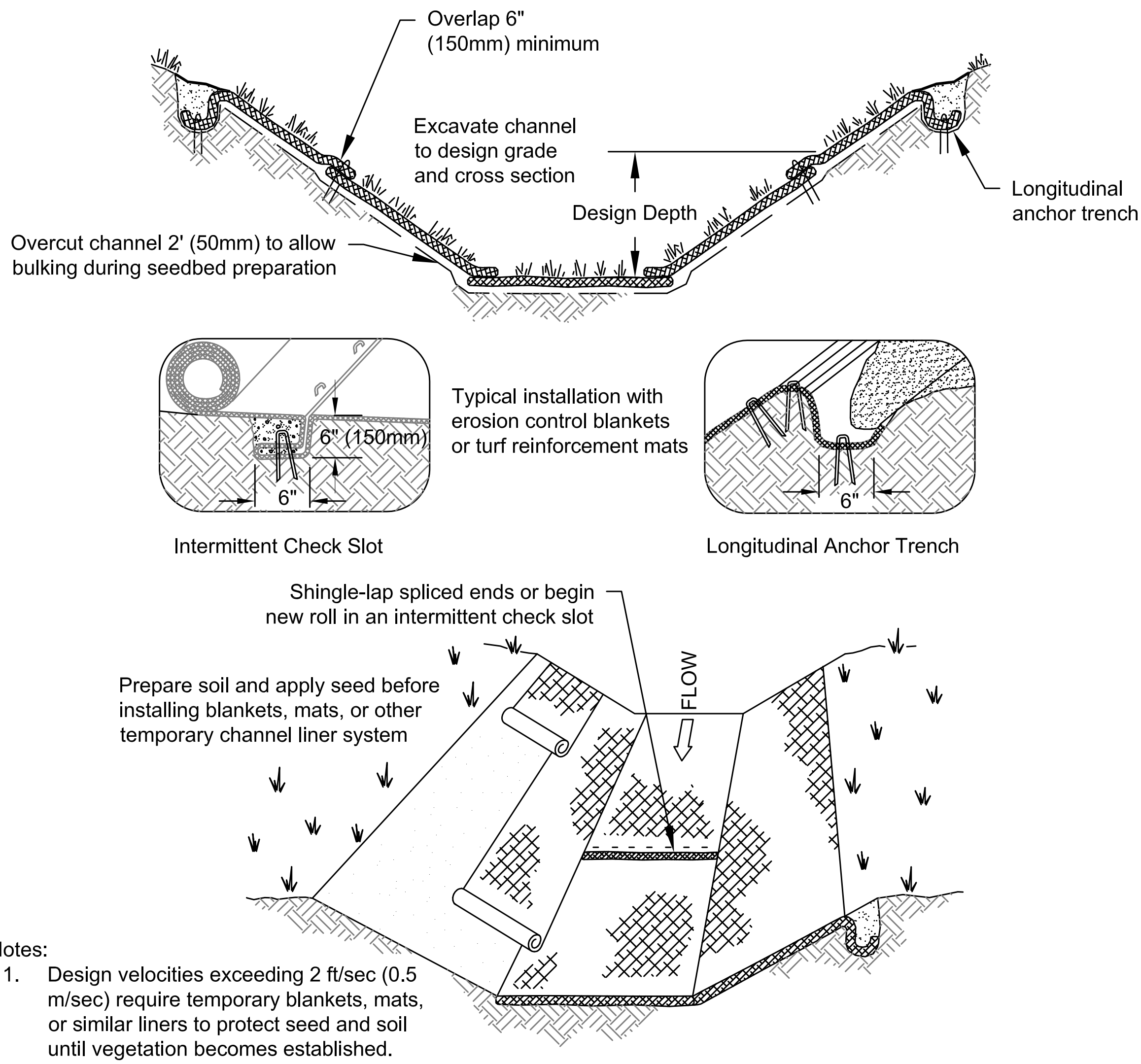


Figure 7.12: Temporary Channel Liners



Notes:

1. Design velocities exceeding 2 ft/sec (0.5 m/sec) require temporary blankets, mats, or similar liners to protect seed and soil until vegetation becomes established.
2. Grass-lined channels with design velocities exceeding 6 ft/sec (2 m/sec) should include turf reinforcement mats.

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State of Washington

Temporary Channel Liners

Revised July 2016

BMP C202: Riprap Channel Lining

Purpose

To protect channels from erosion by providing a channel liner using riprap.

Conditions of Use

Use this BMP when natural soils or vegetated stabilized soils in a channel are not adequate to prevent channel erosion.

Use this BMP when a permanent ditch or pipe system is to be installed and a temporary measure is needed.

An alternative to riprap channel lining is BMP C122: Nets and Blankets.

The Federal Highway Administration recommends not using geotextile liners whenever the slope exceeds 10% or the shear stress exceeds 8 lbs/ft^2.

Design and Installation Specifications

- Since riprap is typically used where erosion potential is high, construction must be sequenced so that the riprap is put in place with the minimum possible delay.
- Disturb areas awaiting riprap only when final preparation and placement of the riprap can follow immediately behind the initial disturbance. Where riprap is used for outlet protection, the riprap should be placed before or in conjunction with the construction of the pipe or channel so that it is in place when the pipe or channel begins to operate.
- The designer, after determining the riprap size that will be stable under the flow conditions, shall consider that size to be a minimum size and then, based on riprap gradations actually available in the area, select the size or sizes that equal or exceed the minimum size. The possibility of drainage structure damage by others shall be considered in selecting a riprap size, especially if there is nearby water or a gully in which to toss the stones.
- Stone for riprap shall consist of field stone or quarry stone that is approximately rectangular in shape. The stone shall be hard and angular and of such quality that it will not disintegrate on exposure to water or weathering and it shall be suitable in all respects for the purpose intended. See Section 9-13 of WSDOT's *Standard Specifications for Road, Bridge, and Municipal Construction* (WSDOT, 2016).
- A lining of engineering filter fabric (geotextile) shall be placed between the riprap and the underlying soil surface to prevent soil movement into or through the riprap. The geotextile should be keyed in at the top of the bank.
- Filter fabric shall not be used on slopes greater than 1.5H:1V as slippage may occur. It should be used in conjunction with a layer of coarse aggregate (granular filter blanket) when the riprap to be placed is 12 inches and larger.

Maintenance Standards

Replace the riprap as needed.

BMP C203: Water Bars

Purpose

A water bar is a small ditch or ridge of material that is constructed diagonally across a road or right-of-way to divert stormwater runoff from the road surface, wheel tracks, or a shallow road ditch. See Figure 7.13: Water Bar.

Conditions of Use

Clearing right-of-way and construction of access for power lines, pipelines, and other similar installations often require long narrow rights-of-ways over sloping terrain. Disturbance and compaction promotes gully formation in these cleared strips by increasing the volume and velocity of runoff. Gully formation may be especially severe in tire tracks and ruts. To prevent gullying, runoff can often be diverted across the width of the right-of-way to undisturbed areas by using small predesigned diversions.

Give special consideration to each individual outlet area, as well as to the cumulative effect of added diversions. Use gravel to stabilize the diversion where significant vehicular traffic is anticipated.

Design and Installation Specifications

- Height: 8-inches minimum, measured from the channel bottom to the ridge top.
- Side slope of channel: 2H:1V maximum; 3H:1V or flatter when vehicles will cross.
- Top width of ridge: 6-inches minimum.
- Locate water bars to use natural drainage systems and to discharge into well vegetated stable areas.
- See Table 7.10: Water Bar Spacing Guidelines:

Table 7.10: Water Bar Spacing Guidelines

Slope Along Road (%)	Spacing (ft)
< 5	125
5 - 10	100
10 - 20	75
20 - 35	50
> 35	Use rock lined ditch

- Grade of water bar and angle: Select an angle that results in a ditch slope less than 2%.
- Install the water bar as soon as the clearing and grading is complete. When utilities are being installed, reconstruct the water bar as construction is complete in each section.

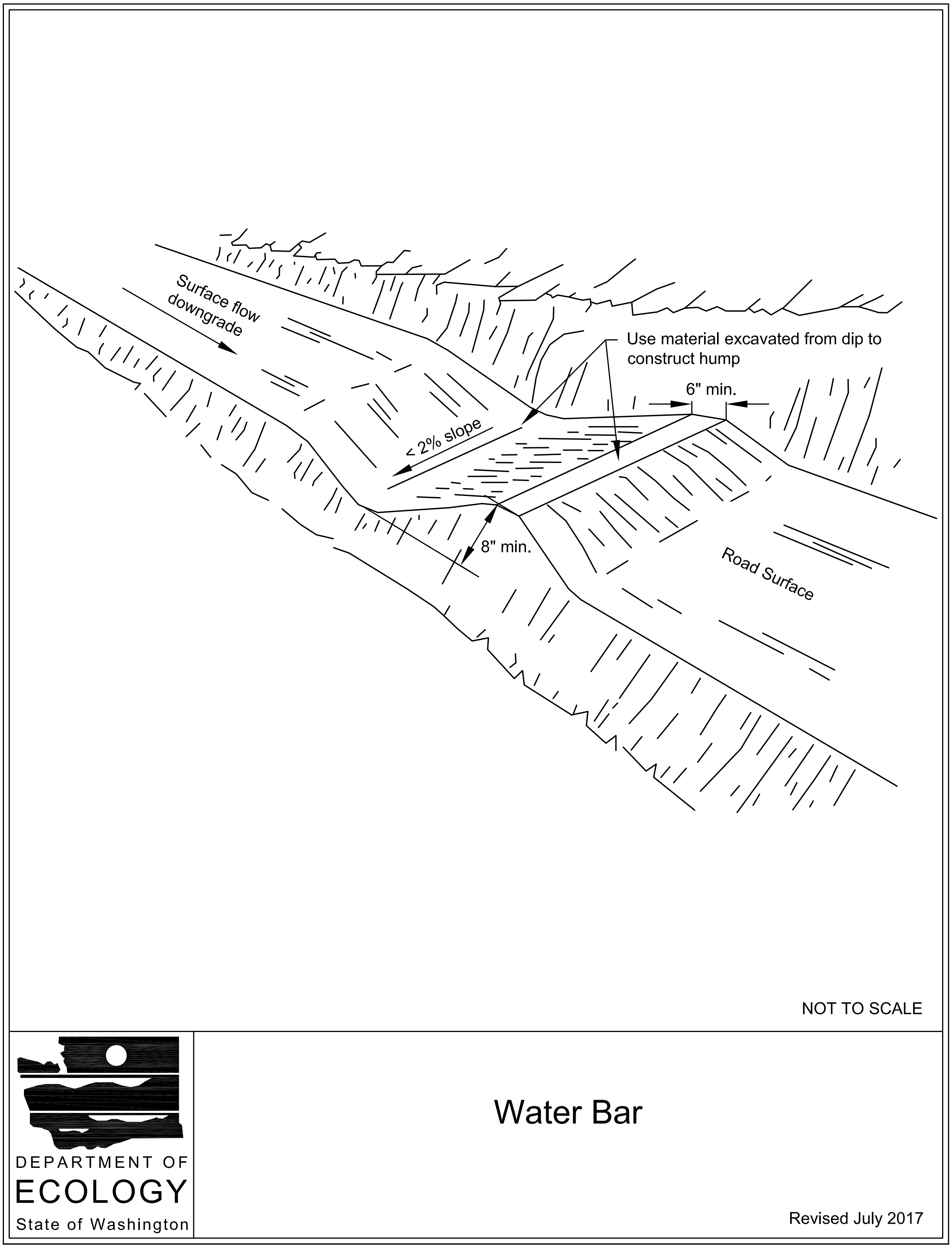
- Compact the water bar ridge.
- Stabilize, seed, and mulch the portions that are not subject to traffic. Gravel the areas crossed by vehicles.
- Note that BMP C208: Triangular Silt Dike (TSD) can be used to create the ridge for the water bar.

Maintenance Standards

Periodically inspect water bars for wear, and after every heavy rainfall for wear and/or erosion damage.

- Immediately remove sediment from the flow area and repair the dike.
- Check outlet areas and make timely repairs as needed.
- When permanent road drainage is established and the area above the temporary water bar is permanently stabilized, remove the dikes and fill the channel to blend with the natural ground, and appropriately stabilize the disturbed area.

Figure 7.13: Water Bar



BMP C204: Pipe Slope Drains

Purpose

The purpose of pipe slope drains is to prevent gullies, channel erosion, and saturation of slide-prone soils by using a pipe to convey stormwater away from or over bare soil.

Conditions of Use

Pipe slope drains should be used when a temporary or permanent stormwater conveyance is needed to move water down a steep slope to avoid erosion.

Pipe slope drains should be used at bridge ends to collect runoff and convey it to the base of the fill slopes along the bridge approaches. Another use on road projects is to collect runoff from pavement in a pipe slope drain and convey it away from side slopes.

Temporary installations of pipe slope drains can be useful because there is generally a time lag between having the first lift of asphalt installed and the curbs, gutters, and permanent drainage installed. Used in conjunction with sand bags, or other temporary diversion devices, these will prevent massive amounts of sediment from leaving a project.

Pipe slope drains can serve the following purposes:

- Connection to new catch basins and temporarily use until permanent piping is installed.
- Drainage of water collected from aquifers exposed on cut slopes and conveyance of water to the base of the slope.
- Collection of clean runoff from plastic sheeting and routing the runoff away from exposed soil.
- Installation in conjunction with silt fence to drain collected water to a controlled area.
- Diversion of small seasonal streams away from construction. They have been used successfully on culvert replacement and extension jobs. Large flex pipe can be used on larger streams during culvert removal, repair, or replacement.
- Connection to existing downspouts and roof drains and diversion of water away from work areas during building renovation, demolition, and construction projects.

There are several commercially available collectors that attach to the pipe inlet and help prevent erosion at the inlet.

Design and Installation Specifications

- See Figure 7.14: Pipe Slope Drain.
- Size the pipe to convey the projected flow.

  Temporary pipe slope drains shall be sized to handle the expected peak flow rate from a 6-month, 3-hour storm (referred to as the short-duration storm) for the worst-case land cover condition.

Permanent pipe slope drains shall be sized to handle the peak volumetric flow rate from the 25-year, 24-hour storm, as calculated using a 10-minute time step.

Worst-case land cover conditions (i.e. producing the most runoff) should be used for analysis (in most cases, this would be the land cover conditions just prior to final landscaping).

- Use care in clearing vegetated slopes for installation.
- Re-establish cover immediately on areas disturbed by installation.
- Use temporary drains on new cut or fill slopes.
- Use BMP C200: Interceptor Dike and Swale to collect water at the top of the slope.
- Ensure that the entrance area is stable and large enough to direct flow into the pipe.
- Piping of water through the berm at the entrance area is a common failure mode.
- 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%. Sand bags may also be used at pipe entrances as a temporary measure.
- 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, be fused, or have gasketed watertight fittings, and shall be securely anchored into the soil.
- Thrust blocks should be installed anytime 90 degree bends are used. 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.
- The 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 the posts. This should be done every 10 to 20 feet of pipe length or so, depending on the size of the pipe and quantity of water to divert.
- BMP C200: Interceptor Dike and Swale shall be used to direct runoff into a pipe slope drain. The height of the dike shall be at least 1 foot higher at all points than the top of the inlet pipe.
- The area below the outlet must be stabilized. See BMP C209: Outlet Protection.
- If the pipe slope drain is conveying sediment-laden water, direct all flows into a sediment trapping BMP.
- Materials specifications for any permanent piped system shall be set by the local jurisdiction.

Maintenance Standards

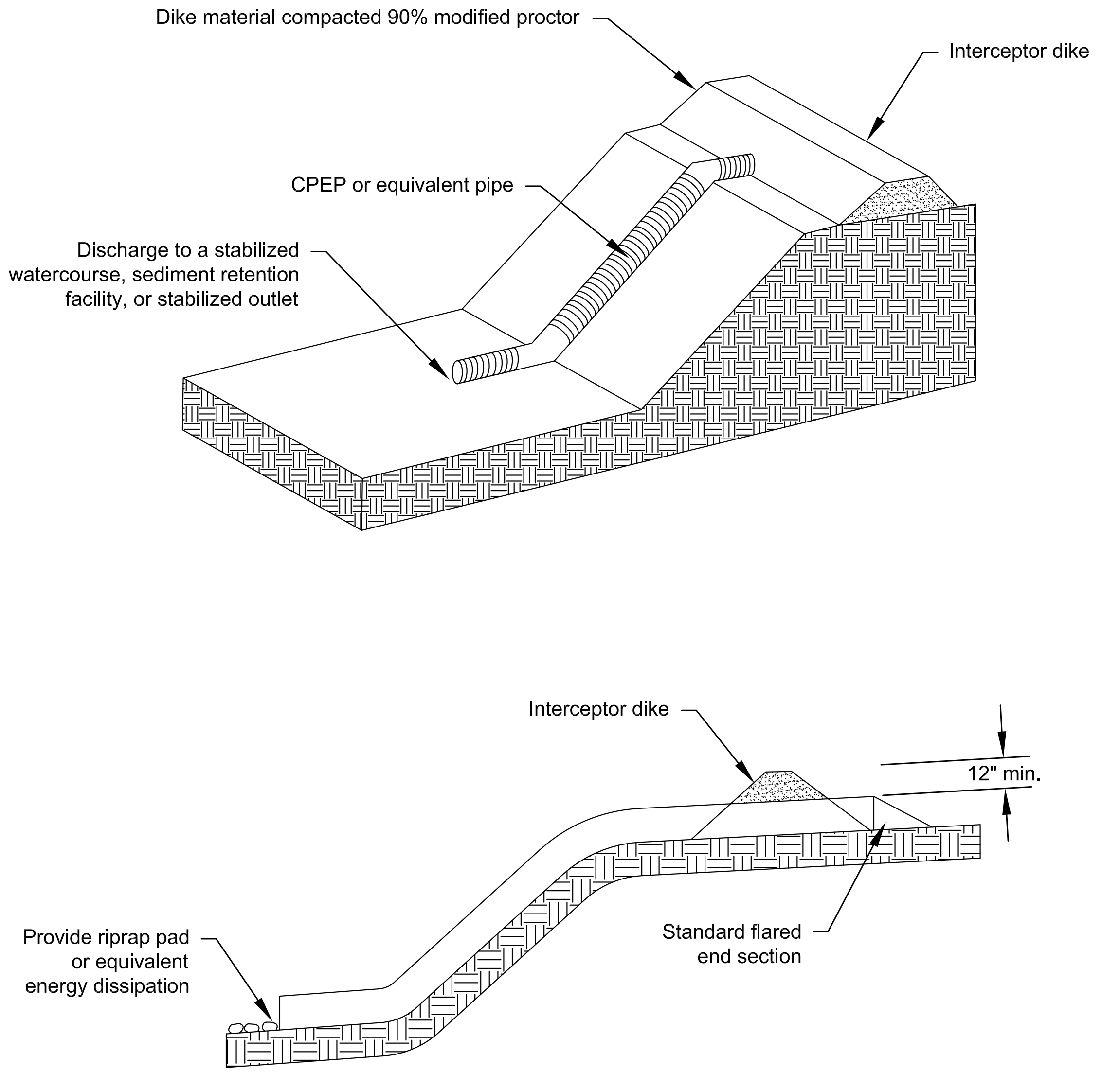
Check inlet and outlet points regularly, especially after storms.

- The inlet should be free of undercutting, and no water should be going around the point of entry. If there are problems, the headwall should be reinforced 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.

Figure 7.14: Pipe Slope Drain



Notes:

1. Inlet and all sections must be securely fastened together with gasketed watertight fittings

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DEPARTMENT OF ECOLOGY
State of Washington

Pipe Slope Drain

Revised June 2016

BMP C205: Subsurface Drains

Purpose

The purpose of subsurface drains is to intercept, collect, and convey groundwater to a satisfactory outlet, using a perforated pipe or other conduit below the ground surface. Subsurface drains are also known as “french drains”. The perforated pipe provides a dewatering mechanism to drain excessively wet soils, which provides a stable base for construction, improves stability of structures with shallow foundations, and/or reduces hydrostatic pressure to improve slope stability.

Conditions of Use

Use subsurface drains when excessive water must be removed from the soil. The soil permeability, depth to water table, and impervious layers are all factors that may govern the use of subsurface drains.

Design and Installation Specifications

Subsurface Drain Type: Relief Drains

- Relief drains are used to lower the water table in large, relatively flat areas, to improve the growth of vegetation or to remove surface water.
- Relief drains are installed along a slope and drain in the direction of the slope.
- Relief drains can be installed in a grid pattern, a herringbone pattern, or a random pattern.

Subsurface Drain Type: Interceptor Drains

- Interceptor drains are used to remove excess groundwater from a slope, stabilize steep slopes, and lower the water table immediately below a slope to prevent the soil from becoming saturated.
- Interceptor drains are installed perpendicular to a slope and drain to the side of the slope.
- Interceptor drains usually consist of a single pipe or series of single pipes instead of a patterned layout.

Subsurface Drain Depth and Spacing

- The depth of a subsurface 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 have depth and sufficient permeability to permit installation of an effective drainage system at a depth of 2 to 6 feet.

Subsurface Drain Sizing and Placement

- The quantity and quality of discharge needs to be accounted for in the receiving stream (additional detention may be required).
- The size of a subsurface drain is determined by first calculating the maximum rate of groundwater flow to be intercepted, and then choosing a subsurface drain pipe (or pipes) with enough capacity to convey that flow. Therefore, it is good practice to make complete subsurface investigations, including hydraulic conductivity of the soil, before designing a subsurface drainage system.
- Size subsurface drains to carry the required capacity without pressure flow. Minimum diameter for a subsurface drain is 4 inches.
- The minimum velocity in the pipe required to prevent silting is 1.4 ft/sec. Grade the subsurface drain to achieve this velocity at a minimum. The maximum allowable velocity using a sand-gravel filter or envelope is 9 ft/sec.
- Filter material and fabric shall be used 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.
- The trench shall be constructed on a continuous grade with no reverse grades or low spots.
- Soft or yielding soils under the subsurface drain shall be stabilized with gravel or other suitable material.
- Backfilling shall be done immediately after placement of the pipe. No sections of pipe shall remain uncovered overnight or during a rainstorm. Backfill material shall be placed in the trench in such a manner that the drain pipe is not displaced or damaged.
- Do not install permanent drains near trees to avoid the tree roots that tend to clog the line. Use solid pipe with watertight connections where it is necessary to pass a subsurface drainage system through a stand of trees.

Subsurface Drain Outlets

- An adequate outlet for the subsurface drain must be available either by gravity or by pumping.
- The outlet of the subsurface drain shall empty into a sediment trapping BMP through a catch basin. If free of sediment, it can then empty into a receiving channel, swale, or stable vegetated area adequately protected from erosion and undermining.
- Ensure that the outlet of a subsurface drain empties into a channel or other watercourse above the normal water level.
- 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 and 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 stream, outlet protection must be provided.

Maintenance Standards

Subsurface drains shall be checked periodically to ensure that they are free-flowing and have not become clogged with sediment or roots.

- The outlet shall be kept clean and free of debris.
- Surface inlets shall be kept 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 or remove the trees as a last resort. Drain placement should be planned to minimize this problem.
- Where drains are crossed by heavy vehicles, the line shall be checked to ensure that it is not crushed.

BMP C206: Level Spreader

Purpose

The purpose of a level spreader as a Construction Stormwater BMP is to provide a temporary outlet for dikes and diversions and convert concentrated runoff to sheet flow prior to releasing it to stabilized areas.

Conditions of Use

Use level spreaders when a concentrated flow of water needs to be dispersed over a large area with existing stable vegetation.

Use only where the slopes are gentle, the water volume is relatively low, and the soil will adsorb most of the low flow events.

Items to consider are:

- What is the risk of erosion or damage if the flow becomes concentrated?
- Is an easement required if the flow is discharged to adjoining property?

Design and Installation Specifications

- Use above undisturbed areas that are stabilized by existing vegetation.
- Discharge area below the outlet must be uniform with a slope flatter than 5H:1V.
- Do not allow any low points in the level spreader. If the level spreader has any low points, flow will concentrate, create channels and may cause erosion.
- Ensure the outlet is level in a stable, undisturbed soil profile (not on fill).

- The runoff shall not re-concentrate on site after release from the level spreader unless it is intercepted by another downstream measure.
- The grade of the channel for the last 20 feet of the dike or interceptor entering the level spreader shall be less than or equal to 1%. The grade of the level spreader shall be 0% to ensure uniform spreading of runoff.
- A 6-inch high gravel berm placed across the level lip shall consist of washed crushed rock, 2- to 4-inch or 3/4-inch to 1½-inch size.
- The spreader length must handle the peak volumetric flow rate calculated from a 6-month, 3-hour storm (referred to as the short-duration storm) for the developed condition.

  The length of the spreader shall be a minimum of 15 feet for 0.1 cfs and shall increase by 10 feet for each 0.1 cfs thereafter to a maximum of 0.5 cfs per spreader. Use multiple spreaders for higher flows.
- The width of the approach to the spreader should be at least 6 feet.
- The depth of the spreader as measured from the lip should be at least 6 inches and it should be uniform across the entire length.
- Level spreaders shall be set back from the property line unless there is an easement for flow.
- Materials that can be used for level spreaders include sand bags, lumber, logs, concrete, pipe, and capped perforated pipe. To function properly, the material needs to be installed level and on contour.
- See Figure 7.15: Cross Section of Level Spreader and Figure 7.16: Detail of Level Spreader.

Maintenance Standards

The level spreader should be inspected during and after runoff events to ensure that it is functioning correctly.

- The contractor should avoid the placement of any material on the level spreader, and should prevent construction traffic from crossing over the level spreader.
- If the level spreader is damaged by construction traffic, it shall be immediately repaired.

Figure 7.15: Cross Section of Level Spreader

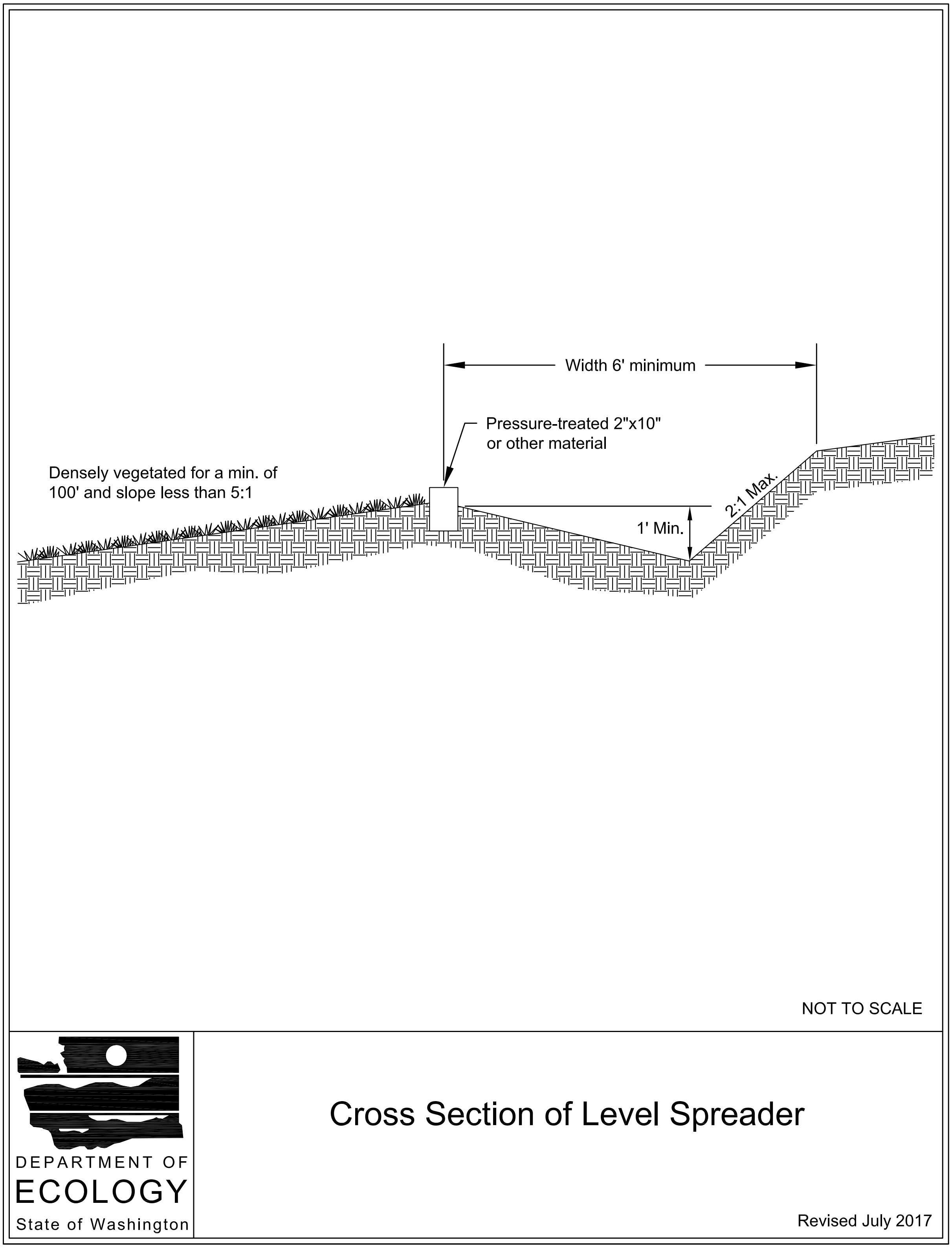
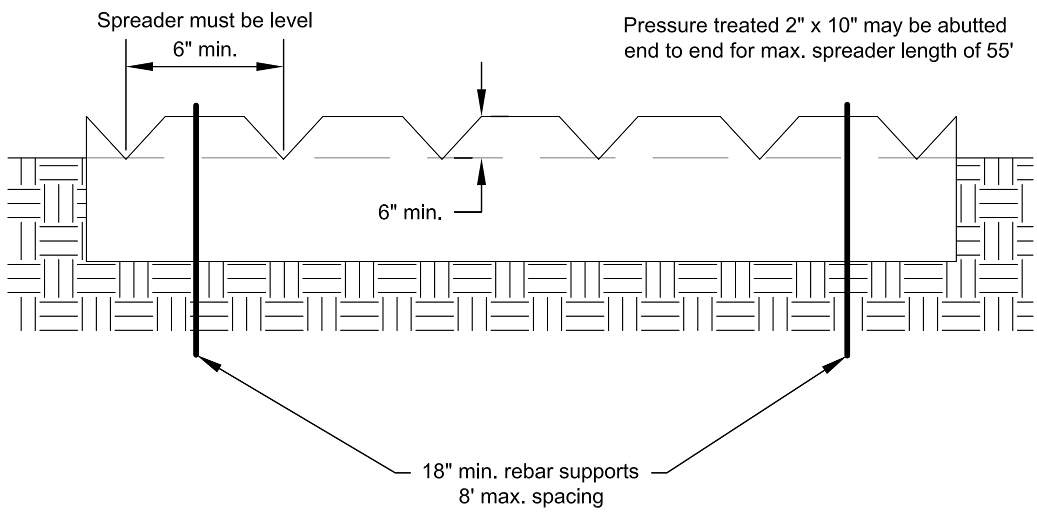


Figure 7.16: Detail of Level Spreader



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Detail of Level Spreader

Revised July 2017

BMP C207: Check Dams

Purpose

Construction of check dams across a swale or ditch reduces the velocity of concentrated flow and dissipates energy at the check dam.

Conditions of Use

Use check dams where temporary or permanent channels are not yet vegetated, channel lining is infeasible, and/or velocity checks are required.

- Check dams may not be placed in streams unless approved by the State Department of Fish and Wildlife.
- Check dams may not be placed in wetlands without approval from a permitting agency.
- Do not place check dams below the expected backwater from any salmonid bearing water between October 1 and May 31 to ensure that there is no loss of high flow refuge habitat for overwintering juvenile salmonids and emergent salmonid fry.

Design and Installation Specifications

- Construct rock check dams from appropriately sized rock. The rock used must be large enough to stay in place given the expected design flow through the channel. The rock must be placed by hand or by mechanical means (do not dump the rock to form the dam) to achieve complete coverage of the ditch or swale and to ensure that the center of the dam is lower than the edges.
- Check dams may also be constructed of either rock or pea-gravel filled bags. Numerous new products are also available for this purpose. They tend to be re-usable, quick and easy to install, effective, and cost efficient.
- Place check dams perpendicular to the flow of water.
- The check dam should form a triangle when viewed from the side. This prevents undercutting as water flows over the face of the check dam rather than falling directly onto the ditch bottom.
- Before installing check dams, impound and bypass upstream water flow away from the work area. Options for bypassing include pumps, siphons, or temporary channels.
- Check dams combined with sumps work more effectively at slowing flow and retaining sediment than a check dam alone. A deep sump should be provided immediately upstream of the check dam.
- In some cases, if carefully located and designed, check dams can remain as permanent installations with very minor regrading. 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.

- The maximum spacing between check dams shall be such that the downstream toe of the upstream dam is at the same elevation as the top of the downstream dam.
- Keep the maximum height at 2 feet at the center of the check 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 stone into the ditch banks and extend it beyond the abutments a minimum of 18 inches to avoid washouts from overflow around the dam.
- Use filter fabric foundation under a rock or sand bag check dam. If a blanket ditch liner is used, filter fabric is not necessary. A piece of organic or synthetic blanket cut to fit will also work for this purpose.
- In the case of grass-lined ditches and swales, all check dams and accumulated sediment shall be removed when the grass has matured sufficiently to protect the ditch or swale - unless the slope of the swale is greater than 4%. The area beneath the check dams shall be seeded and mulched immediately after dam removal.
- Ensure that channel appurtenances, such as culvert entrances below check dams, are not subject to damage or blockage from displaced stones.
- See Figure 7.17: Rock Check Dam.

Maintenance Standards

Check dams shall be monitored for performance and sediment accumulation during and after each rainfall that produces runoff. Sediment shall be removed when it reaches one half the sump depth.

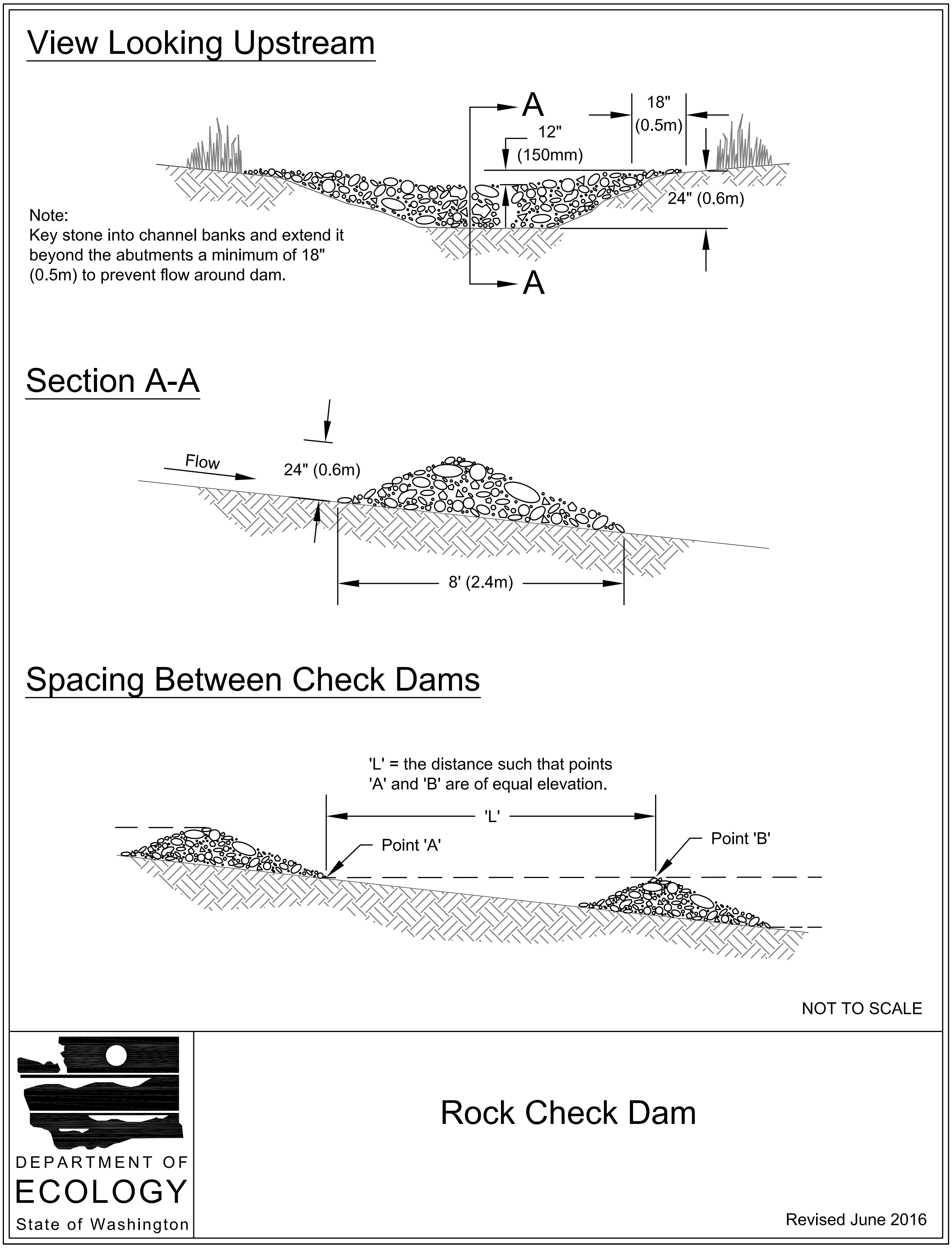
- Anticipate submergence and deposition above the check dam and erosion from high flows around the edges of the dam.
- If significant erosion occurs between dams, install a protective riprap liner in that portion of the channel. See BMP C202: Riprap Channel Lining.

Approved as Functionally Equivalent

Ecology has approved products as able to meet the requirements of this BMP. The products did not pass through the Technology Assessment Protocol – Ecology (TAPE) process. Local jurisdictions may choose not to accept these products, or may require additional testing prior to consideration for local use. Products that Ecology has approved as functionally equivalent are available for review on Ecology’s website at:

https://ecology.wa.gov/Regulations-Permits/Guidance-technical-assistance/Stormwater-permittee-guidance-resources/Emerging-stormwater-treatment-technologies

Figure 7.17: Rock Check Dam



BMP C208: Triangular Silt Dike (TSD)

Purpose

Triangular silt dikes (TSDs) may be used as check dams, for perimeter protection, for temporary soil stockpile protection, for drop inlet protection, or as a temporary interceptor dike.

Conditions of Use

- TSDs may be used on soil or pavement with adhesive or staples.
- TSDs have been used to build the following temporary BMPs:
  - BMP C241: Sediment Pond (Temporary);
  - BMP C200: Interceptor Dike and Swale;
  - BMP C154: Concrete Washout Area;
  - BMP C203: Water Bars;
  - BMP C206: Level Spreader;
  - BMP C220: Inlet Protection;
  - BMP C207: Check Dams
  - curbing; and
  - berms.

Design and Installation Specifications

- TSDs are made of urethane foam sewn into a woven geosynthetic fabric.
- TSDs are triangular, 10 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 200 to 300 mm in length.
- When multiple units are installed, the sleeve of fabric at the end of the unit shall overlap the abutting unit and be stapled.
- When TSDs are used as check dams, the following guidelines apply:
  - TSDs should be located and installed as soon as construction will allow.
  - TSDs should be placed perpendicular to the flow of water.

- The leading edge of the TSD must be secured with rocks, sandbags, or a small key slot and staples.
- In the case of grass-lined ditches and swales, check dams and accumulated sediment shall be removed when the grass has matured sufficiently to protect the ditch or swale unless the slope of the swale is greater than 4%. The area beneath the check dams shall be seeded and mulched immediately after dam removal.

Maintenance Standards

- Inspect TSDs for performance and sediment accumulation during and after each rainfall that produces runoff. Remove sediment when it reaches one half the height of the TSD.
- Anticipate submergence and deposition above the TSD and erosion from high flows around the edges of the TSD. Immediately repair any damage or any undercutting of the TSD.

BMP C209: Outlet Protection

Purpose

Outlet protection prevents scour at conveyance outlets and minimizes the potential for downstream erosion by reducing the velocity of concentrated stormwater flows.

Conditions of Use

Use outlet protection at the outlets of all ponds, pipes, ditches, or other conveyances that discharge to a natural or constructed drainage feature such as a stream, wetland, lake, or ditch.

Design and Installation Specifications

- The receiving channel at the outlet of a pipe shall be protected from erosion by lining a minimum of 6 feet downstream and extending up the channel sides a minimum of 1 foot above the maximum tailwater elevation, or 1 foot above the crown, whichever is higher. For pipes larger than 18 inches in diameter, the outlet protection lining of the channel shall be four times the diameter of the outlet pipe.
- Standard wingwalls, tapered outlets, and paved channels should also be considered when appropriate for permanent culvert outlet protection (WSDOT, 2015).
- BMP C122: Nets and Blankets or BMP C202: Riprap Channel Lining provide suitable options for lining materials.
- With low flows, BMP C201: Grass-Lined Channels can be an effective alternative for lining material.
- The following guidelines shall be used for outlet protection with riprap:
    - If the discharge velocity at the outlet is less than 5 fps, use 2-inch to 8-inch riprap. Minimum thickness is 1 foot.
    - For a 5 to 10 fps discharge velocity at the outlet, use 24-inch to 48-inch riprap. Minimum thickness is 2 feet.

- For outlets at the base of steep slope pipes (pipe slope greater than 10 percent), use an engineered energy dissipator.
- Filter fabric or erosion control blankets should always be used under riprap to prevent scour and channel erosion. See BMP C122: Nets and Blankets.

- Bank stabilization, bioengineering, and habitat features may be required for disturbed areas. This work may require a Hydraulic Project Approval (HPA) from the Washington State Department of Fish and Wildlife. See 1.2.13 Hydraulic Project Approvals.

Maintenance Standards

- Inspect and repair as needed.
- Add rock as needed to maintain the intended function.
- Clean energy dissipator if sediment builds up.

BMP C220: Inlet Protection

Purpose

Inlet protection prevents coarse sediment from entering drainage systems prior to permanent stabilization of the disturbed area.

Conditions of Use

Use inlet protection at inlets that are operational before permanent stabilization of the disturbed areas that contribute runoff to the inlet. Provide protection for all storm drain inlets downslope and within 500 feet of a disturbed or construction area, unless those inlets are preceded by a sediment trapping BMP.

Also consider inlet protection for lawn and yard drains on new home construction. These small and numerous drains coupled with lack of gutters can add significant amounts of sediment into the roof drain system. If possible, delay installing lawn and yard drains until just before landscaping, or cap these drains to prevent sediment from entering the system until completion of landscaping. Provide 18-inches of sod around each finished lawn and yard drain.

Table 7.11: Storm Drain Inlet Protection (continued) lists several options for inlet protection. All of the methods for inlet protection tend to plug and require a high frequency of maintenance. Limit contributing drainage areas for an individual inlet to one acre or less. If possible, provide emergency overflows with additional end-of-pipe treatment where stormwater ponding would cause a hazard.

Table 7.11: Storm Drain Inlet Protection

Type of Inlet Protection	Emergency Overflow	Applicable for Paved / Earthen Surfaces	Conditions of Use
Drop Inlet Protection			
Excavated drop	Yes, temporary	Earthen	Applicable for heavy flows. Easy

Table 7.11: Storm Drain Inlet Protection (continued)

Type of Inlet Protection	Emergency Overflow	Applicable for Paved / Earthen Surfaces	Conditions of Use
inlet protection	flooding may occur		to maintain. Large area requirement: 30'x30'/acre
Block and gravel drop inlet protection	Yes	Paved or Earthen	Applicable for heavy concentrated flows. Will not pond.
Gravel and wire drop inlet protection	No	Paved or Earthen	Applicable for heavy concentrated flows. Will pond. Can withstand traffic.
Catch basin filters	Yes	Paved or Earthen	Frequent maintenance required.
Curb Inlet Protection			
Curb inlet protection with wooden weir	Small capacity overflow	Paved	Used for sturdy, more compact installation.
Block and gravel curb inlet protection	Yes	Paved	Sturdy, but limited filtration.
Culvert Inlet Protection			
Culvert inlet sediment trap	N/A	N/A	18 month expected life.

Design and Installation Specifications

Excavated Drop Inlet Protection

Excavated drop inlet protection consists of an excavated impoundment around the storm drain inlet. Sediment settles out of the stormwater prior to entering the storm drain. Design and installation specifications for excavated drop inlet protection include:

- Provide a depth of 1 to 2 feet as measured from the crest of the inlet structure.
- Side slopes of excavation should be no steeper than 2H:1V.
- Minimum volume of excavation is 35 cubic yards.
- Shape the excavation to fit the site, with the longest dimension oriented toward the longest inflow area.
- Install provisions for draining to prevent standing water.
- Clear the area of all debris.
- Grade the approach to the inlet uniformly.

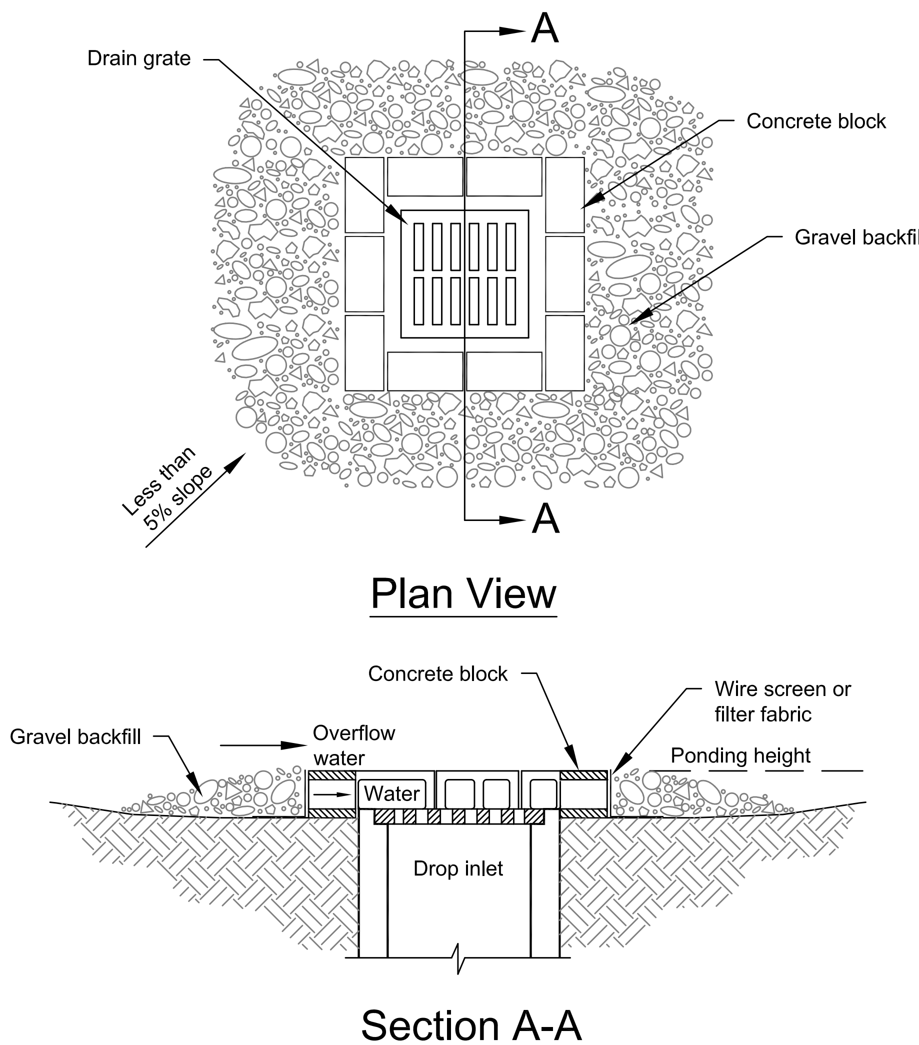
- Drill weep holes into the side of the inlet.
- Protect weep holes with screen wire and washed aggregate.
- Seal weep holes when removing structure and stabilizing area.
- Build a temporary dike, if necessary, to the down slope side of the structure to prevent bypass flow.

Block and Gravel Filter

A block and gravel filter is a barrier formed around the inlet with standard concrete blocks and gravel. See Figure 7.18: Block and Gravel Filter. Design and installation specifications for block and gravel filters include:

- Provide a height of 1 to 2 feet above the inlet.
- Recess the first row of blocks 2-inches into the ground for stability.
- Support subsequent courses by placing a pressure treated wood (2x4) through the block opening.
- Do not use mortar.
- Lay some blocks in the bottom row on their side to allow for dewatering the pool.
- Place hardware cloth or comparable wire mesh with 0.5-inch openings over all block openings.
- Place gravel to just below the top of blocks on slopes of 2H:1V or flatter.
- An alternative design is a gravel berm surrounding the inlet, as follows:
    - Provide a slope of 3H:1V on the upstream side of the berm.
    - Provide a slope of 2H:1V on the downstream side of the berm.
    - Provide a 1-foot wide level rock area between the gravel berm and the inlet.
    - Use rocks 3 inches in diameter or larger on the upstream slope of the berm.
    - Use gravel 0.5 to 0.75 inch at a minimum thickness of 1-foot on the downstream slope of the berm.

Figure 7.18: Block and Gravel Filter



Notes:

1. Drop inlet sediment barriers are to be used for small, nearly level drainage areas. (less than 5%)
2. Excavate a basin of sufficient size adjacent to the drop inlet.
3. The top of the structure (ponding height) must be well below the ground elevation downslope to prevent runoff from bypassing the inlet. A temporary dike may be necessary on the downslope side of the structure.

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Block and Gravel Filter

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Gravel and Wire Mesh Filter

Gravel and wire mesh filters are gravel barriers placed over the top of the inlet. This method does not provide an overflow. Design and installation specifications for gravel and wire mesh filters include:

- Use a hardware cloth or comparable wire mesh with 0.5 inch openings.
    - Place wire mesh over the drop inlet so that the wire extends a minimum of 1-foot beyond each side of the inlet structure.
    - Overlap the strips if more than one strip of mesh is necessary.
- Place coarse aggregate over the wire mesh.
    - Provide at least a 12-inch depth of aggregate over the entire inlet opening and extend at least 18-inches on all sides.

Catch Basin Filters

Catch basin filters are designed by manufacturers for construction sites. The limited sediment storage capacity increases the amount of inspection and maintenance required, which may be daily for heavy sediment loads. To reduce maintenance requirements, combine a catch basin filter with another type of inlet protection. This type of inlet protection provides flow bypass without overflow and therefore may be a better method for inlets located along active rights-of-way. Design and installation specifications for catch basin filters include:

- Provides 5 cubic feet of storage.
- Requires dewatering provisions.
- Provides a high-flow bypass that will not clog under normal use at a construction site.
- Insert the catch basin filter in the catch basin just below the grating.

Curb Inlet Protection with Wooden Weir

Curb inlet protection with wooden weir is an option that consists of a barrier formed around a curb inlet with a wooden frame and gravel. Design and installation specifications for curb inlet protection with wooden weirs include:

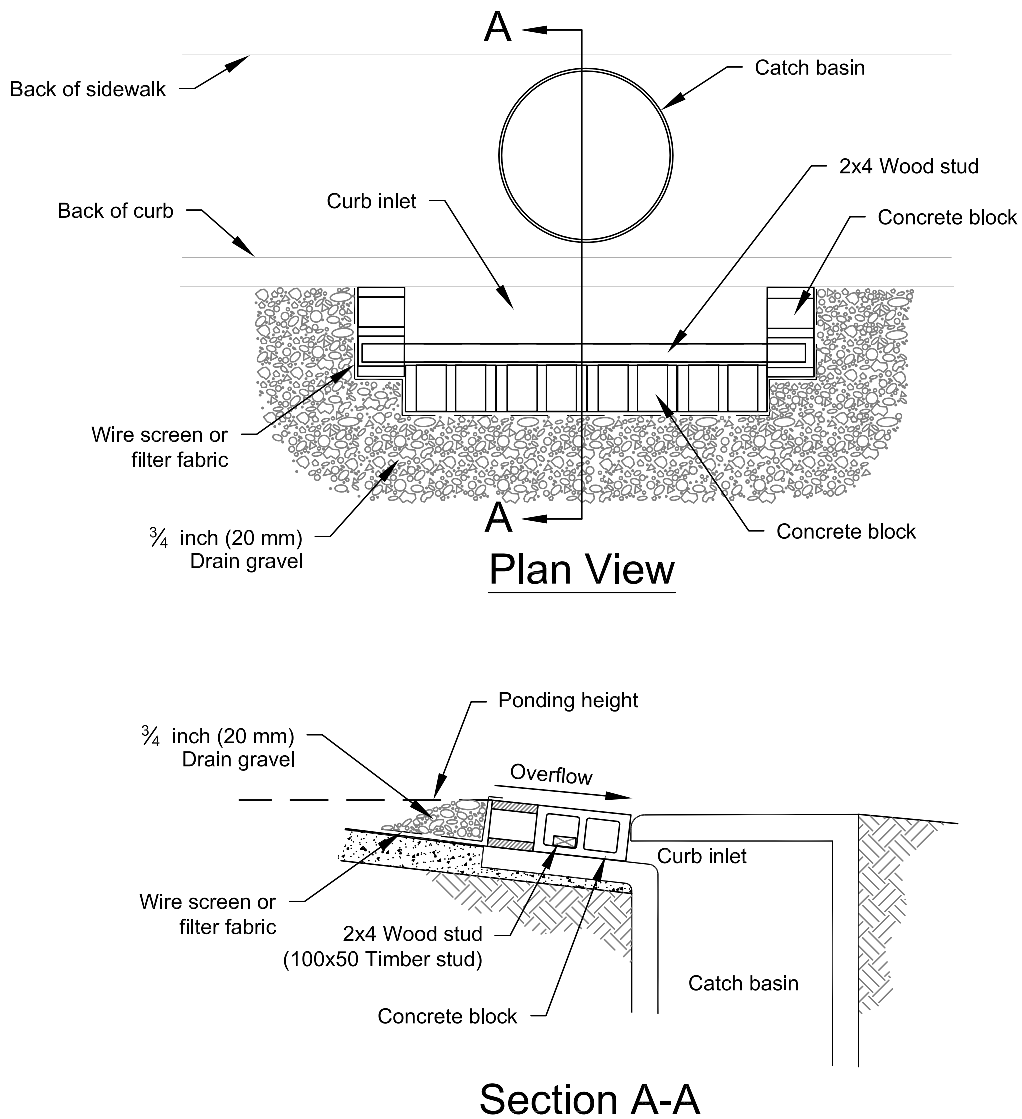
- Use wire mesh with 0.5 inch openings.
- Use extra strength filter cloth.
- Construct a frame.
- Attach the wire and filter fabric to the frame.
- Pile coarse washed aggregate against the wire and fabric.
- Place weight on the frame anchors.

Block and Gravel Curb Inlet Protection

Block and gravel curb inlet protection is a barrier formed around a curb inlet with concrete blocks and gravel. See Figure 7.19: Block and Gravel Curb Inlet Protection. Design and installation specifications for block and gravel curb inlet protection include:

- Use wire mesh with 0.5 inch openings.
- Place two concrete blocks on their sides abutting the curb at either side of the inlet opening. These are spacer blocks.
- Place a 2x4 stud 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 over the outside vertical face.
- Pile coarse aggregate against the wire to the top of the barrier.

Figure 7.19: Block and Gravel Curb Inlet Protection



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.

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Block and Gravel Curb Inlet Protection

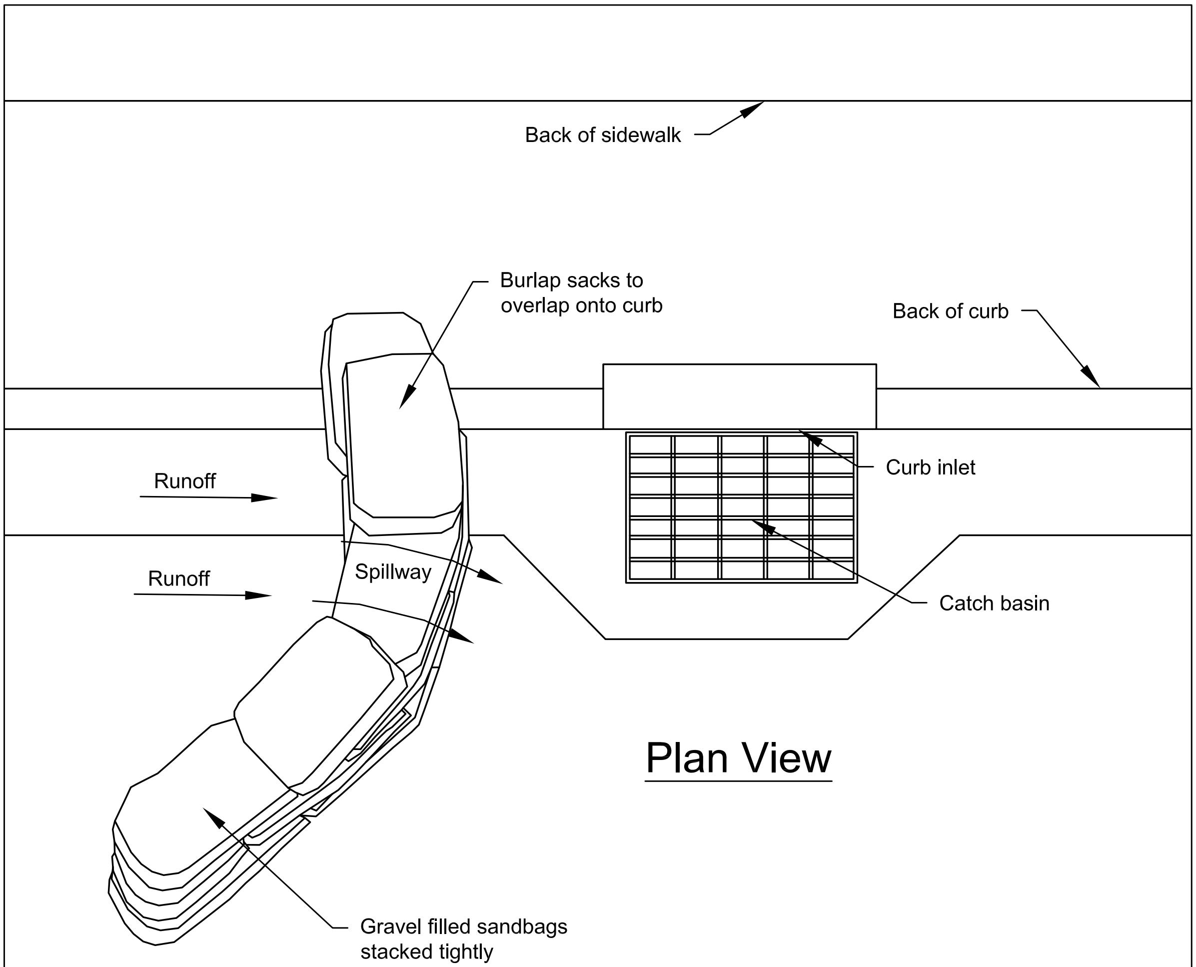
Revised June 2016

Curb and Gutter Sediment Barrier

A curb and gutter sediment barrier is a sandbag or rock berm (riprap and aggregate) 3 feet high and 3 feet wide in a horseshoe shape. See Figure 7.20: Curb and Gutter Barrier. Design and installation specifications for curb and gutter sediment barriers include:

- Construct a horseshoe shaped berm, faced with coarse aggregate if using riprap, 3 feet high and 3 feet wide, at least 2 feet from the inlet.
- Construct a horseshoe shaped sedimentation trap on the upstream side of the berm. Size the trap to sediment trap standards for protecting a culvert inlet.

Figure 7.20: Curb and Gutter Barrier



Notes:

1. Place curb type sediment barriers on gently sloping street segments, where water can pond and allow sediment to separate from runoff.
2. Sandbags of either burlap or woven 'geotextile' fabric, are filled with gravel, layered and packed tightly.
3. Leave a one sandbag gap in the top row to provide a spillway for overflow.
4. Inspect barriers and remove sediment after each storm event. Sediment and gravel must be removed from the traveled way immediately.

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Curb and Gutter Barrier

Revised June 2016

Maintenance Standards

- Inspect all forms of inlet protection frequently, especially after storm events. Clean and replace clogged catch basin filters. For rock and gravel filters, pull away the rocks from the inlet and clean or replace. An alternative approach would be to use the clogged rock as fill and put fresh rock around the inlet.
- 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.

Approved as Functionally Equivalent

Ecology has approved products as able to meet the requirements of this BMP. The products did not pass through the Technology Assessment Protocol – Ecology (TAPE) process. Local jurisdictions may choose not to accept these products, or may require additional testing prior to consideration for local use. Products that Ecology has approved as functionally equivalent are available for review on Ecology's website at:

https://ecology.wa.gov/Regulations-Permits/Guidance-technical-assistance/Stormwater-permittee-guidance-resources/Emerging-stormwater-treatment-technologies

BMP C231: Brush Barrier

Purpose

The purpose of brush barriers is to reduce the transport of coarse sediment from a construction site by providing a temporary physical barrier to sediment and reducing the runoff velocities of overland flow.

Conditions of Use

- Brush barriers may be used downslope of disturbed areas that are less than one-quarter acre.
- Brush barriers are not intended to treat concentrated flows, nor are they intended to treat substantial amounts of overland flow. Any concentrated flows must be directed to a sediment trapping BMP. The only circumstance in which overland flow can be treated solely by a brush barrier, rather than by a sediment trapping BMP, is when the area draining to the barrier is small.
- Brush barriers should only be installed on contours.

Design and Installation Specifications

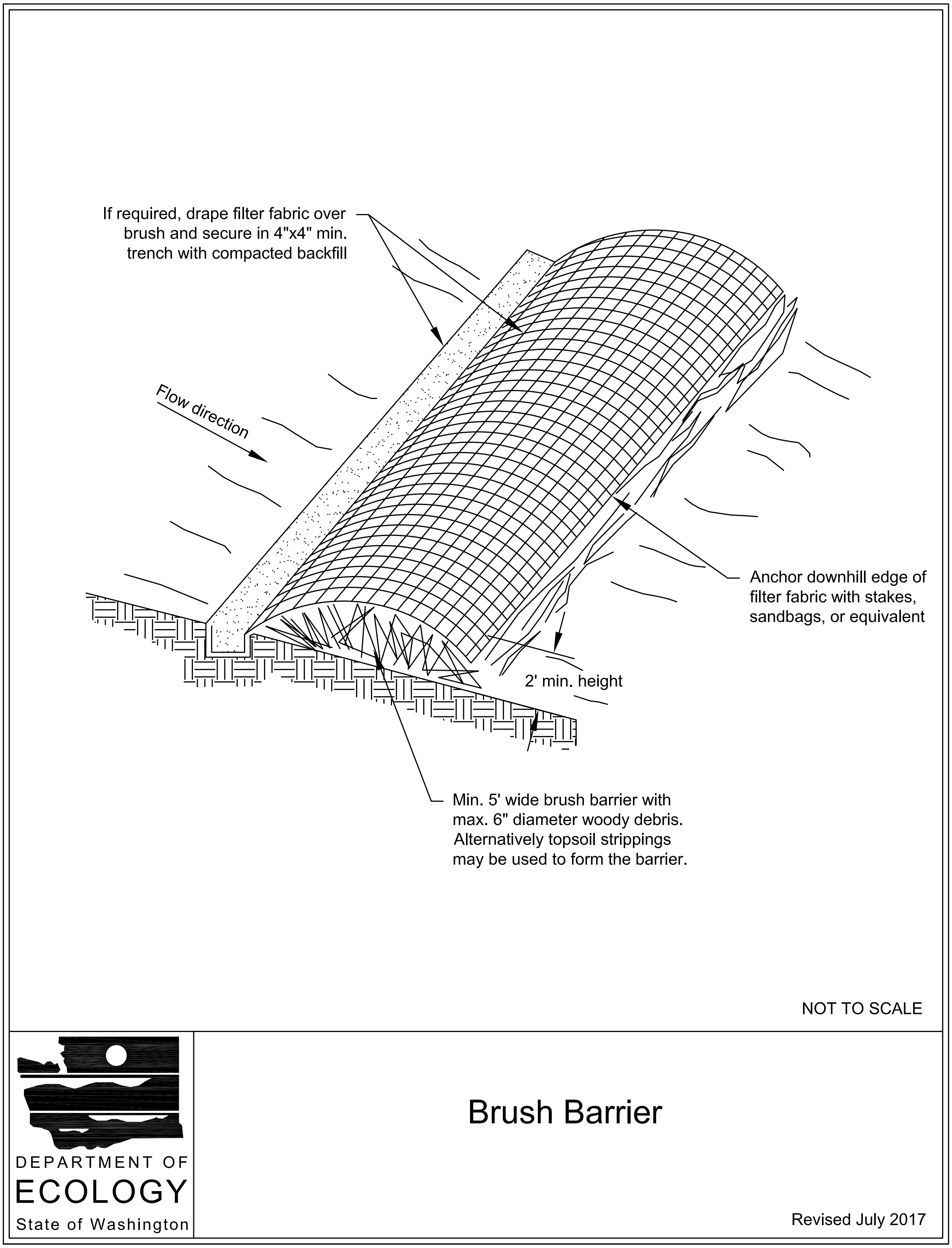
- Height: 2 feet (minimum) to 5 feet (maximum).
- Width: 5 feet at base (minimum) to 15 feet (maximum).
- Filter fabric (geotextile) may be anchored over the brush berm to enhance the filtration ability of the barrier. Ten-ounce burlap is an adequate alternative to filter fabric.
- Chipped site vegetation, composted mulch, or wood-based mulch (hog fuel) are acceptable materials to construct brush barriers.

- A 100% biodegradable installation can be constructed using 10-ounce burlap held in place by wooden stakes.
- Figure 7.21: Brush Barrier depicts a typical brush barrier.

Maintenance Standards

- There shall be no signs of erosion or concentrated runoff under or around the barrier. If concentrated flows are bypassing the barrier, it must be expanded or augmented by toed-in filter fabric.
- The dimensions of the barrier must be maintained.

Figure 7.21: Brush Barrier



BMP C232: Gravel Filter Berm

Purpose

A gravel filter berm retains sediment by filtering runoff through a berm of gravel or crushed rock.

Conditions of Use

Use a gravel filter berm where a temporary measure is needed to retain sediment from construction sites.

Do not place gravel filter berms in traffic areas; gravel filter berms are not intended to be driven over.

Place gravel filter berms perpendicular to the flow of runoff, such that the runoff will filter through the berm prior to leaving the site.

Design and Installation Specifications

- Berm material shall be 0.75 to 3 inches in size, washed well-graded gravel or crushed rock with less than 5% fines. Do not use crushed concrete.
- Spacing of berms:
  - Every 300 feet on slopes less than 5%
  - Every 200 feet on slopes between 5% and 10%
  - Every 100 feet on slopes greater than 10%
- Berm dimensions:
  - 1 foot high with 3H:1V side slopes
  - 8 linear feet per 1 cfs runoff based on the 10-year, 24-hour design storm
- See Figure 7.22: Gravel Filter Berm for a photo of a gravel filter berm application.

Maintenance Standards

Regular inspection is required. Sediment shall be removed and filter material replaced as needed.

Figure 7.22: Gravel Filter Berm

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State of Washington

Gravel Filter Berm

Revised July 2017

BMP C233: Silt Fence

Purpose

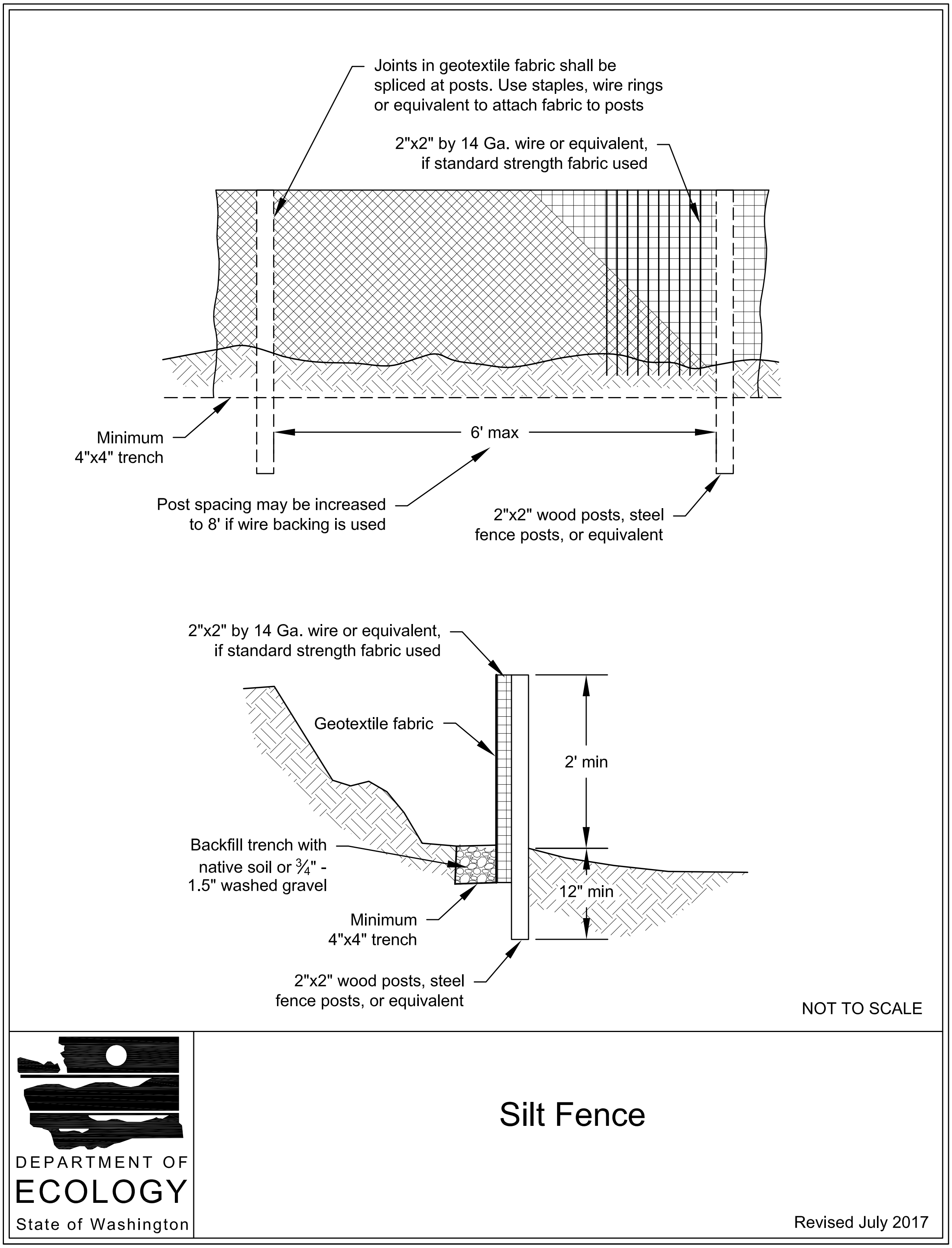
Silt fence reduces the transport of coarse sediment from a construction site by providing a temporary physical barrier to sediment and reducing the runoff velocities of overland flow.

Conditions of Use

Silt fence may be used downslope of all disturbed areas.

- Silt fence shall prevent sediment carried by runoff from going beneath, through, or over the top of the silt fence, but shall allow the water to pass through the fence.
- Silt fence is not intended to treat concentrated flows, nor is it intended to treat substantial amounts of overland flow. Convey any concentrated flows through the drainage system to a sediment trapping BMP.
- Do not construct silt fences in streams or use in V-shaped ditches. Silt fences do not provide an adequate method of silt control for anything deeper than sheet or overland flow.

Figure 7.23: Silt Fence



Design and Installation Specifications

- Use in combination with other construction stormwater BMPs.
- Maximum slope steepness (perpendicular to the silt fence line) 1H:1V.
- Maximum sheet or overland flow path length to the silt fence of 100 feet.
- Do not allow flows greater than 0.5 cfs.
- Use geotextile fabric that meets the following standards. All geotextile properties listed below are minimum average roll values (i.e. the test result for any sampled roll in a lot shall meet or exceed the values shown in Table 7.12: Geotextile Fabric Standards for Silt Fence):

Table 7.12: Geotextile Fabric Standards for Silt Fence

Geotextile Property	Minimum Average Roll Value
Polymeric Mesh AOS (ASTM D4751)	0.60 mm maximum for slit film woven (#30 sieve). 0.30 mm maximum for all other geotextile types (#50 sieve). 0.15 mm minimum for all fabric types (#100 sieve).
Water Permittivity (ASTM D4491)	0.02 sec^{-1} minimum
Grab Tensile Strength (ASTM D4632)	180 lbs minimum for extra strength fabric. 100 lbs minimum for standard strength fabric.
Grab Tensile Strength (ASTM D4632)	30% maximum
Ultraviolet Resistance (ASTM D4355)	70% minimum

- Support standard strength geotextiles with wire mesh, chicken wire, 2-inch x 2-inch wire, safety fence, or jute mesh to increase the strength of the geotextile. Silt fence materials are available that have synthetic mesh backing attached.
- Silt fence material shall 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.
- 100% biodegradable silt fence is available that is strong, long lasting, and can be left in place after the project is completed, if permitted by the local jurisdiction.
- Refer to Figure 7.23: Silt Fence for standard silt fence details. Include the following Standard Notes for silt fence on construction plans and specifications:

    1. The Contractor shall install and maintain temporary silt fences at the locations shown in the Plans.

2. Construct silt fences in areas of clearing, grading, or drainage prior to starting those activities.
3. The silt fence shall have a 2-foot min. and a 2.5-feet max. height above the original ground surface.
4. The geotextile fabric shall be sewn together at the point of manufacture to form fabric lengths as required. Locate all sewn seams at support posts. Alternatively, two sections of silt fence can be overlapped, provided that the overlap is long enough and that the adjacent silt fence sections are close enough together to prevent silt laden water from escaping through the fence at the overlap.
5. Attach the geotextile fabric on the up-slope side of the posts and secure with staples, wire, or in accordance with the manufacturer's recommendations. Attach the geotextile fabric to the posts in a manner that reduces the potential for tearing.
6. Support the geotextile fabric with wire or plastic mesh, dependent on the properties of the geotextile selected for use. If wire or plastic mesh is used, fasten the mesh securely to the up-slope side of the posts with the geotextile fabric up-slope of the mesh.
7. Mesh support, if used, shall consist of steel wire with a maximum mesh spacing of 2-inches, or a prefabricated polymeric mesh. The strength of the wire or polymeric mesh shall be equivalent to or greater than 180 lbs grab tensile strength. The polymeric mesh must be as resistant to the same level of ultraviolet radiation as the geotextile fabric it supports.
8. Bury the bottom of the geotextile fabric 4-inches min. below the ground surface. Backfill and tamp soil in place over the buried portion of the geotextile fabric, so that no flow can pass beneath the silt fence and scouring cannot occur. When wire or polymeric back-up support mesh is used, the wire or polymeric mesh shall extend into the ground 3-inches min.
9. Drive or place the silt fence posts into the ground 18-inches min. A 12–inch min. depth is allowed if topsoil or other soft subgrade soil is not present and 18-inches cannot be reached. Increase fence post min. depths by 6 inches if the fence is located on slopes of 3H:1V or steeper and the slope is perpendicular to the fence. If required post depths cannot be obtained, the posts shall be adequately secured by bracing or guying to prevent overturning of the fence due to sediment loading.
10. Use wood, steel or equivalent posts. The spacing of the support posts shall be a maximum of 6 feet. Posts shall consist of one of the following:
    - Wood with minimum dimensions of 2 inches by 2 inches by 3 feet. Wood shall be free of defects such as knots, splits, or gouges.
    - No. 6 steel rebar or larger.
    - ASTM A 120 steel pipe with a minimum diameter of 1-inch.
    - U, T, L, or C shape steel posts with a minimum weight of 1.35 lbs./ft.

- Other steel posts having equivalent strength and bending resistance to the post sizes listed above.

11. Locate silt fences on contour as much as possible, except at the ends of the fence, where the fence shall be turned uphill such that the silt fence captures the runoff water and prevents water from flowing around the end of the fence.

12. If the fence must cross contours, with the exception of the ends of the fence, place check dams perpendicular to the back of the fence to minimize concentrated flow and erosion. The slope of the fence line where contours must be crossed shall not be steeper than 3H:1V.

    - Check dams shall be approximately 1 foot deep at the back of the fence. Check dams shall be continued perpendicular to the fence at the same elevation until the top of the check dam intercepts the ground surface behind the fence.

    - Check dams shall consist of crushed surfacing base course, gravel backfill for walls, or shoulder ballast. Check dams shall be located every 10 feet along the fence where the fence must cross contours.

- Refer to Figure 7.24: Silt Fence Installation by Slicing Method for slicing method details. The following are specifications for silt fence installation using the slicing method:

    1. The base of both end posts must be at least 2 to 4 inches above the top of the geotextile fabric on the middle posts for ditch checks to drain properly. Use a hand level or string level, if necessary, to mark base points before installation.

    2. Install posts 3 to 4 feet apart in critical retention areas and 6 to 7 feet apart in standard applications.

    3. Install posts 24 inches deep on the downstream side of the silt fence, and as close as possible to the geotextile fabric, enabling posts to support the geotextile fabric from upstream water pressure.

    4. Install posts with the nipples facing away from the geotextile fabric.

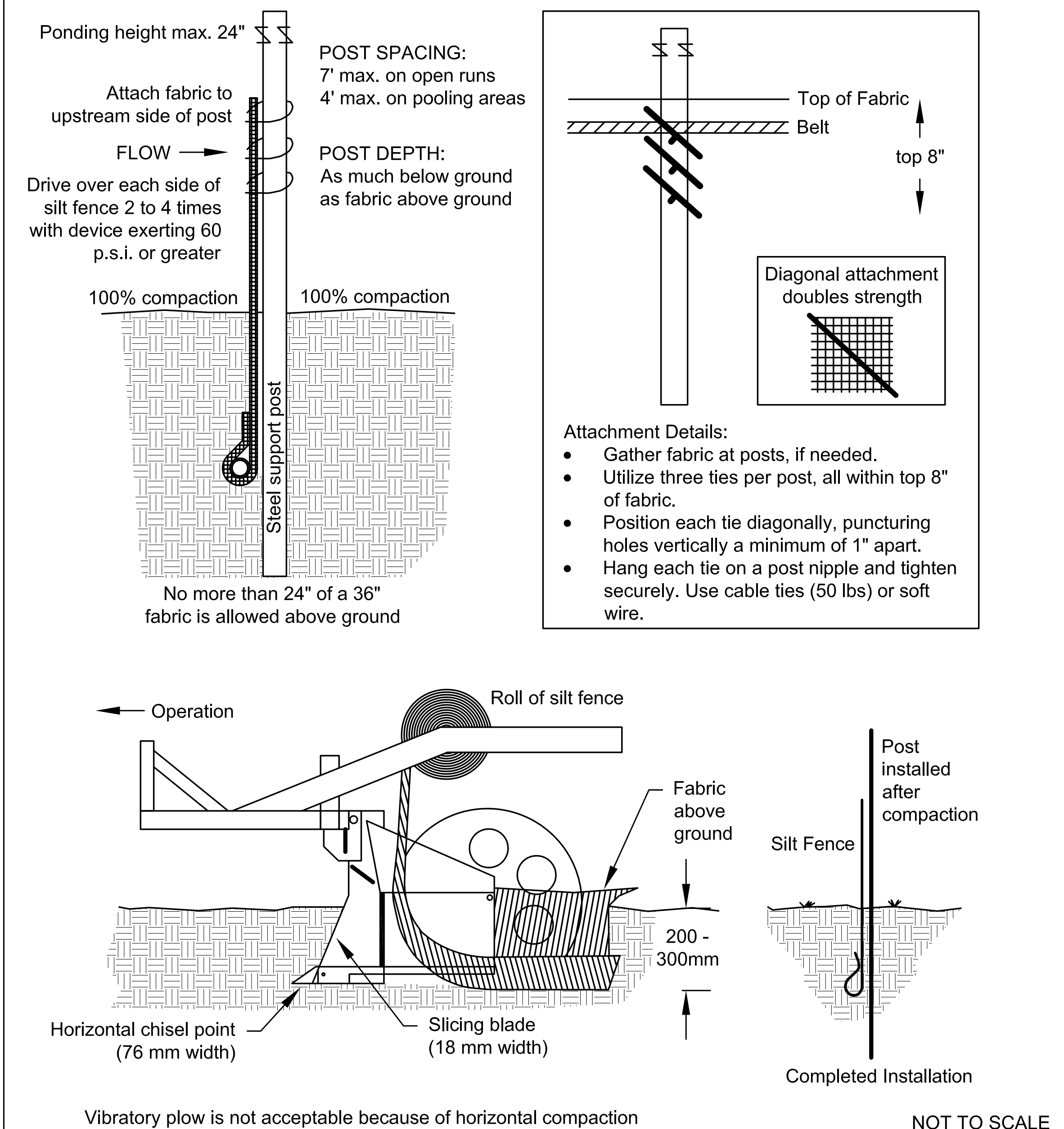
    5. Attach the geotextile fabric to each post with three ties, all spaced within the top 8 inches of the fabric. Attach each tie diagonally 45 degrees through the fabric, with each puncture at least 1-inch vertically apart. Each tie should be positioned to hang on a post nipple when tightening to prevent sagging.

    6. Wrap approximately 6 inches of the geotextile fabric around the end posts and secure with 3 ties.

    7. No more than 24 inches of a 36 inch geotextile fabric is allowed above ground level.

    8. Compact the soil immediately next to the geotextile fabric with the front wheel of the tractor, skid steer, or roller exerting at least 60 pounds per square inch. Compact the upstream side first and then each side twice for a total of four trips. Check and correct the silt fence installation for any deviation before compaction. Use a flat-bladed shovel to tuck the fabric deeper into the ground if necessary.

Figure 7.24: Silt Fence Installation by Slicing Method



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Silt Fence Installation by Slicing Method

Revised June 2016

Maintenance Standards

- Repair any damage immediately.
- Intercept and convey all evident concentrated flows uphill of the silt fence to a sediment trapping BMP.
- Check the uphill side of the silt fence for signs of the fence clogging and acting as a barrier to flow and then causing channelization of flows parallel to the fence. If this occurs, replace the fence and remove the trapped sediment.
- Remove sediment deposits when the deposit reaches approximately one-third the height of the silt fence, or install a second silt fence.
- Replace geotextile fabric that has deteriorated due to ultraviolet breakdown.

BMP C234: Vegetated Strip

Purpose

Vegetated strips reduce the transport of coarse sediment from a construction site by providing a physical barrier to sediment and reducing the runoff velocities of overland flow.

Conditions of Use

- Vegetated strips may be used downslope of all disturbed areas.
- 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 BMP C241: Sediment Pond (Temporary) or other sediment trapping BMP. The only circumstance in which overland flow can be treated solely by a vegetated strip, rather than by a sediment trapping BMP, is when the following criteria are met (see Table 7.13: Contributing Drainage Area for Vegetated Strips):

Table 7.13: Contributing Drainage Area for Vegetated Strips

Average Contributing Area Slope	Average Contributing Area Percent Slope	Maximum Contributing Area Flowpath Length
1.5H : 1V or flatter	67% or flatter	100 feet
2H : 1V or flatter	50% or flatter	115 feet
4H : 1V or flatter	25% or flatter	150 feet
6H : 1V or flatter	16.7% or flatter	200 feet
10H : 1V or flatter	10% or flatter	250 feet

Design and Installation Specifications

- The vegetated strip shall consist of a continuous strip of dense vegetation with topsoil for a minimum length of 25 feet along the flow path. Grass-covered, landscaped areas are generally not adequate because the volume of sediment overwhelms the grass. Ideally, vegetated strips shall consist of undisturbed native growth with a well-developed soil that allows for infiltration of runoff.

- The slope within the vegetated strip shall not exceed 4H:1V.
- The uphill boundary of the vegetated strip shall be delineated with clearing limits.

Maintenance Standards

- Any areas damaged by erosion or construction activity shall be seeded immediately and protected by mulch.
- If more than 5 feet of the original vegetated strip width has had vegetation removed or is being eroded, sod must be installed.
- If there are indications that concentrated flows are traveling across the vegetated strip, stormwater runoff controls must be installed to reduce the flows entering the vegetated strip, or additional perimeter protection must be installed.

BMP C235: Wattles

Purpose

Wattles are temporary erosion and sediment control barriers consisting of straw, compost, or other material that is wrapped in netting made of natural plant fiber or similar encasing material. They reduce the velocity and can spread the flow of rill and sheet runoff, and can capture and retain sediment.

Conditions of Use

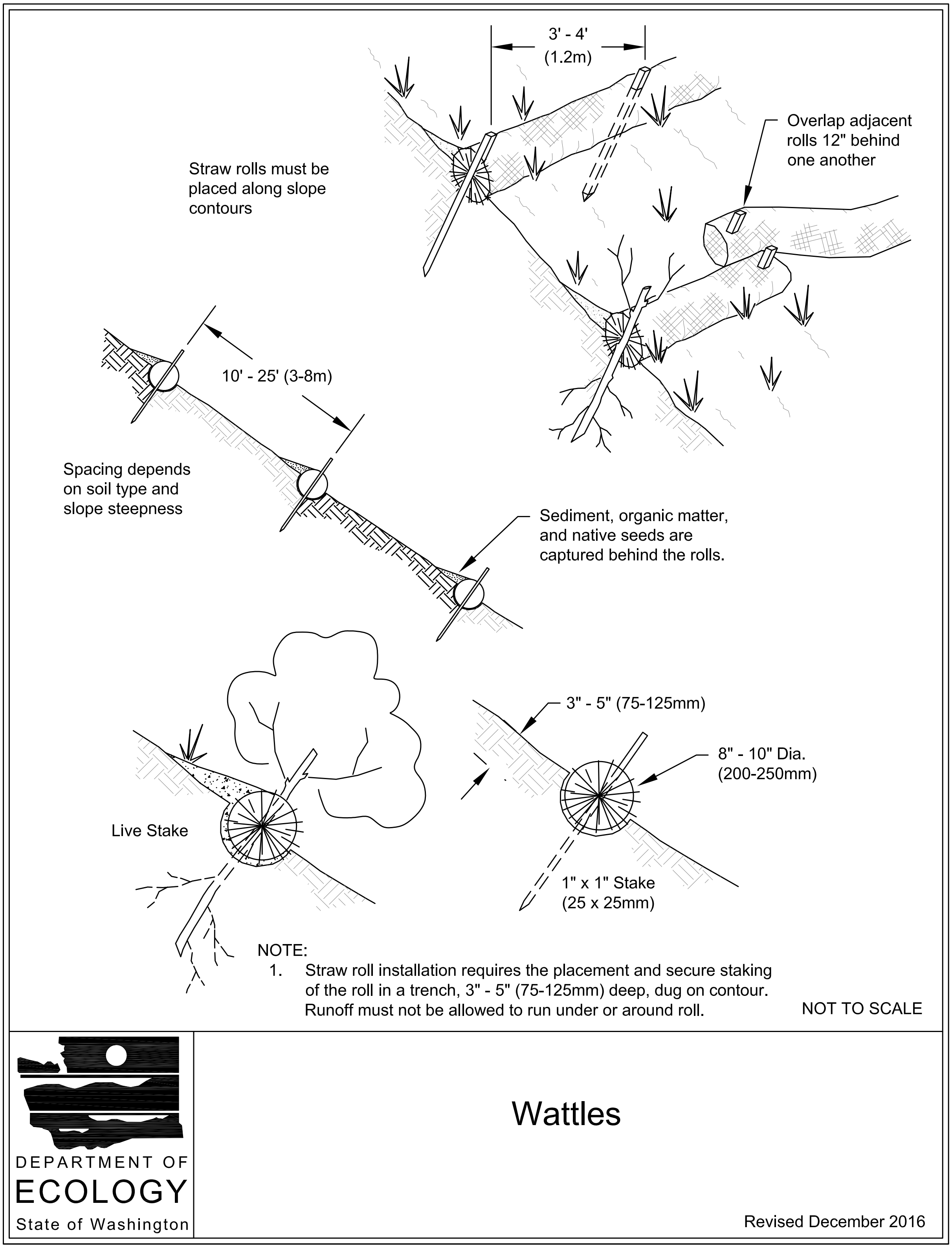
- Use wattles:
    - In disturbed areas that require immediate erosion protection.
    - On exposed soils during the period of short construction delays, or over winter months.
    - On slopes requiring stabilization until permanent vegetation can be established.
- The material used dictates the effectiveness period of the wattle. Generally, wattles are effective for one to two seasons.
- Prevent rilling beneath wattles by entrenching and overlapping wattles to prevent water from passing between them.

Design Criteria

- Wattles shall consist of cylinders of plant material such as weed-free straw, coir, wood chips, excelsior, or wood fiber or shavings encased within netting made of natural plant fibers unaltered by synthetic materials.
- See Figure 7.25: Wattles for typical construction details.
- Wattles are typically 8 to 10 inches in diameter and 25 to 30 feet in length.

- Install wattles perpendicular to the flow direction and parallel to the slope contour.
- Place wattles in shallow trenches, staked along the contour of disturbed or newly constructed slopes. Dig narrow trenches across the slope (on contour) to a depth of 3 to 5 inches on clay soils and soils with gradual slopes. On loose soils, steep slopes, and areas with high rainfall, the trenches should be dug to a depth of 5 to 7 inches, or 1/2 to 2/3 of the thickness of the wattle.
- 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 it using hand tamping or other methods.
- Construct trenches at intervals of 10 to 25 feet depending on the steepness of the slope, soil type, and rainfall. The steeper the slope the closer together the trenches.
- Install the wattles snugly into the trenches and overlap the ends of adjacent wattles 12 inches behind one another.
- 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.
- Wooden stakes should be approximately 0.75 x 0.75 x 24 inches minimum. Willow cuttings or 3/8 inch rebar can also be used for stakes.
- Stakes should be driven through the middle of the wattle, leaving 2 to 3 inches of the stake protruding above the wattle.

Figure 7.25: Wattles



Maintenance Standards

- Wattles may require maintenance to ensure they are in contact with soil and thoroughly entrenched, especially after significant rainfall on steep sandy soils.
- Inspect the slope after significant storms and repair any areas where wattles are not tightly abutted or water has scoured beneath the wattles.

Approved as Functionally Equivalent

Ecology has approved products as able to meet the requirements of this BMP. The products did not pass through the Technology Assessment Protocol – Ecology (TAPE) process. Local jurisdictions may choose not to accept these products, or may require additional testing prior to consideration for local use. Products that Ecology has approved as functionally equivalent are available for review on Ecology's website at:

https://ecology.wa.gov/Regulations-Permits/Guidance-technical-assistance/Stormwater-permittee-guidance-resources/Emerging-stormwater-treatment-technologies

BMP C236: Vegetative Filtration

Purpose

Vegetative filtration as a BMP is used in conjunction with detention storage in the form of portable tanks or BMP C241: Sediment Pond (Temporary), BMP C206: Level Spreader, and a pumping system with surface intake. Vegetative filtration improves turbidity levels of stormwater discharges by filtering runoff through existing vegetation where undisturbed forest floor duff layer or established lawn with thatch layer are present. Vegetative filtration can also be used to infiltrate dewatering waste from foundations, vaults, and trenches as long as runoff does not occur.

Conditions of Use

- For every 5 acres of disturbed soil, use 1 acre of grass field, farm pasture, or wooded area. Reduce or increase this area depending on project size, groundwater table height, and other site conditions.
- Wetlands shall not be used for vegetative filtration.
- Do not use this BMP in areas with a high groundwater table, or in areas that will have a high seasonal groundwater table during the use of this BMP.
- This BMP may be less effective on soils that prevent the infiltration of the water, such as hard till.
- Using other effective source control measures throughout a construction site will prevent the generation of additional highly turbid water and may reduce the time period or area need for this BMP.
- Stop distributing water into the vegetated filtration area if standing water or erosion results.
- On large projects that phase the clearing of the site, areas retained with native vegetation may be used as a temporary vegetative filtration area.

Design Criteria

- Find land adjacent to the project site that has a vegetated field, preferably a farm field or wooded area.
- If the site does not contain enough vegetated field area consider obtaining permission from adjacent landowners (especially for farm fields).
- Install a pump and downstream distribution manifold depending on the project size. Generally, the main distribution line should reach 100 to 200 feet long. Large projects, or projects on tight soil, will require systems that reach several thousand feet long with numerous branch lines off of the main distribution line.
- The manifold should have several valves, allowing for control over the distribution area in the field.
- Install several branches of 4 inch diameter schedule 20 polyvinyl chloride (PVC), swaged-fit common septic tight-lined sewer line, or 6 inch diameter fire hose, which can convey the turbid water out to various sections of the field. See Figure 7.26: Manifold and Branches in a Wooded, Vegetated Spray Field.
- Determine the branch length based on the field area geography and number of branches. Typically, branches stretch from 200 feet to several thousand feet. Lay the branches on contour with the slope.
- On uneven ground, sprinklers perform well. Space sprinkler heads so that spray patterns do not overlap.
- On relatively even surfaces, a level spreader using 4 inch diameter perforated pipe may be used as an alternative option to the sprinkler head setup. Install drain pipe at the highest point on the field and at various lower elevations to ensure full coverage of the filtration area. Place the pipe with the holes up to allow for gentle weeping evenly out all holes. Leveling the pipe by staking and using sandbags may be required.
- To prevent over saturating of the vegetative filtration area, rotate the use of branches or spray heads. Repeat as needed based on monitoring of the spray field.

Table 7.14: Flowpath Guidelines for Vegetative Filtration

Average Slope	Average Area % Slope	Estimated Flowpath Length (ft)
1.5H:1V	67%	250
2H:1V	50%	200
4H:1V	25%	150
6H:1V	16.7%	115
10H:1V	10%	100

Figure 7.26: Manifold and Branches in a Wooded, Vegetated Spray Field

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Manifold and Branches in a Wooded, Vegetated Spray Field

Revised June 2016

Maintenance Standards

- Monitor the spray field on a daily basis to ensure that over saturation of any portion of the field does not occur at any time. The presence of standing puddles of water or creation of concentrated flows visually signify that over saturation of the field has occurred.
- Monitor the vegetated spray field all the way down to the nearest surface water, or farthest spray area, to ensure that the water has not caused overland or concentrated flows, and has not created erosion around the spray nozzle(s).
- Do not exceed water quality standards for turbidity.
- Ecology recommends that a separate inspection log be developed, maintained, and kept with the existing site logbook to aid the operator conducting inspections. This separate “Field Filtration Logbook” can also aid in demonstrating compliance with permit conditions.
- Inspect the spray nozzles daily, at a minimum, for leaks and plugging from sediment particles.
- If erosion, concentrated flows, or over saturation of the field occurs, rotate the use of branches or spray heads or move the branches to a new field location.
- Check all branches and the manifold for unintended leaks.

BMP C240: Sediment Trap

Purpose

A sediment trap is a small temporary ponding area with a gravel outlet used to collect and store sediment from sites during construction. Sediment traps, along with other perimeter controls, shall be installed before any land disturbance takes place in the contributing drainage area.

Conditions of Use

- Sediment traps are intended for use on sites where the contributing drainage area is less than 3 acres, with no unusual drainage features, and a projected build-out time of 6 months or less. The sediment trap is a temporary measure (with a design life of approximately 6 months) and shall be maintained until the contributing drainage area is permanently protected against erosion by vegetation and/or structures.
- Sediment traps are only effective in removing sediment down to about the medium silt size fraction. Runoff with sediment of finer grades (fine silt and clay) will pass through untreated, emphasizing the need to control erosion to the maximum extent first.
- Projects that are constructing permanent Flow Control BMPs, or permanent Runoff Treatment BMPs that use ponding for treatment, may use the rough-graded or final-graded permanent BMP footprint for the temporary sediment trap. When permanent BMP footprints are used as temporary sediment traps, the surface area requirement of the sediment trap must be met. If the surface area requirement of the sediment trap is larger than the surface area of the permanent BMP, then the sediment trap shall be enlarged beyond the permanent BMP footprint to comply with the surface area requirement.

- A floating pond skimmer may be used for the sediment trap outlet if approved by the Local Permitting Authority.
- Sediment traps may not be feasible on utility projects due to the limited work space or the short-term nature of the work. Portable tanks may be used in place of sediment traps for utility projects.

Design and Installation Specifications

- See Figure 7.27: Cross Section of Sediment Trap and Figure 7.28: Sediment Trap Outlet for details.
- To determine the sediment trap geometry, first calculate the design surface area (SA) of the trap, measured at the invert of the weir. Use the following equation:

  $$SA = FS * (Q_2/V_s)$$

  where:

  SA = Design surface area of the trap (square feet)

  FS = A safety factor of 2 to account for non-ideal settling.

  Q_2 = The peak volumetric flow rate (cubic feet per second), calculated using one of the following options:

  - Option 1 - Single Event Hydrograph Method

    The peak volumetric flow rate calculated using a 10-minute time step from a 2-year, 24-hour frequency storm for the developed condition. The 10-year peak volumetric flow rate shall be used if the project size, expected timing and duration of construction, or downstream conditions warrant a higher level of protection.

  - Option 2 - The Rational Method

    For construction sites that are less than 1 acre, the peak volumetric flow rate calculated using the Rational Method.

  V_s = The settling velocity of the soil particle of interest. The 0.02 mm (medium silt) particle with an assumed density of 2.65 g/cm3 has been selected as the particle of interest and has a settling velocity (V_s) of 0.00096 ft/sec.

  Therefore, the equation for computing sediment trap surface area becomes:

  $$SA = 2 \times Q_2/0.00096$$

  or

  2080 square feet per cfs of inflow

- Sediment trap depth shall be 3.5 feet minimum from the bottom of the trap to the top of the overflow weir.
- To aid in determining sediment depth, all sediment traps shall have a staff gauge with a prominent mark 1 foot above the bottom of the trap.
- Design the discharge from the sediment trap by using the guidance for discharge from temporary sediment ponds in BMP C241: Sediment Pond (Temporary).

Maintenance Standards

- Sediment shall be removed from the trap when it reaches 1 foot in depth.
- Any damage to the trap embankments or slopes shall be repaired.

Figure 7.27: Cross Section of Sediment Trap

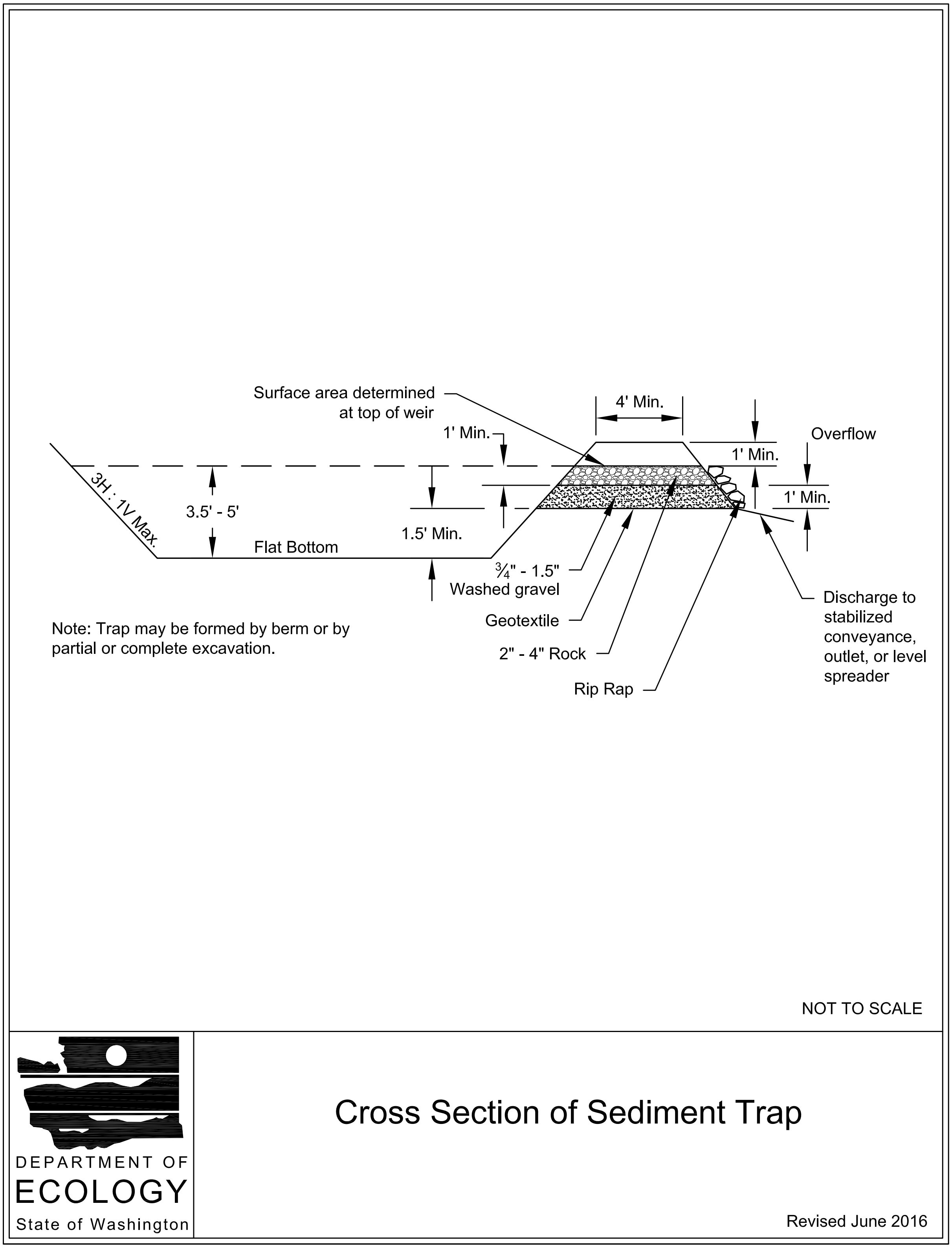
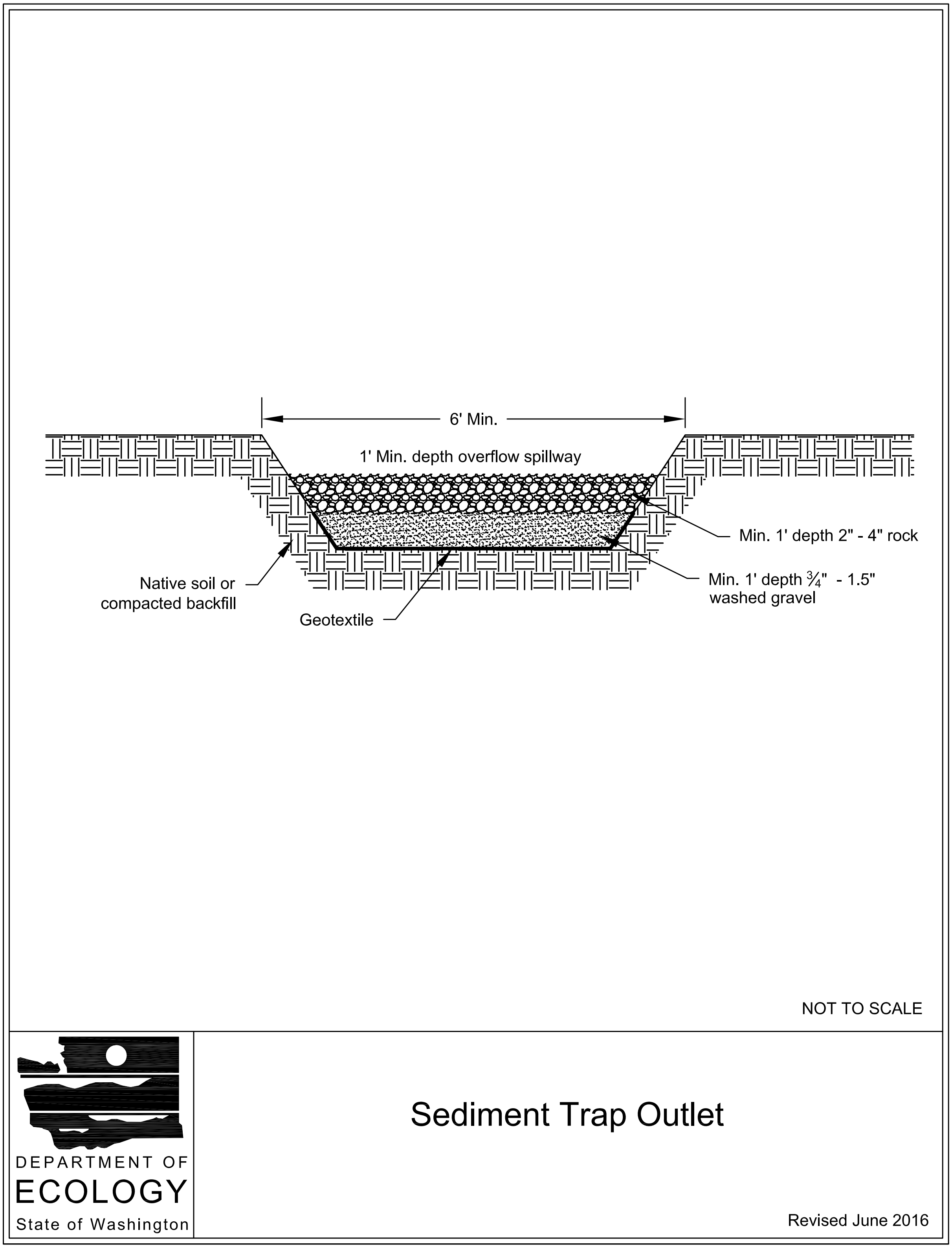


Figure 7.28: Sediment Trap Outlet



BMP C241: Sediment Pond (Temporary)

Purpose

Sediment ponds are temporary ponds used during construction to remove sediment from runoff originating from disturbed areas of the project site. Sediment ponds are typically designed to remove sediment no smaller than medium silt (0.02 mm). Consequently, they usually reduce turbidity only slightly.

Conditions of Use

- Use a sediment pond where the contributing drainage area to the pond is 3 acres or more. Ponds must be used in conjunction with other Construction Stormwater BMPs to reduce the amount of sediment flowing into the pond. For drainage areas smaller than 3 acres, use the guidance in BMP C240: Sediment Trap.
- Do not install sediment ponds on sites where failure of the BMP would result in loss of life, damage to homes or buildings, or interruption of use or service of public roads or utilities. Also, sediment ponds are attractive to children and can be dangerous. Compliance with local ordinances regarding health and safety must be addressed. If fencing of the pond is required, show the type of fence and its location on the drawings in the Construction SWPPP.
- Sediment ponds that can impound 10 acre-ft (435,600 cu-ft, or 3.26 million gallons) or more are subject to the Washington Dam Safety Regulations (Chapter 173-175 WAC). See BMP F6.10: Detention Ponds for more information regarding dam safety considerations for detention ponds.
- 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 pond. When permanent BMP footprints are used as temporary sediment ponds, the surface area requirement of the temporary sediment pond must be met. If the surface area requirement of the sediment pond is larger than the surface area of the permanent BMP, then the sediment pond shall be enlarged beyond the permanent BMP footprint to comply with the surface area requirement.

  The permanent control structure must be temporarily replaced with a control structure that only allows water to leave the temporary sediment pond from the surface or by pumping. Alternatively, the permanent control structure may be used if it is temporarily modified by plugging any outlet holes below the riser. The permanent control structure must be installed as part of the permanent BMP after the site is fully stabilized.

Design and Installation Specifications

General

- See Figure 7.29: Sediment Pond Plan View, Figure 7.30: Sediment Pond Cross Section, and Figure 7.31: Sediment Pond Riser Detail for details.

- Use of permanent infiltration BMP footprints for temporary sediment ponds during construction tends to clog the soils and reduce their capacity to infiltrate. If permanent infiltration BMP footprints are used, the sides and bottom of the temporary sediment pond must only be rough excavated to a minimum of 2 feet above final grade of the permanent infiltration BMP. Final grading of the permanent infiltration BMP shall occur only when all contributing drainage areas are fully stabilized. Any proposed permanent pretreatment BMP prior to the infiltration BMP should be fully constructed and used with the temporary sediment pond to help prevent clogging of the soils.

  See 7.2.13 Element 13: Protect Infiltration BMPs for more information about protecting permanent infiltration BMPs.

- The pond shall be divided into two roughly equal volume cells by a permeable divider that will reduce turbulence while allowing movement of water between the cells. The divider shall be at least one-half the height of the riser, and at least one foot below the top of the riser. Wire-backed, 2 to 3 foot high, high strength geotextile fabric supported by treated 4x4s can be used as a divider. Alternatively, staked straw bales wrapped with geotextile fabric may be used. If the pond is more than 6 feet deep, a different divider design must be proposed. A riprap embankment is one acceptable method of separation for deeper ponds. Other designs that satisfy the intent of this provision are allowed as long as the divider is permeable, structurally sound, and designed to prevent erosion under and around the divider.

- The most common structural failure of sediment ponds is caused by piping. Piping refers to two phenomena:

  1. Water seeping through fine-grained soil, eroding the soil grain by grain and forming pipes or tunnels; and,
  2. Water under pressure flowing upward through a granular soil with a head of sufficient magnitude to cause soil grains to lose contact and capability for support.

  The most critical construction practices to prevent piping are:

  - Tight connections between the riser and outlet pipe, and other pipe connections.
  - Adequate anchoring of the riser.
  - Proper soil compaction of the embankment and riser footing.
  - Proper construction of anti-seep devices.

Sediment Pond Geometry

To determine the sediment pond geometry, first calculate the design surface area (SA) of the pond, measured at the top of the riser pipe. Use the following equation:

$$SA = 2 \times Q_2/0.00096$$

or

2,080 square feet per cfs of inflow

where:

SA = design surface area of the pond (sf)

Q_2 = Peak volumetric flow rate (cfs)

See BMP C240: Sediment Trap for more information on the above equation.

The basic geometry of the pond can now be determined using the following design criteria:

- Required surface area SA (from the equation above) at the top of the riser.
- Minimum 3.5 foot depth from the top of the riser to the bottom of the pond.
- Maximum 3H:1V interior side slopes and maximum 2H:1V exterior slopes. The interior slopes can be increased to a maximum of 2H:1V if fencing is provided at or above the maximum water surface.
- One foot of freeboard between the top of the riser and the crest of the emergency spillway.
- Flat bottom.
- Minimum 1 foot deep spillway.
- Length-to-width ratio between 3:1 and 6:1.

Sediment Pond Discharge

The outlet for the pond consists of a combination of principal and emergency spillways. These outlets must pass the peak runoff expected from the contributing drainage area for a 100-year storm. If, due to site conditions and basin geometry, a separate emergency spillway is not feasible, the principal spillway must pass the entire peak runoff expected from the 100-year storm. However, an attempt to provide a separate emergency spillway should always be made. Base the runoff calculations on the site conditions during construction. The flow through the dewatering orifice cannot be utilized when calculating the 100-year storm elevation because of its potential to become clogged; therefore, available spillway storage must begin at the principal spillway riser crest.

The principal spillway designed by the procedures described below will result in some reduction in the peak rate of runoff. However, the design will not control the discharge flow rates to the extent required to comply with 2.4.6 CE6: Flow Control. The size of the contributing basin, the expected life of the construction project, the anticipated downstream effects, and the anticipated weather conditions during construction should be considered to determine the need for additional discharge control.

Principal Spillway: Determine the required diameter for the principal spillway (riser pipe). The diameter shall be the minimum necessary to pass the peak volumetric flow rate using a 10-minute time step from a 10-year, 24-hour frequency storm for the developed condition. Use Figure 7.32: Riser Inflow Curves to determine the riser diameter.

To aid in determining sediment depth, 1 foot intervals shall be prominently marked on the riser.

Emergency Overflow Spillway: Size the emergency overflow spillway for the peak volumetric flow rate using a 10-minute time step from a Type 1A, 100-year, 24-hour frequency storm for the developed condition. See BMP F6.10: Detention Ponds for additional guidance for Emergency Overflow Spillway design

Dewatering Orifice: Size the dewatering orifice(s) (minimum 1-inch diameter) using a modified version of the discharge equation for a vertical orifice and a basic equation for the area of a circular orifice. Determine the required area of the orifice with the following equation:

$$A_o = \frac{A_s * (2h)^{0.5}}{0.6 * 3600 * T * g^{0.5}}$$

where:

A_o = orifice area (square feet)

A_s = pond surface area (square feet)

h = head of water above orifice (height of riser in feet)

T = dewatering time (24 hours)

g = acceleration of gravity (32.2 feet/second^2)

Convert the orifice area (in square feet) to the orifice diameter D (in inches):

$$D = 24 \times \sqrt{\frac{A_o}{\pi}} = 13.54 \times \sqrt{A_o}$$

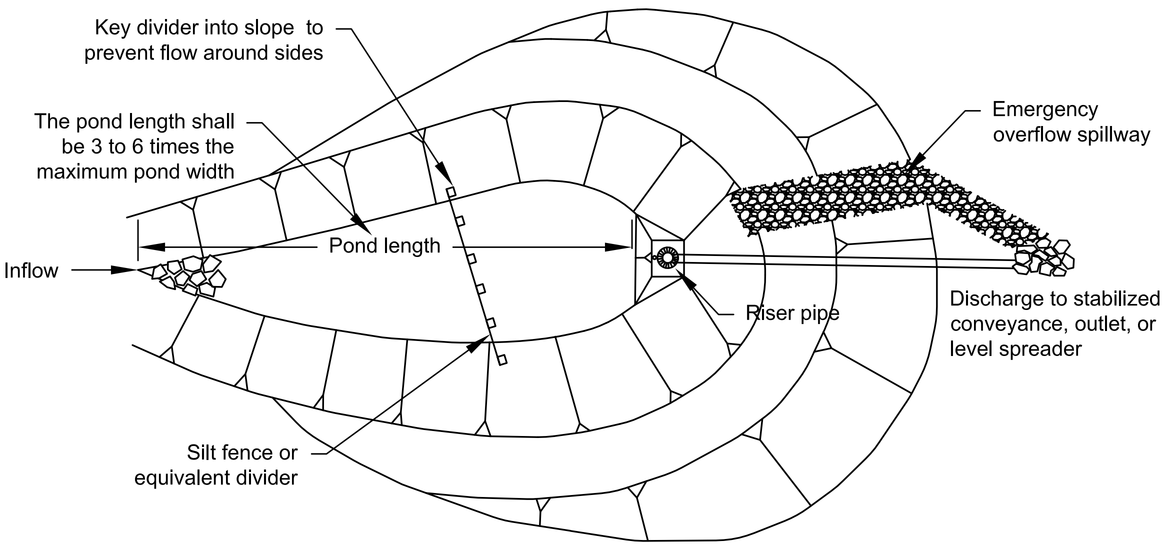
where:

D = orifice diameter (inches)

A_o = orifice area (sf)

The vertical, perforated tubing connected to the dewatering orifice must be at least 2 inches larger in diameter than the orifice to improve flow characteristics. The size and number of perforations in the tubing should be large enough so that the tubing does not restrict flow. The orifice should control the flow rate.

Figure 7.29: Sediment Pond Plan View



Note: Pond may be formed by berm or by partial or complete excavation

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Sediment Pond Plan View

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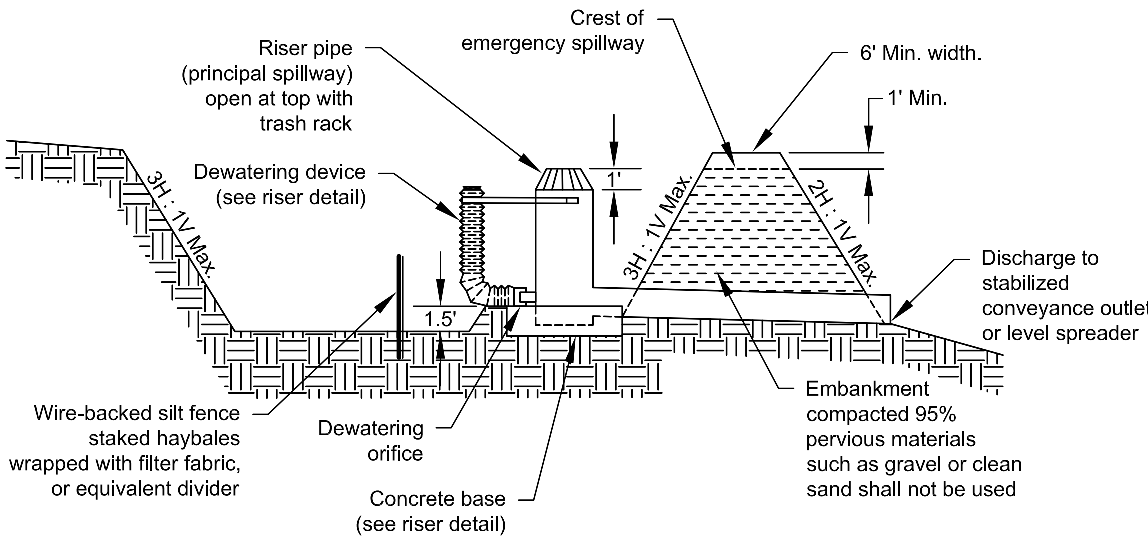
Figure 7.30: Sediment Pond Cross Section



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Sediment Pond Cross Section

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Figure 7.31: Sediment Pond Riser Detail

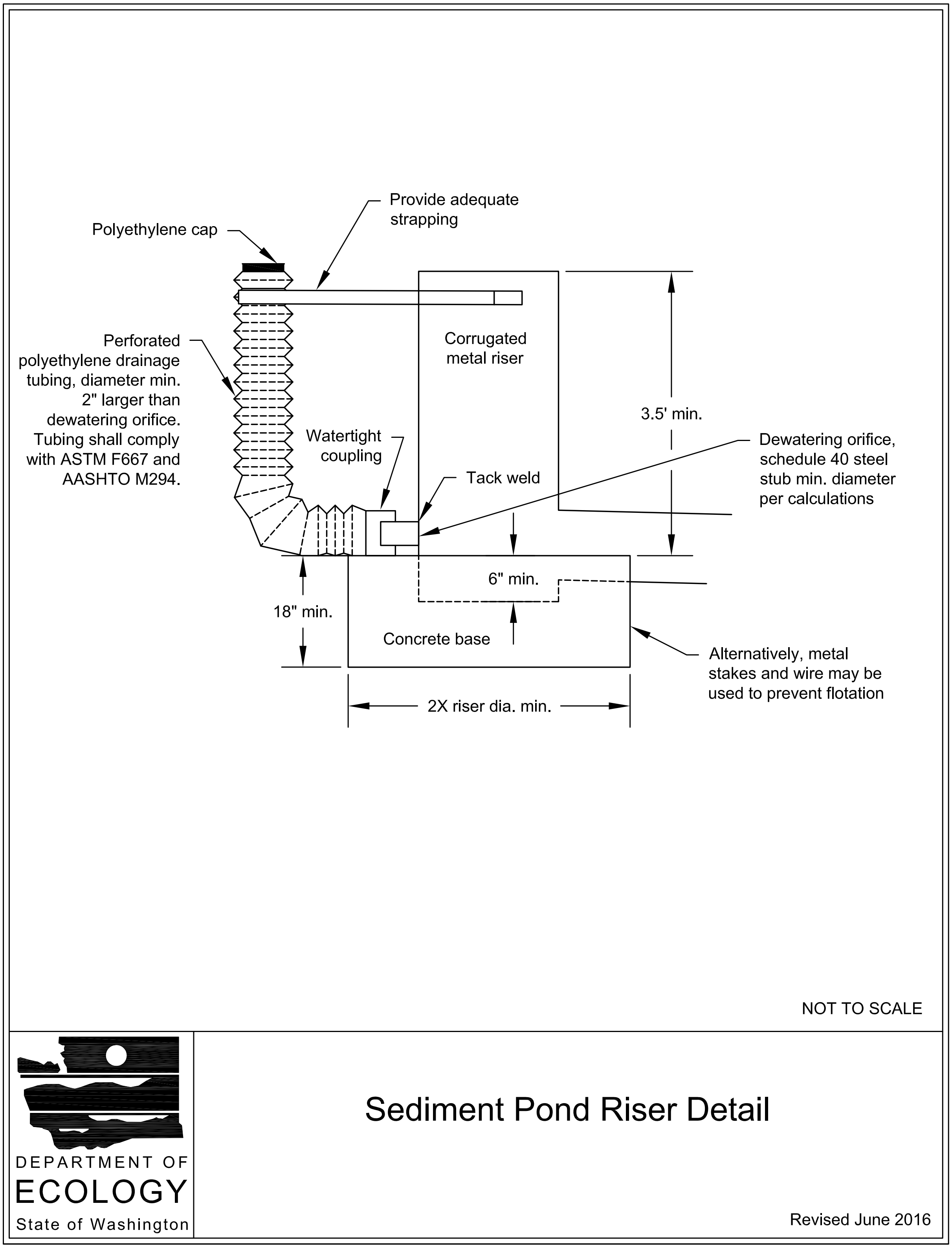
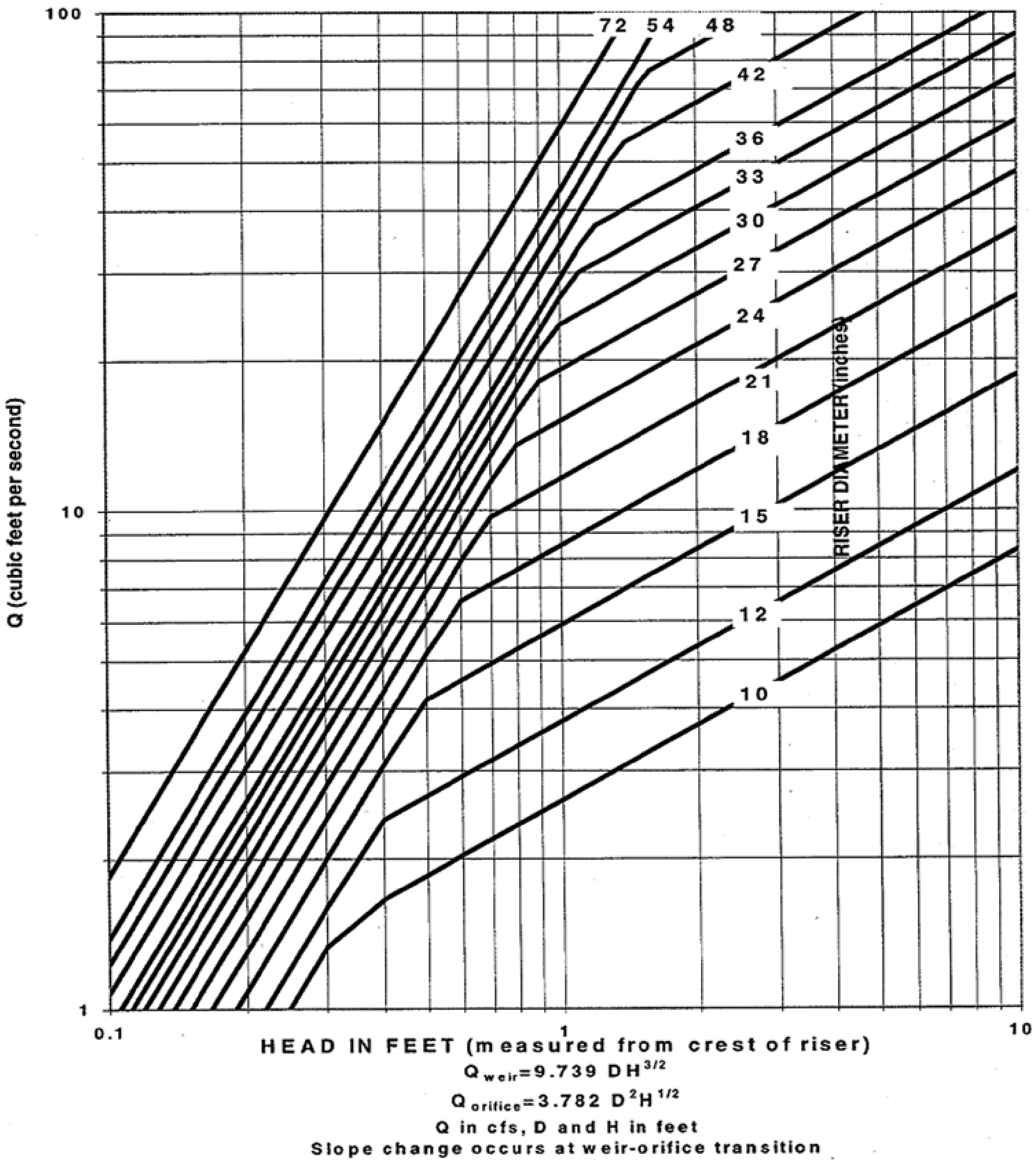


Figure 7.32: Riser Inflow Curves



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Riser Inflow Curves

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Maintenance Standards

- Remove sediment from the pond when it reaches 1 foot in depth.
- Repair any damage to the pond embankments or slopes.

BMP C250: Construction Stormwater Chemical Treatment

Purpose

This BMP applies when using chemicals to treat turbidity in stormwater by either batch or flow-through chemical treatment.

Turbidity is difficult to control once fine particles are suspended in stormwater runoff from a construction site. BMP C241: Sediment Pond (Temporary) is effective at removing larger particulate matter by gravity settling, but is ineffective at removing smaller particulates such as clay and fine silt. Traditional Construction Stormwater BMPs may not be adequate to ensure compliance with the water quality standards for turbidity in the receiving water.

Chemical treatment can reliably provide exceptional reductions of turbidity and associated pollutants. Chemical treatment may be required to meet turbidity stormwater discharge requirements, especially when construction proceeds through the wet season.

Conditions of Use

Formal written approval from Ecology is required for the use of chemical treatment, regardless of site size. See Ecology's Request for Chemical Treatment form at the following web address:

https://fortress.wa.gov/ecy/publications/SummaryPages/ecy070258.html

The Local Permitting Authority may also require review and approval. When authorized, the chemical treatment systems must be included in the Construction Stormwater Pollution Prevention Plan (SWPPP).

Chemically treated stormwater discharged from construction sites must be nontoxic to aquatic organisms. The Chemical Technology Assessment Protocol - Ecology (CTAPE) must be used to evaluate chemicals proposed for stormwater treatment. Only chemicals approved by Ecology under the CTAPE may be used for stormwater treatment. The approved chemicals, their allowable application techniques (batch treatment or flow-through treatment), allowable application rates, and conditions of use can be found at Ecology's Emerging Technologies website:

https://ecology.wa.gov/Regulations-Permits/Guidance-technical-assistance/Stormwater-permittee-guidance-resources/Emerging-stormwater-treatment-technologies

Background on Chemical Treatment Systems

Coagulation and flocculation have been used for over a century to treat water. The use of coagulation and flocculation to treat stormwater is a very recent application. Experience with the treatment of water and wastewater has resulted in a basic understanding of the process, in particular factors that affect performance. This experience can provide insights as to how to most effectively design and operate similar systems in the treatment of stormwater.

Fine particles suspended in water give it a milky appearance, measured as *turbidity*. Their small size, often much less than 1 micron (μm) in diameter, give them a very large surface area relative to their volume. These fine particles typically carry a negative surface charge. Largely because of these two factors (small size and negative charge), these particles tend to stay in suspension for extended periods of time. Thus, removal is not practical by gravity settling. These are called stable suspensions. Chemicals like polymers, as well as inorganic chemicals such as alum, speed the settling process. The added chemical destabilizes the suspension and causes the smaller particles to flocculate. The process consists of three primary steps: *coagulation*, *flocculation*, and settling or *clarification*. Ecology requires a fourth step, *filtration*, on all stormwater chemical treatment systems to reduce floc discharge and to provide monitoring prior to discharge.

General Design and Installation Specifications

- Chemicals approved for use in Washington State are listed on Ecology's TAPE website, under the "Construction" tab, at the following web address:

  http://www.ecy.wa.gov/programs/wq/stormwater/newtech/technologies.html

- Care must be taken in the design of the withdrawal system to minimize outflow velocities and to prevent floc discharge. Stormwater that has been chemically treated must be filtered through BMP C251: Construction Stormwater Filtration for filtration and monitoring prior to discharge.
- System discharge rates must take into account downstream conveyance integrity.
- The following equipment should be located on site in a lockable shed:
  - The chemical injector.
  - Secondary containment for acid, caustic, buffering compound, and treatment chemical.
  - Emergency shower and eyewash.
  - Monitoring equipment which consists of a pH meter and a turbidimeter.
- There are two types of systems for applying the chemical treatment process to stormwater: the batch chemical treatment system and the flow-through chemical treatment system. See below for further details for both types of systems.

Batch Chemical Treatment Systems

A batch chemical treatment system consists of four steps: *coagulation*, *flocculation*, *clarification*, and polishing and monitoring via *filtration*.

Step 1: Coagulation

Coagulation is the process by which negative charges on the fine particles are disrupted. By disrupting the negative charges, the fine particles are able to flocculate. Chemical addition is one method of destabilizing the suspension, and polymers are one class of chemicals that are generally effective. Chemicals that are used for this purpose are called coagulants. Coagulation is complete when the suspension is destabilized by the neutralization of the negative charges.

Coagulants perform best when they are thoroughly and evenly dispersed under relatively intense mixing. This rapid mixing involves adding the coagulant in a manner that promotes rapid dispersion, followed by a short time period for destabilization of the particle suspension. The particles are still very small and are not readily separated by clarification until flocculation occurs.

Step 2: Flocculation

Flocculation is the process by which fine particles that have been destabilized bind together to form larger particles that settle rapidly. Flocculation begins naturally following coagulation, but is enhanced by gentle mixing of the destabilized suspension. Gentle mixing helps to bring particles in contact with one another such that they bind and continually grow to form "flocs". As the size of the flocs increase, they become heavier and settle.

Step 3: Clarification

The final step is the settling of the particles, or clarification. Particle density, size and shape are important during settling. Dense, compact flocs settle more readily than less dense, fluffy flocs. Because of this, flocculation to form dense, compact flocs is particularly important during chemical treatment. Water temperature is important during settling. Both the density and viscosity of water are affected by temperature; these in turn affect settling. Cold temperatures increase viscosity and density, thus slowing down the rate at which the particles settle.

The conditions under which clarification is achieved can affect performance. Currents can affect settling. Currents can be produced by wind, by differences between the temperature of the incoming water and the water in the clarifier, and by flow conditions near the inlets and outlets. Quiescent water, such as that which occurs during batch clarification, provides a good environment for settling. One source of currents in batch chemical treatment systems is movement of the water leaving the clarifier unit. Because flocs are relatively small and light, the velocity of the water must be as low as possible. Settled flocs can be resuspended and removed by fairly modest currents.

Step 4: Filtration

After clarification, Ecology requires stormwater that has been chemically treated to be filtered and monitored prior to discharge. The sand filtration system continually monitors the stormwater effluent for turbidity and pH. If the discharge water is ever out of an acceptable range for turbidity or pH, the water is returned to the untreated stormwater pond where it will begin the treatment process again.

Design and Installation of Batch Chemical Treatment Systems

A batch chemical treatment system consists of a stormwater collection system (either a temporary diversion or the permanent site drainage system), an untreated stormwater storage pond, pumps, a chemical feed system, treatment cells, a filtering and monitoring system, and interconnecting piping.

The batch treatment system uses a storage pond for untreated stormwater, followed by a minimum of two lined treatment cells. Multiple treatment cells allow for clarification of chemically treated water in one cell, while other cells are being filled or emptied. Treatment cells may be ponds or tanks.

Ponds that can impound 10 acre-feet or more are subject to the Washington Dam Safety Regulations (Chapter 173-175 WAC). See BMP F6.10: Detention Ponds for more information regarding dam safety considerations for ponds.

Stormwater is collected at interception point(s) on the site and is diverted by gravity or by pumping to an untreated stormwater storage pond or other untreated stormwater holding area. The stormwater is stored until treatment occurs. It is important that the storage pond is large enough to provide adequate storage.

The first step in the treatment sequence is to check the pH of the stormwater in the untreated stormwater storage pond. The pH is adjusted by the application of carbon dioxide or a base until the stormwater in the untreated storage pond is within the desired pH range, 6.5 to 8.5. When used, carbon dioxide is added immediately downstream of the transfer pump. Typically sodium bicarbonate (baking soda) is used as a base, although other bases may be used. When needed, base is added directly to the untreated stormwater storage pond. The stormwater is recirculated with the treatment pump to provide mixing in the storage pond. Initial pH adjustments should be based on daily bench tests. Further pH adjustments can be made at any point in the process. See BMP C252: Treating and Disposing of High pH Water for more information on pH adjustments as a part of chemical treatment.

Once the stormwater is within the desired pH range (which is dependent on the coagulant being used), the stormwater is pumped from the untreated stormwater storage pond to a lined treatment cell as a coagulant is added. The coagulant is added upstream of the pump to facilitate rapid mixing.

The water is kept in the lined treatment cell for clarification. In a batch mode process, clarification typically takes from 30 minutes to several hours. Prior to discharge, samples are withdrawn for analysis of pH, coagulant concentration, and turbidity. If these levels are acceptable, the treated water is withdrawn, filtered, and discharged.

Several configurations have been developed to withdraw treated water from the treatment cell. The original configuration is a device that withdraws the treated water from just beneath the water surface using a float with adjustable struts that prevent the float from settling on the cell bottom. This reduces the possibility of picking up floc from the bottom of the cell. The struts are usually set at a minimum clearance of about 12 inches; that is, the float will come within 12 inches of the bottom of the cell. Other systems have used vertical guides or cables which constrain the float, allowing it to drift up and down with the water level. More recent designs have an H-shaped array of pipes, set on the horizontal. This scheme provides for withdrawal from four points rather than one. This configuration reduces the likelihood of sucking settled solids from the bottom. It also reduces the tendency for a vortex to form. Inlet diffusers, a long floating or fixed pipe with many small holes in it, are also an option.

Safety is a primary concern. Design should consider the hazards associated with operations, such as sampling. Facilities should be designed to reduce slip hazards and drowning. Tanks and ponds should have life rings, ladders, or steps extending from the bottom to the top.

Sizing Batch Chemical Treatment Systems

Chemical treatment systems must be designed to control the velocity and peak volumetric flow rate that is discharged from the system and consequently the project site. See 7.2.3 Element 3: Control Flow Rates for further details on this requirement.

The total volume of the untreated stormwater storage pond and treatment cell(s) must be large enough to treat stormwater that is produced during multiple day storm events. It is recommended that at a minimum the untreated stormwater storage pond be sized to hold 1.5 times the volume of runoff generated from the site during the 10-year, 24-hour storm event. Bypass should be provided around the chemical treatment system to accommodate extreme storm events. Runoff volume shall be calculated using the methods presented in Chapter 4 - Hydrologic Analysis and Design. If no hydrologic analysis is required for the site, the Rational Method may be used. Worst-case land cover conditions (i.e., producing the most runoff) should be used for analyses (in most cases, this would be the land cover conditions just prior to final landscaping).

Primary settling should be encouraged in the untreated stormwater storage pond. A forebay with access for maintenance may be beneficial.

There are two opposing considerations in sizing the treatment cells. A larger cell is able to treat a larger volume of water each time a batch is processed. However, the larger the cell, the longer the time required to empty the cell. A larger cell may also be less effective at flocculation and therefore require a longer settling time. The simplest approach to sizing the treatment cell is to multiply the allowable discharge flow rate (as determined by the guidance in 7.2.3 Element 3: Control Flow Rates) times the desired drawdown time. A 4 hour drawdown time allows one batch per cell per 8 hour work period, given 1 hour of flocculation followed by 2 hours of settling.

See BMP C251: Construction Stormwater Filtration for details on sizing the filtration system at the end of the batch chemical treatment system.

If the chemical treatment system design does not allow you to discharge at the rates as required by 7.2.3 Element 3: Control Flow Rates, and if the site has a permanent Flow Control BMP that will serve the planned development, the discharge from the chemical treatment system may be directed to the permanent Flow Control BMP to comply with 7.2.3 Element 3: Control Flow Rates. In this case, all discharge (including water passing through the treatment system and stormwater bypassing the treatment system) will be directed into the permanent Flow Control BMP. If site constraints make locating the untreated stormwater storage pond difficult, the permanent Flow Control BMP may be divided to serve as the untreated stormwater storage pond and the post-treatment temporary flow control pond. A berm or barrier must be used in this case so the untreated water does not mix with the treated water. Both untreated stormwater storage requirements, and adequate post-treatment flow control must be achieved. The designer must document in the Construction SWPPP how the permanent Flow Control BMP is able to attenuate the discharge from the site to meet the requirements of 7.2.3 Element 3: Control Flow Rates. If the design of the permanent Flow Control BMP was modified for temporary construction flow control purposes, the construction of the permanent Flow Control BMP must be finalized, as designed for its permanent function, at project completion.

Flow-Through Chemical Treatment Systems

Background on Flow-Through Chemical Treatment Systems

A flow-through chemical treatment system adds a sand filtration component to the batch chemical treatment system's treatment train following flocculation. The coagulant is added to the stormwater upstream of the sand filter so that the coagulation and flocculation step occur immediately prior to the filter. The advantage of a flow-through chemical treatment system is the time saved by immediately filtering the water, as opposed to waiting for the clarification process necessary in a batch chemical treatment system. See BMP C251: Construction Stormwater Filtration for more information on filtration.

Design and Installation of Flow-Through Chemical Treatment Systems

At a minimum, a flow-through chemical treatment system consists of a stormwater collection system (either a temporary diversion or the permanent site drainage system), an untreated stormwater storage pond, and a chemically enhanced sand filtration system.

As with a batch treatment system, stormwater is collected at interception point(s) on the site and is diverted by gravity or by pumping to an untreated stormwater storage pond or other untreated stormwater holding area. The stormwater is stored until treatment occurs. It is important that the holding pond be large enough to provide adequate storage.

Stormwater is then pumped from the untreated stormwater storage pond to the chemically enhanced sand filtration system where a coagulant is added. Adjustments to pH may be necessary before coagulant addition. The sand filtration system continually monitors the stormwater effluent for turbidity and pH. If the discharge water is ever out of an acceptable range for turbidity or pH, the water is returned to the untreated stormwater pond where it will begin the treatment process again.

Sizing Flow-Through Chemical Treatment Systems

Refer to BMP C251: Construction Stormwater Filtration for sizing requirements of flow-through chemical treatment systems.

Factors Affecting the Chemical Treatment Process

Coagulants

Cationic polymers can be used as coagulants to destabilize negatively charged turbidity particles present in natural waters, wastewater and stormwater. Polymers are large organic molecules that are made up of subunits linked together in a chain-like structure. Attached to these chain-like structures are other groups that carry positive or negative charges, or have no charge. Polymers that carry groups with positive charges are called cationic, those with negative charges are called anionic, and those with no charge (neutral) are called nonionic. In practice, the only way to determine whether a polymer is effective for a specific application is to perform preliminary or on-site testing.

Aluminum sulfate (alum) can also be used as a coagulant, as this chemical becomes positively charged when dispersed in water.

Polymers are available as powders, concentrated liquids, and emulsions (which appear as milky liquids). The latter are petroleum based, which are not allowed for construction stormwater treatment. Polymer effectiveness can degrade with time and also from other influences. Thus, manufacturers' recommendations for storage should be followed. Manufacturer's recommendations usually do not provide assurance of water quality protection or safety to aquatic organisms. Consideration of water quality protection is necessary in the selection and use of all polymers.

Application

Application of coagulants at the appropriate concentration or dosage rate for optimum turbidity removal is important for management of chemical cost, for effective performance, and to avoid aquatic toxicity. The optimum dose in a given application depends on several site-specific features. Turbidity of untreated water can be important with turbidities greater than 5,000 NTU. The surface charge of particles to be removed is also important. Environmental factors that can influence dosage rate are water temperature, pH, and the presence of constituents that consume or otherwise affect coagulant effectiveness. Laboratory experiments indicate that mixing previously settled sediment (floc sludge) with the untreated stormwater significantly improves clarification, therefore reducing the effective dosage rate. Preparation of working solutions and thorough dispersal of coagulants in water to be treated is also important to establish the appropriate dosage rate.

For a given water sample, there is generally an optimum dosage rate that yields the lowest residual turbidity after settling. When dosage rates below this optimum value (underdosing) are applied, there is an insufficient quantity of coagulant to react with, and therefore destabilize, all of the turbidity present. The result is residual turbidity (after flocculation and settling) that is higher than with the optimum dose. Overdosing, application of dosage rates greater than the optimum value, can also negatively impact performance. Like underdosing, the result of overdosing is higher residual turbidity than that with the optimum dose.

Mixing

The G-value, or just "G", is often used as a measure of the mixing intensity applied during coagulation and flocculation. The symbol G stands for “velocity gradient”, which is related in part to the degree of turbulence generated during mixing. High G-values mean high turbulence, and vice versa.

High G-values provide the best conditions for coagulant addition. With high G's, turbulence is high and coagulants are rapidly dispersed to their appropriate concentrations for effective destabilization of particle suspensions.

Low G-values provide the best conditions for flocculation. Here, the goal is to promote formation of dense, compact flocs that will settle readily. Low G's provide low turbulence to promote particle collisions so that flocs can form. Low G's generate sufficient turbulence such that collisions are effective in floc formation, but do not break up flocs that have already formed.

pH Adjustment

The pH must be in the proper range for the coagulants to be effective, which is typically 6.5 to 8.5. As polymers tend to lower the pH, it is important that the stormwater have sufficient buffering capacity. Buffering capacity is a function of alkalinity. Without sufficient alkalinity, the application of the polymer may lower the pH to below 6.5. A pH below 6.5 not only reduces the effectiveness of the polymer as a coagulant, but it may also create a toxic condition for aquatic organisms. Stormwater may not be discharged without readjustment of the pH to above 6.5. The target pH should be within 0.2 standard units of the receiving water's pH.

Experience gained at several projects in the City of Redmond has shown that the alkalinity needs to be at least 50 mg/L to prevent a drop in pH to below 6.5 when the polymer is added.

Maintenance Standards

Monitoring

At a minimum, the following monitoring shall be conducted. Test results shall be recorded on a daily log kept on site. Additional testing may be required by the NPDES permit based on site conditions.

- Operational Monitoring
  - Total volume treated and discharged.
  - Flow must be continuously monitored and recorded at not greater than 15-minute intervals.
  - Type and amount of chemical used for pH adjustment.
  - Type and amount of coagulant used for treatment.
  - Settling time.
- Compliance Monitoring
  - Influent and effluent pH, flocculent chemical concentration, and turbidity must be continuously monitored and recorded at not greater than 15-minute intervals.
  - pH and turbidity of the receiving water.
- Biomonitoring
  - Treated stormwater must be non-toxic to aquatic organisms. Treated stormwater must be tested for aquatic toxicity or residual chemicals. Frequency of biomonitoring will be determined by Ecology.
  - Residual chemical tests must be approved by Ecology prior to their use.
  - If testing treated stormwater for aquatic toxicity, you must test for acute (lethal) toxicity. Bioassays shall be conducted by a laboratory accredited by Ecology, unless otherwise approved by Ecology. Acute toxicity tests shall be conducted per the

CTAPE protocol and Appendix G of *Whole Effluent Toxicity Testing Guidance and Test Review Criteria* (Marshall, 2016).

Discharge Compliance

Prior to discharge, treated stormwater must be sampled and tested for compliance with pH, flocculent chemical concentration, and turbidity limits. These limits may be established by the Construction Stormwater General Permit or a site-specific discharge permit. Sampling and testing for other pollutants may also be necessary at some sites. pH must be within the range of 6.5 to 8.5 standard units and not cause a change in the pH of the receiving water by more than 0.2 standard units. Treated stormwater samples and measurements shall be taken from the discharge pipe or another location representative of the nature of the treated stormwater discharge. Samples used for determining compliance with the water quality standards in the receiving water shall not be taken from the treatment pond prior to decanting. Compliance with the water quality standards is determined in the receiving water.

Operator Training

Each project site using chemical treatment must have a trained operator who is certified for operation of an Enhanced Chemical Treatment system. The operator must be trained and certified by an organization approved by Ecology. Organizations approved for operator training are found at the following web address:

https://ecology.wa.gov/Regulations-Permits/Guidance-technical-assistance/Stormwater-permittee-guidance-resources/Contaminated-water-on-construction-sites

Sediment Removal and Disposal

- Sediment shall be removed from the untreated stormwater storage pond and treatment cells as necessary. Typically, sediment removal is required at least once during a wet season and at the decommissioning of the chemical treatment system. Sediment remaining in the cells between batches may enhance the settling process and reduce the required chemical dosage.
- Sediment that is known to be non-toxic may be incorporated into the site away from drainages.

BMP C251: Construction Stormwater Filtration

Purpose

Filtration removes sediment from runoff originating from disturbed areas of the site.

Conditions of Use

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 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.

The use of construction stormwater filtration does not require approval from Ecology as long as treatment chemicals are not used. Filtration in conjunction with BMP C250: Construction Stormwater Chemical 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. See Ecology's Request for Chemical Treatment form at the following web address:

https://fortress.wa.gov/ecy/publications/SummaryPages/ecy070258.html

Design and Installation Specifications

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. They can achieve relatively high hydraulic flow rates, on the order of 2 to 20 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 post construction BMPs to treat stormwater (see 6.7 Filtration BMPs). Slow filtration is mechanically simple in comparison to rapid filtration, but requires a much larger filter area.

Filter Types 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 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 to and through the filtration media.

Sizing

Filtration treatment systems must be designed to control the velocity and peak volumetric flow rate that is discharged from the system and consequently the project site. See 7.2.3 Element 3: Control Flow Rates for further details on this requirement.

The untreated stormwater storage pond or tank should be sized to hold 1.5 times the volume of runoff generated from the site during the 6-month, 3-hour storm (referred to as the short duration storm) event, minus the filtration treatment system flow rate for an 8-hour period. For a chitosan-enhanced sand filtration system, the filtration treatment system flow rate should be sized using a hydraulic loading rate between 6 and 8 gpm/ft^2. Other hydraulic loading rates may be more appropriate for other systems. Bypass should be provided around the filtration treatment system to accommodate extreme storm events. Runoff volume shall be calculated using the methods presented in Chapter 4 - Hydrologic Analysis and Design. Worst-case land cover conditions (i.e., producing the most runoff) should be used for analyses (in most cases, this would be the land cover conditions just prior to final landscaping).

If the filtration treatment system design does not allow you to discharge at the rates as required by 7.2.3 Element 3: Control Flow Rates, and if the site has a permanent Flow Control BMP that will serve the planned development, the discharge from the filtration treatment system may be directed to the permanent Flow Control BMP to comply with 7.2.3 Element 3: Control Flow Rates. In this case, all discharge (including water passing through the treatment system and stormwater bypassing the treatment system) will be directed into the permanent Flow Control BMP. If site constraints make locating the untreated stormwater storage pond difficult, the permanent Flow Control BMP may be divided to serve as the untreated stormwater storage pond and the post-treatment temporary flow control pond. A berm or barrier must be used in this case so the untreated water does not mix with the treated water. Both untreated stormwater storage requirements, and adequate post-treatment flow control must be achieved. The designer must document in the Construction SWPPP how the permanent Flow Control BMP is able to attenuate the discharge from the site to meet the requirements of 7.2.3 Element 3: Control Flow Rates. If the design of the permanent Flow Control BMP was modified for temporary construction flow control purposes, the construction of the permanent Flow Control BMP must be finalized, as designed for its permanent function, at project completion.

Maintenance Standards

- Rapid sand filters typically have automatic backwash systems that are triggered by a pre-set pressure drop across the filter. If the backwash water volume is not large or substantially more turbid than the untreated stormwater stored in the holding pond or tank, backwash return to the untreated stormwater pond or tank may be appropriate. However, other means of treatment and disposal may be necessary.
- Screen, bag, and fiber filters must be cleaned and/or replaced when they become clogged.
- Sediment shall be removed from the storage and/or treatment ponds as necessary. Typically, sediment removal is required once or twice during a wet season and at the decommissioning of the ponds.
- Disposal of filtration equipment must comply with applicable local, state, and federal regulations.

BMP C252: Treating and Disposing of High pH Water

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 prior to discharge to surface or groundwater. A pH level range of 6.5 to 8.5 is typical for most natural watercourses, and this neutral pH range 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.

Conditions of Use

- The water quality standard for pH in Washington State is in the range of 6.5 to 8.5. Stormwater with pH levels exceeding water quality standards may be either neutralized on site or disposed of to a sanitary sewer or concrete batch plant with pH neutralization capabilities.
- Neutralized stormwater may be discharged to surface waters under the Construction Stormwater General Permit.
- Passive percolation of a limited volume of pH-affected stormwater is acceptable, with the understanding it does not "pond" or result in runoff from the project boundary or to waters of the state. Any visible accumulations of such water must be considered pH-affected and managed to protect waters of the state.

  NOTE: this only applies to high pH stormwater or conditionally authorized non-stormwater, it does not apply to process water, which may be subject to numeric effluent limits under certain permits, or otherwise not authorized for discharge to waters of the state.
- Neutralized process water such as concrete truck washout, hydrodemolition, or sawcutting slurry must be managed to prevent discharge to surface waters. Any stormwater contaminated during concrete work is considered process wastewater and must not be discharged to waters of the State or stormwater collection systems.
- The process used for neutralizing and/or disposing of high pH stormwater from the site must be documented in the Construction SWPPP.
- There are other options for neutralizing or managing high pH stormwater beyond what Ecology provides formal guidance on. Regardless of the stormwater management methods selected, the resulting pH-affected stormwater must be managed in a way that meets permit conditions for discharge.

  NOTE: If the proposed option to neutralize high-pH stormwater involves a chemical treatment beyond what is described in this BMP, additional authorization for the chemical treatment may be necessary.

Causes of High pH

High pH at construction sites is most commonly caused by the contact of stormwater with poured or recycled concrete, cement, mortars, and other Portland cement or lime containing construction materials. See BMP C151: Concrete Handling for more information on concrete handling procedures. The principal caustic agent in cement is calcium hydroxide (free lime).

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 waters of the state is not allowed. Groundwater standard for calcium and other dissolved solids in Washington State is less than 500 mg/l.

Treating High pH Stormwater by Carbon Dioxide Sparging

Advantages of Carbon Dioxide 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 of Carbon Dioxide Sparging

When carbon dioxide (CO_2) is added to water (H_2O), carbonic acid (H_2CO_3) is formed which can further dissociate into a proton (H+) and a bicarbonate anion (HCO_3-) as shown below:

$$CO_2 + H_2O \leftrightarrow H_2CO_3 \leftrightarrow H^+ + HCO_3^-$$

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 is, the slower the reaction occurs. The warmer the water temperature is, 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 simultaneous.

The Treatment Process of Carbon Dioxide Sparging

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. Prior to treatment, the appropriate jurisdiction should be notified in accordance with the regulations set by the jurisdiction.
2. Every effort should be made to isolate the potential high pH water in order to treat it separately from other stormwater on-site.
3. Water should be stored in an acceptable storage facility, detention pond, or containment cell prior to pH treatment.
4. Transfer water to be treated for pH to the pH treatment structure. Ensure that the pH treatment structure size is sufficient to hold the amount of water that is to be treated. Do not fill the pH treatment structure completely, allow at least 2 feet of freeboard.
5. The operator samples the water within the pH treatment structure for pH and notes the clarity of the water. As a rule of thumb, less CO_2 is necessary for clearer water. The results

of the samples and water clarity observations should be recorded.

6. In the pH treatment structure, add CO_2 until the pH falls into the range of 6.9 to 7.1. 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 pH treatment structure, this will allow carbon dioxide to bubble up through the water and diffuse more evenly.

7. Slowly discharge the water, making sure water does not get stirred up in the process. Release about 80% of the water from the pH treatment structure leaving any sludge behind. If turbidity remains above the maximum allowable, consider adding filtration to the treatment train. See BMP C251: Construction Stormwater Filtration.

8. Discharge treated water through a pond or drainage system.

9. Excess sludge needs to 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% of the treatment structure volume.

10. Disposal must comply with applicable local, state, and federal regulations.

Treating High pH Stormwater by Food Grade Vinegar

Food grade vinegar that meets FDA standards may be used to neutralize high pH water. Food grade vinegar is only 4% to 18% acetic acid with the remainder being water. Food grade vinegar may be used if dosed just enough to lower pH sufficiently. Use a treatment process as described above for CO_2 sparging, but add food grade vinegar instead of CO_2.

This treatment option for high pH stormwater does not apply to anything but food grade vinegar. Acetic acid does not equal vinegar. Any other product or waste containing acetic acid must go through the evaluation process in Appendix G of *Whole Effluent Toxicity Testing Guidance and Test Review Criteria* (Marshall, 2016).

Disposal of High pH Stormwater

Sanitary Sewer Disposal

Local sewer authority approval is required prior to disposal via the sanitary sewer.

Concrete Batch Plant Disposal

- Only permitted facilities may accept high pH water.
- Contact the facility to ensure they can accept the high pH water.

Maintenance Standards

Safety and materials handling:

- All equipment should be handled in accordance with OSHA rules and regulations.
- Follow manufacturer guidelines for materials handling.

Each operator should provide:

- A diagram of the monitoring and treatment equipment.
- A description of the pumping rates and capacity the treatment equipment is capable of treating.

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 or food grade vinegar 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 client/contractor who should retain the record for 3 years.

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Chapter 8 - Source Control

8.1 Choosing Your Source Control BMPs

This section provides guidance to the following users for selecting Source Control Best Management Practices (BMPs):

- Project proponents with new development or redevelopment, to meet 2.4.3 CE3: Source Control of Pollution.
- Permittees under the following Ecology NPDES Permits, to meet SWPPP requirements of their Permit:
    - Industrial Stormwater General Permit
    - Industrial Stormwater Individual Permit
    - Boatyard General Permit
    - Sand and Gravel General Permit
- Permittees under Ecology's Phase I or Western Washington Phase II Municipal Stormwater Permits, to comply with the Permit's Source Control Program Requirements (Note that the Eastern Washington Phase II Municipal Stormwater Permit does not have a Source Control Program Requirement at this time)

When are Source Control BMPs Required?

Where required by local code or by an Ecology NPDES Stormwater General Permit, implement Source Control BMPs at:

- Commercial properties
- Industrial properties
- Multifamily properties
- Boatyards
- Sand and gravel mining operations

Note that single family residential sites may not be required to provide Source Control BMPs. Ecology encourages single family residential sites and other sites not required by an NPDES permit or local government to select Source Control BMPs using the information provided in this section to the maximum extent practical.

Regulatory programs such as the State Environmental Policy Act (SEPA), Water Quality Certifications (see 1.2.10 Section 401 Water Quality Certifications), and Hydraulic Project Approvals (see 1.2.13 Hydraulic Project Approvals) may require use of Source Control BMPs.

Local governments may require commercial, industrial, and multifamily properties to implement Source Control BMPs through ordinances or other documents. Operators of these property types should check with their jurisdiction about local requirements related to Source Control BMPs and SWPPPs.

How to Determine Which Source Control BMPs are Appropriate for the Site

Chapter 8 - Source Control provides Ecology's library of Source Control BMPs. These BMPs are categorized as either "operational" or "structural", and either "applicable" or "recommended".

For the sites listed above that must implement Source Control BMPs, use the following steps to guide selection of appropriate Source Control BMPs:

1. All sites must implement the Source Control BMPs listed in 8.2 Source Control BMPs Applicable to All Sites.

2. Next, base selection of additional Source Control BMPs on land use and the pollutant generating sources at the site.

    - Use Appendix 8-A: Urban Land Uses and Pollutant Generating Sources to help determine activities and the potential pollutant generating sources associated with those activities for various land uses.

    - Applicable operational and structural Source Control BMPs for each pollutant source can then be selected by reviewing the BMPs in Chapter 8 - Source Control, which are categorized by activity. Land uses not included in Appendix 8-A: Urban Land Uses and Pollutant Generating Sources should also consider implementing Source Control BMPs for their pollutant sources.

    For example, if a commercial printing business conducts weed control with herbicides, loading and unloading of materials, and vehicle washing, it should refer to the following BMP sections for these activities:

    - S411 BMPs for Landscaping and Lawn / Vegetation Management

    - S412 BMPs for Loading and Unloading Areas for Liquid or Solid Material

    - S431 BMPs for Washing and Steam Cleaning Vehicles / Equipment / Building Structures

    - S404 BMPs for Commercial Printing Operations

3. Within the text for each Source Control BMP, there are "applicable" and "recommended" BMPs listed.

    The reader should interpret the term “applicable” when referring to specific operational or structural Source Control BMPs as meaning “mandatory” or “required”. These BMPs must be implemented at the site.

    Ecology offers "recommended" Source Control BMPs as approaches that go beyond or complement the applicable (mandatory) BMPs. Implementing the recommended Source

Control BMPs may improve control of pollutants and provide a more comprehensive and environmentally effective stormwater management program. Ecology encourages all operators to review their SWPPPs and use recommended BMPs where possible.

4. The project may have additional source control responsibilities as a result of area-specific pollution control plans (e.g. watershed or basin plans, water clean-up plans, groundwater management plans, lakes management plans), ordinances, and/or regulations.

Additional Guidance Specific to Industrial Stormwater Permit Permittees

- Operators under the Industrial Stormwater General Permit should take special care to review the Source Control BMPs in Chapter 8 - Source Control to ensure that all of the applicable (mandatory) Source Control BMPs are included within their Industrial SWPPP, regardless of the listings in Appendix 8-A: Urban Land Uses and Pollutant Generating Sources.
- Under the Industrial Stormwater General Permit, if a facility's sampling triggers Level 1 or Level 2 Corrective Action requirements, operators should consider the *recommended* operational (Level 1) and structural (Level 2) Source Control BMPs to fulfill permit requirements and reduce pollutant concentrations.
- All sites covered under the Industrial Stormwater General Permit must include and implement the applicable (mandatory) BMPs in their Industrial SWPPP.
- Industrial sites covered by individual industrial stormwater permits must comply with the specific Source Control and Runoff Treatment BMPs listed in their permits. Operators under individual industrial stormwater permits may include additional BMPs from this manual, if desired.

Additional Guidance Specific to Boatyard General Permit Permittees

- Operators under the Boatyard General Permit should take special care to review the Source Control BMPs in Chapter 8 - Source Control to ensure that all of the applicable (mandatory) Source Control BMPs are included within their Boatyard SWPPP, regardless of the listings in Appendix 8-A: Urban Land Uses and Pollutant Generating Sources.
- All sites covered under the Boatyard General Permit must include and implement the applicable (mandatory) BMPs in their Boatyard SWPPP.

Additional Guidance Specific to Sand and Gravel General Permit Permittees

Facilities covered under the Sand and Gravel General Permit must include Source Control BMPs as necessary in their Sand and Gravel SWPPP to achieve AKART and compliance with the stormwater discharge limits in their permit.

Additional Guidance Specific to New and Redevelopment Project Proponents

If the project involves any of the activities described in Chapter 8 - Source Control, the “applicable” structural Source Control BMPs described in that section must be constructed as part of the project. In addition, if the specific business enterprise that will occupy the site is known, the “applicable” operational Source Control BMPs must also be identified.

8.2 Source Control BMPs Applicable to All Sites

S101 BMPs for Formation of a Pollution Prevention Team

The pollution prevention team should be responsible for implementing and maintaining all BMPs and treatment for the site. This team should be able to address any corrective actions needed on site to mitigate potential stormwater contamination. The team members should:

- Consist of those people who are familiar with the facility and its operations.
- Possess the knowledge and skills to assess conditions and activities that could impact stormwater quality at your facility, and who can evaluate the effectiveness of control measures.
- Assign pollution prevention team staff to be on duty on a daily basis to cover applicable permittee facilities when those facilities are in operation.
- Have the primary responsibility for developing and overseeing facility activities necessary to comply with stormwater requirements.
- Have access to all applicable permit, monitoring, SWPPP, and other records.
- Be trained in the operation, maintenance and inspections of all BMPs and reporting procedures.
- Establish responsibilities for inspections, operation, maintenance, and emergencies.
- Regularly meet to review overall facility operations and BMP effectiveness.

S102 BMPs for Preventive Maintenance and Good Housekeeping

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.

Applicable BMPs:

- Prevent the discharge of unpermitted liquid or solid wastes, process wastewater, and sewage to groundwater or surface water, or to storm drains that discharge to surface water, or to the ground. Conduct all oily parts cleaning, steam cleaning, or pressure washing of equipment or containers inside a building, or on an impervious contained area, such as a concrete pad. Direct contaminated stormwater from such an area to a sanitary sewer where allowed by local sewer authority, or to other approved treatment.

- Promptly contain and clean up solid and liquid pollutant leaks and spills including oils, solvents, fuels, and dust from manufacturing operations on any exposed soil, vegetation, or paved area.
- If a contaminated surface must be pressure washed, collect the resulting washwater for proper disposal (usually involves plugging storm drains or otherwise preventing discharge, and pumping or vactoring up washwater for discharge to sanitary sewer or for vactor truck transport to a wastewater treatment plant for disposal).
- Do not hose down pollutants from any area to the ground, storm drains, conveyance ditches, or receiving water. Convey pollutants before discharge to a treatment system approved by the local jurisdiction.
- Sweep all appropriate surfaces with vacuum sweepers quarterly, or more frequently as needed, for the collection and disposal of dust and debris that could contaminate stormwater. Use mechanical sweepers, and manual sweeping as necessary to access areas that a vacuum sweeper can't reach to ensure that all surface contaminants are routinely removed.
- Do not pave over contaminated soil unless it has been determined that groundwater has not been and will not be contaminated by the soil. Call Ecology for assistance.
- Construct impervious areas that are compatible with the materials handled. Portland cement concrete, asphalt, or equivalent material may be considered.
- Use drip pans to collect leaks and spills from industrial/commercial equipment such as cranes at ship/boat building and repair facilities, log stackers, industrial parts, and trucks and other vehicles stored outside.
- At industrial and commercial facilities, drain oil and fuel filters before disposal. Discard empty oil and fuel filters, oily rags, and other oily solid waste into appropriately closed and properly labeled containers, and in compliance with the Uniform Fire Code or International Building Code.
- 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, water tight, rodent-proof, and equipped with a close fitting cover.
- For the temporary storage of solid wastes contaminated with liquids or other potential polluted materials use dumpsters, garbage cans, drums, and comparable containers, which are durable, corrosion resistant, non-absorbent, non-leaking, and equipped with either a solid cover or screen cover to prevent littering. If covered with a screen, the container must be stored under a roof or other form of adequate cover.
- Where exposed to stormwater, use containers, piping, tubing, pumps, fittings, and valves that are appropriate for their intended use and for the contained liquid.
- Clean oils, debris, sludge, etc. from all stormwater BMPs regularly, including catch basins, settling/detention basins, oil/water separators, boomed areas, and conveyance systems, to

prevent the contamination of stormwater. Refer to Ecology Requirements for Generators of Dangerous Wastes in 1.2.16 Other Regulations and Programs for references to assist in handling potentially dangerous waste.

- Promptly repair or replace all substantially cracked or otherwise damaged paved secondary containment, high-intensity parking, and any other contributing drainage areas, subjected to pollutant material leaks or spills. Promptly repair or replace all leaking connections, pipes, hoses, valves, etc., that can contaminate stormwater.
- Do not connect floor drains in potential pollutant source areas to storm drains, receiving waters, or to the ground.

Recommended BMPs:

- Where feasible, store potential stormwater pollutant materials inside a building or under a cover and/or containment.
- 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.
- Recycle waste materials such as solvents, coolants, oils, degreasers, and batteries to the maximum extent feasible. Contact Ecology's *Hazardous Waste & Toxics Reduction Program* at the following web address, or your local jurisdiction, for recommendations on recycling or disposal of vehicle waste liquids and other waste materials:

  https://ecology.wa.gov/About-us/Get-to-know-us/Our-Programs/Hazardous-Waste-Toxics-Reduction
- Empty drip pans immediately after a spill or leak is collected in an uncovered area.
- Stencil warning signs at catch basins and drains, e.g., “Dump no waste – Drains to stream”. See S442 BMPs for Labeling Storm Drain Inlets On Your Property.
- Use solid absorbents, e.g., clay and peat absorbents and rags for cleanup of liquid spills/leaks, where practicable.
- Promptly repair/replace/reseal damaged paved areas at industrial facilities.
- Recycle materials, such as oils, solvents, and wood waste, to the maximum extent practicable.

Note: Evidence of stormwater contamination can include the presence of visible sheen, color, or turbidity in the runoff, or present or historical operational problems at the facility. Operators can use simple pH tests, for example with litmus or pH paper. These tests can screen for high or low pH levels (anything outside the 6.5 to 8.5 range) due to contamination of stormwater.

S104 BMPs for Spill Prevention and Cleanup

Description of Pollutant Sources: Spills and leaks 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 required based on the specific activity occurring on site.

Applicable BMPs:

Spill Prevention

- Clearly label or mark 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.
- 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 techniques for handling materials used on the site and to check for leaks and spills.

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, product storage areas, waste storage areas, and near a phone. The spill plan may need to be posted at multiple locations. 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.
- Designate spill response employees to be on-site during business activities. Provide a current list of the names and telephone numbers (home and office) of designated spill response employees who are responsible for implementing the spill plan.
- Provide a site plan showing the locations of storage areas for chemicals, inlets/catch basins, spill kits and other relevant infrastructure or materials information.
- Describe the emergency cleanup and disposal procedures. Note the location of all spill kits in the spill plan.
- List the names and telephone numbers of public agencies to contact in the event of a spill.

Spill Cleanup Kits

- Store all cleanup kits near areas with a high potential for spills so that 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 on-board mobile fuel trucks.

Note: Ecology recommends that the kit(s) include salvage drums or containers, such as high density polyethylene, polypropylene or polyethylene sheet-lined steel; polyethylene or equivalent disposal bags; an emergency response guidebook; safety gloves/clothes/equipment; shovels or other soil removal equipment; and oil containment booms and absorbent pads; all stored in an impervious container.

Spill Cleanup and Proper Disposal of Waste

- Stop, contain, and clean up all spills immediately upon discovery.
- Implement the spill plan immediately.
- Contact the designated spill response employees.
- Block off and seal nearby inlets/catch basins to prevent materials from entering the drainage system or combined sewer.
- Use the appropriate material to clean up the spill.
- Do not use emulsifiers or dispersants such as liquid detergents or degreasers unless disposed of proplerly. Emulsifiers and dispersants are not allowed to be used on surface water, or in a place where they may enter storm drains, surface waters, treatments systems, or sanitary sewers.
- Immediately notify Ecology and the local jurisdiction if a spill has reached or may reach a sanitary or storm sewer, groundwater, or surface water. Notification must comply with state and federal spill reporting requirements.
- Do not wash absorbent material into interior floor drains or inlets/catch basins.
- Place used spill control materials in appropriate containers and dispose of according to regulations.

S105 BMPs for Employee Training

Train all employees that work in pollutant source areas about the following topics:

- Identifying Pollution Prevention Team members.
- Identifying pollutant sources.
- Understanding pollutant control measures.
- Spill prevention and response.
- Emergency response procedures.

- Handling practices that are environmentally acceptable. Particularly those related to vehicle/equipment liquids such as fuels, and vehicle/equipment cleaning.

Additional specialized training may be needed for staff who will be responsible for handling hazardous materials.

S106 BMPs for Inspections

Qualified personnel shall conduct inspections monthly. Make and maintain a record of each inspection on-site. The following requirements apply to inspections:

- Be conducted by someone familiar with the facility's site, operations, and BMPs.
- Verify the accuracy of the pollutant source descriptions in the SWPPP.
- Assess all BMPs that have been implemented for effectiveness and needed maintenance and locate areas where additional BMPs are needed.
- Reflect current conditions on the site.
- Include written observations of the presence of floating materials, suspended solids, oil and grease, discoloration, turbidity and odor in the stormwater discharges; in outside vehicle maintenance/repair; and liquid handling, and storage areas. In areas where acid or alkaline materials are handled or stored use a simple litmus or pH paper to identify those types of stormwater contaminants where needed.
- Eliminate or obtain a permit for unpermitted non-stormwater discharges to storm drains or receiving waters, such as process wastewater and vehicle/equipment washwater.
- Identify actions to address inspection deficiencies.

S107 BMPs for Record Keeping

See the applicable permit for specific record-keeping requirements and retention schedules for the following reports. At a minimum, retain the following reports for five years:

- Inspection reports which should include:
    - Time and date of the inspection
    - Locations inspected
    - Statement on status of compliance with the permit
    - Summary report of any remediation activities required
    - Name, title, and signature of person conducting the inspection
- Reports on spills of oil or hazardous substances in greater than reportable quantities (Code of Federal Regulations Title 40 Parts 302.4 and 117). Report spills of the following: antifreeze, oil, gasoline, or diesel fuel, that cause:

- A violation of the State of Washington's Water Quality Standards.
- A film or sheen upon or discoloration of the waters of the State or adjoining shorelines.
- A sludge or emulsion to be deposited beneath the surface of the water or upon adjoining shorelines.

To report a spill or to determine if a spill is a substance of a reportable quantity, call the Ecology regional office and ask for an oil spill operations or a dangerous waste specialist:

- **Northwest Region:** (206) 594-0000
- **Southwest Region:** (360) 407-6300
- **Eastern Region:** (509) 329-3400
- **Central Region:** (509) 575-2490

In addition, call the Washington Emergency Management Division at 1-800-258-5990 or 1-800-OILS-911 AND the National Response Center at 1-800-424-8802.

Also, refer to *Focus on Emergency Spill Response* (Ecology, 2013b).

The following is additional recommended record keeping:

Maintain records of all related pollutant control and pollution generating activities such as training, materials purchased, material use and disposal, maintenance performed, etc.

S108 BMPs for Correcting Illicit Discharges to Storm Drains

Description of Pollutant Sources: Illicit discharges are unpermitted sanitary or process wastewater discharges to a storm sewer or to surface water, rather than to a sanitary sewer, industrial process wastewater, or other appropriate treatment. They can also include swimming pool water, filter backwash, cleaning solutions/washwaters, cooling water, etc. Experience has shown that illicit discharges are common, particularly in older buildings.

Pollutant Control Approach: Identify and eliminate unpermitted discharges or obtain an NPDES permit, where necessary, particularly at industrial and commercial facilities.

Applicable Operational BMPs:

- For all real properties, responsible parties must examine their plumbing systems to identify any potential illicit discharges. Review site plans, engineering drawings, or other sources of information for the plumbing systems on the property.
- If an illicit discharge is suspected, trace the source using an appropriate method such as visual reconnaissance, smoke test, flow test, dye test with a nontoxic dye, or closed circuit television (CCTV) inspection. These tests are to be performed by qualified personnel such as a plumbing contractor. Note: Contact Ecology prior to performing a dye test which may result in a discharge to a receiving water.

- If illicit connections are found, permanently plug or disconnect the connections.
- Eliminate prohibited discharges to storm sewer(s), groundwater, or surface water(s).
- Convey unpermitted discharges to a sanitary sewer if allowed by the local sewer authority, or to other approved treatment.
- Obtain all necessary permits for altering or repairing 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 replace the connection.
- Obtain appropriate state and local permits for these discharges.

Recommended Operational BMPs:

At commercial and industrial facilities, conduct a survey of wastewater discharge connections to storm drains and to surface water as follows:

- Conduct a field survey of buildings, particularly older buildings, and other industrial areas to locate storm drains from buildings and paved surfaces. Note where these discharge.
- During non-stormwater conditions, inspect each storm drain for non-stormwater discharges. Record the locations of all non-stormwater discharges. Include all permitted discharges.
- If useful, prepare a map of each area. Show on the map the known location of storm sewers, sanitary sewers, and permitted and unpermitted discharges. Aerial photos may be useful. Check records such as piping schematics to identify known side sewer connections and show these on the map. Consider using smoke, dye, or chemical analysis tests to detect connections between two conveyance systems (e.g. process water and stormwater). If desirable, conduct Closed Circuit Television (CCTV) inspections of the storm drains and record the footage.
- Compare the observed locations of connections with the information on the map and revise the map accordingly. Note suspect connections that are inconsistent with the field survey.
- Identify all connections to storm sewers or to surface water and take the actions specified above as applicable BMPs.

8.3 Cleaning or Washing Source Control BMPs

S431 BMPs for Washing and Steam Cleaning Vehicles / Equipment / Building Structures

Description of Pollutant Sources: Pollutant sources include the commercial cleaning of vehicles, aircraft, vessels, and other transportation, restaurant kitchens, carpets, and industrial equipment, and large buildings with pressurized water or steam. This includes “charity” car washes at gas stations and commercial parking lots. The cleaning can include hand washing, scrubbing, sanding, etc. Washwater from cleaning activities can contain oil and grease, suspended solids, heavy metals, organics, soaps, and detergents that can contaminate stormwater.

Between 1950 and 1980, PCBs were added to a range of building materials used on the exterior of industrial, commercial, government, and larger residential buildings to increase the material's longevity. Without proper precautions, PCBs from paint, caulk and other joint materials, sealants, roofing, and other items can be released into the environment and enter stormwater conveyances during building washing activities. Recent guidance for characterizing and abating PCBs in building materials recommends against washing PCB-containing materials on a building's exterior, and provides more detailed guidance on specific stormwater BMPs to apply when PCB-containing materials are or are assumed to be present (Ecology, 2024).

Permitting Requirements: Obtain all necessary permits for installing, altering, or repairing onsite drainage and side sewers. Restrictions on certain types of discharges may require pretreatment before they enter the sanitary sewer. For commercial building washdown, properties served by a municipal stormwater system may be required to assess for PCB-containing building materials prior to building washing activities.

Pollutant Control Approach: The preferred approach is to cover and/or contain the cleaning activity, or conduct the activity inside a building, to separate the uncontaminated stormwater from the washwater sources. Convey washwater to a sanitary sewer after approval by the local sewer authority. Provide temporary storage before proper disposal. Under this preferred approach, no discharge of washwater to the ground, to a storm drain, or to surface water should occur.

The Industrial Stormwater General Permit (ISGP) prohibits the discharge of process wastewater (e.g. vehicle, building, or equipment washing wastewater) to groundwater or surface water. Stormwater that commingles with process wastewater is considered process wastewater.

Facilities not covered under the ISGP that are unable to follow one of the preferred approaches listed above may discharge washwater to the ground only after proper treatment in accordance with *Vehicle and Equipment Washwater Discharges Best Management Practices Manual* (Ecology, 2012).

The quality of any discharge to the ground after proper treatment must comply with Ecology's Groundwater Quality Standards, Chapter 173-200 WAC.

Facilities not covered under the ISGP that are unable to comply with one of the preferred approaches and want to discharge to the storm sewer, must meet their local stormwater requirements. Local authorities may require treatment prior to discharge.

The Municipal Stormwater Permits (Phase I, Phase II western Washington, and Phase II eastern Washington) prohibit the discharge of building washdown water to municipal stormwater systems from structures suspected or confirmed to have PCB-containing materials. Commercial buildings, industrial facilities, and multi-story residential structures that were contructed or renovated between the years 1950-1980 are those most likely to have PCB containing building materials. Refer to *How to Find and Address PCBs in Building Materials* (Ecology, 2022) for additional information.

Contact the local Ecology Regional Office to discuss permitting options for discharge of washwater to surface water or to a storm drain after on-site treatment.

Applicable Structural Source Control BMPs:

- Conduct vehicle/equipment washing in one of the following locations:
  - At a commercial washing facility in which the washing occurs in an enclosure and drains to the sanitary sewer.
  - In a building constructed specifically for washing of vehicles and equipment, which drains to a sanitary sewer.
- Conduct outside washing operations in a designated wash area with the following features:
  - In a paved area, construct a spill containment pad to prevent the run-on of stormwater from adjacent areas. Slope the spill containment area to collect washwater in a containment pad drain system with perimeter drains, trench drains or catchment drains. Size the containment pad to extend out a minimum of 4 feet on all sides of the washed vehicles and/or equipment.
  - Convey the washwater to a sump (like a grit separator) and then to a sanitary sewer (if allowed by the local Sewer Authority), or other appropriate wastewater treatment or recycle system. The containment sump must have a positive control outlet valve for spill control with live containment volume, and oil/water separation. Size the minimum live storage volume to contain the maximum expected daily washwater flow plus the sludge storage volume below the outlet pipe. Shut the outlet valve during the washing cycle to collect the washwater in the sump. The valve should remain shut for at least 2 hours following the washing operation to allow the oil and solids to separate before discharge to a sanitary sewer.
  - Use a two way valve for discharges from the containment pad. This valve should be normally switched to direct water to treatment, but may be switched to the drainage system after that pad is clean to handle stormwater runoff. The stormwater can then drain into the conveyance/discharge system outside of the wash pad (essentially bypassing the sanitary sewer or recycle system). Post signs to inform people of the operation and purpose of the valve. Clean the concrete pad thoroughly until there is no foam or visible sheen in the washwater prior to closing the inlet valve and allowing uncontaminated stormwater to overflow and drain off the pad.

    Note that the purpose of the valve is to convey only washwater and contaminated stormwater to a treatment system.
  - Collect the washwater from building structures and convey it to appropriate treatment such as a sanitary sewer system if it contains or is suspected to contain oils, soaps, detergents, or PCBs. If the washwater does not contain oils, soaps, detergents, or PCBs (in this case only a low pressure, clean, cold water rinse is allowed) then it could drain to soils that have sufficient natural attenuation capacity for dust and sediment.

    - Sweep surfaces prior to cleaning/washing to remove excess sediment and other pollutants.
    - If roof equipment or hood vents are cleaned, ensure that no washwater or process water is discharged to the roof drains or drainage systems.
    - Label all mobile cleaning equipment as follows: "Properly dispose of all wastewater. Do not discharge to an inlet/catch basin, ditch, stream, or on the ground".
- Contact the local jurisdiction's stormwater program to inform them when PCB-containing materials are, or are likely to be, present.
- Assess commercial structures (including industrial facilities and multi-story residential structures) constructed or renovated between 1950-1980 for PCB-containing materials consistent with *How to Find and Address PCBs in Building Materials* (Ecology, 2022) prior to building washdown. Single-family residential buildings are exempt from PCB assessment.

Recommended Additional BMPs:

- Mark the wash area at gas stations, multifamily residences and any other business where non-employees wash vehicles.
- Operators may use a manually operated positive control valve for uncovered wash pads, but a pneumatic or electric valve system is preferable. The valve may be on a timer circuit and opened upon completion of a wash cycle. After draining the sump or separator, the timer would then close the valve.
- Minimize the use of water and detergents in washing operations when practicable.
- Use phosphate-free biodegradable detergents when practicable.
- Use the least hazardous cleaning products available.
- Consider recycling the washwater.
- Operators may use soluble/emulsifiable detergents in the wash medium and should use it with care and the appropriate treatment. Carefully consider the selection of soaps and detergents and treatment BMPs. Oil/water separators are ineffective in removing emulsified or water soluble detergents. Another treatment appropriate for emulsified and water soluble detergents may be required.

Exceptions:

- At gas stations (for charity car washes) or commercial parking lots, where it is not possible to discharge the washwater to a sanitary sewer, a temporary plug or a temporary sump pump can be used at the storm drain to collect the washwater for off-site disposal such as to a nearby sanitary sewer.
- New and used car dealerships may wash vehicles in the parking stalls as long as employees use a temporary plug system to collect the washwater for disposal as stated

above, or an approved treatment system for the washwater is in place.

- At industrial sites, contact Ecology for NPDES Permit requirements even when not using soaps, detergents, and/or other chemical cleaners in washing trucks.

S434 BMPs for Dock Washing

Description of Pollutant Sources: Washing docks (or wharves, piers, floats, and boat ramps) can result in the discharge dirt, bird feces, soaps, and detergents that can be toxic to aquatic life, especially after they take on contaminants while cleaning. The BMPs in this section do not address dry docks, graving docks, or marine railway cleaning operations.

Pollutant Control Approach: Use dry methods and equipment (scraping, sweeping, vacuuming) to remove debris and contaminants prior to cleaning with water to prevent these substances from entering surface water.

Applicable Operational BMPs:

Surface Preparation and Spot Cleaning

- Scoop and collect debris and bird feces.
- Sweep, capture, and dispose of debris from the dock as solid waste. Sweep or vacuum docks to minimize the need for chemical cleaners.
- During cleaning activities, if debris, substances, or wash water could enter surface waters through drains, temporarily block the drains and collect the water for proper disposal.
- Hose down the area if necessary and collect water as feasible.
- Try spot cleaning with water and a coarse cloth before using soaps or detergents.
- If a cleaner is needed for spot cleaning:
    - Mix it in a bucket and use it to scrub down only the areas that need extra attention.
    - Start with vinegar and baking soda and move to other options as needed. Spot clean using a rag if harsher cleaning products are needed.
    - Avoid or minimize the use of petroleum distillates, chlorinated solvents, and ammoniated cleaning agents.
    - Use degreasers or absorbent material to remove residual grease by hand and do not allow this material to enter surface water.
    - Keep cleaners in sealed containers. Keep cleaner containers closed securely when transporting between the shore and docks.
    - Properly dispose of the dirty bucket water.
- Minimize the scour impact of wash water to any exposed soil at the landward end(s) of the

dock or below the dock. Place a tarp over exposed soil, plant vegetation, or put berms to contain eroded soil.

Dock Washing and Disposal

- To the extent practicable, collect any wash water generated from hosing down, pressure washing, or cleaning dock areas, and dispose of it properly.
- The following video, provided courtesy of the Port of Seattle, highlights the methods they have developed to collect wash water generated during dock washing.

  Video: Dock Scrubbing at Port of Seattle (YouTube Link): https://www.youtube.com/watch?v=7RBFdjC3K1Q
- Try pressure washing using light pressure. This uses less water and decreases the need for soap and scrubbing when washing the dock. Avoid using excessive pressure, which may damage the dock or send flakes of paint and other material into the water.
- Do not place any debris and substances resulting from cleaning activities in shoreline areas, riparian areas, or on adjacent land where these substances may erode into waters of the state.
- Where treated wood associated with the structure being washed are present, use non-abrasive methods and tools that, to the maximum extent practicable, minimize removal of the creosote or treated wood fibers when it removes marine growth from creosote or any other treated wood.
- Do not discharge removed marine growth to waters of the state where such marine growth would accumulate on the sea bed.
- Do not discharge emulsifiers, dispersants, solvents, or other toxic deleterious materials to waters of the state.

S441 BMPs for Potable Water Line Flushing, Water Tank Maintenance, and Hydrant Testing

Description of Pollutant Sources: Flushing is a common maintenance activity used to improve pipe hydraulics and to remove pollutants in systems. Flushing done improperly can result in the discharge of solids to receiving waters. Hydrant testing may result in the discharge of rust particles.

Chemicals used in line flushing and tank maintenance are highly toxic to aquatic organisms and can degrade receiving waters.

Pollutant Control Approach: Dechlorinate and pH adjust water used for flushing, tank maintenance, or hydrant testing. Dispose of the water to the sanitary sewer if possible.

Applicable Operational BMPs:

- Remove solids from associated curbs and gutters before flushing water. Use erosion and sediment control BMPs such as BMP C235: Wattles, BMP C220: Inlet Protection, etc. to collect any solids resulting from flushing activities.

- If using super chlorination or chemical treatment as part of flushing, discharge water to the sanitary sewer. If sanitary sewer is not available, the water may be infiltrated to the ground as long as all of the following are met:
  - The water is dechlorinated to a total residual chlorine of 0.1 ppm or less.
  - Water quality standards are met.
  - A diffuser is used to prevent erosion.
  - The water does not cross property lines.
- Discharging water to a drainage system requires approval from the local jurisdiction. Check with the local jurisdiction to determine their requirements for approval. Most jurisdictions will require the water to be dechlorinated to a total residual chlorine concentration of 0.1 ppm or less and pH adjusted if necessary. Water must be volumetrically and velocity controlled to prevent resuspension of sediments or pollutants in the Municipal Separate Storm Sewer System (MS4).
- Do not over apply dechlorination agents. This can deplete the dissolved oxygen concentration and reduce the pH in discharge / receiving waters.

Optional Operational BMPs:

- If possible, design flushing to convey accumulated material to strategic locations, such as to the sanitary sewer or to a treatment facility; thus, preventing re-suspension and overflow of a portion of the solids during storm events.
- If possible, conduct flushing and tank maintenance activities on non-rainy days and during the time of year that poses the least risk to aquatic biota.

Optional Treatment BMPs:

- Treatment for dechlorinating can include an application of a stoichiometric quantity of:
  - Ascorbic Acid, Sodium Ascorbate (Vitamin C)
  - Calcium Thiosulfate
  - Sodium Sulfite tablets
  - Sodium Thiosulfate
  - Sodium Bisulfite
  - Alternate Dechlorination Solutions

S453 BMPs for Washing Light Rail Elevated Guideways

Description of Pollutant Sources: Pollutant sources are from the light rail electrical and mechanical components which may include metals, dust, and hydrocarbons. The pollutants have the ability to fall and collect on the elevated guideways.

Pollutant Control Approach: The preferred approach is for washing activities to remove accumulated pollutants from the elevated guideways. Under this preferred approach, pollutants accumulated on the elevated guideways are removed, resulting in reduced contributions to the area surrounding the elevated guideways.

Applicable Operational BMPs:

Conduct elevated guideway washing with a dedicated vactor truck that collects and contains water sprayed onto the elevated guideway. All elevated guideway washing activities shall only take place during track downtimes.

Elevated guideway washing BMP components include:

- **Frequency:** Due to limited service down time, frequency is determined by light rail operational performance needs to clean the elevated guideway. With this BMP, pollutants accumulated on the elevated guideway are removed, which provides stormwater benefit by reducing contributions to the environment.
- **Areas of Focus:** The entire elevated guideway area shall be washed with additional emphasis placed on the rail and rail seat.
- **Vactor Truck:** A vactor truck shall be used for all elevated guideway washing activities. The truck shall be designed to vacuum up water sprayed during the cleaning process. The water will be properly discharged to the wastewater collection system, with approval from the owner, when the truck returns to the maintenance facility (see Appendix 8-B: Management of Street Waste Solids and Liquids).

  Upon return to the maintenance facility, discharge timing shall be determined in coordination with washing and rinsing flushing intervals for compliance will all permits.
- **Elevated guideway Drains:** All runoff from elevated guideway washing will be contained, collected, and disposed of with the vactor truck water.

S454 BMPs for Washing Light Rail Vehicles

Description of Pollutant Sources: Potential pollutant sources are from the light rail vehicle (LRV) electrical and mechanical components which may include metals, dust, and hydrocarbons. Materials tend to accumulate on the tops and sides of light rail vehicles.

Pollutant Control Approach: The preferred approach is for LRV wash facilities to remove any accumulated pollutants from the vehicles. Under this preferred approach, pollutants accumulated on LRVs are removed, resulting in reduced contributions to the light rail guideways.

Applicable Operational BMPs:

Conduct LRV washing in a dedicated LRV washing facility in which the washing occurs in an enclosure and drains to the sanitary sewer.

Dedicated Light Rail Vehicle Washing Facility

LRVs should go through the following steps during a wash cycle: pre-rinse, detergent, brush/scrub, final rinse, and then blowers. LRVs are targeted for washing one time per week. See Figure 8.1: Typical Light Rail Vehicle Wash (Plan View) for a typical LRV wash.

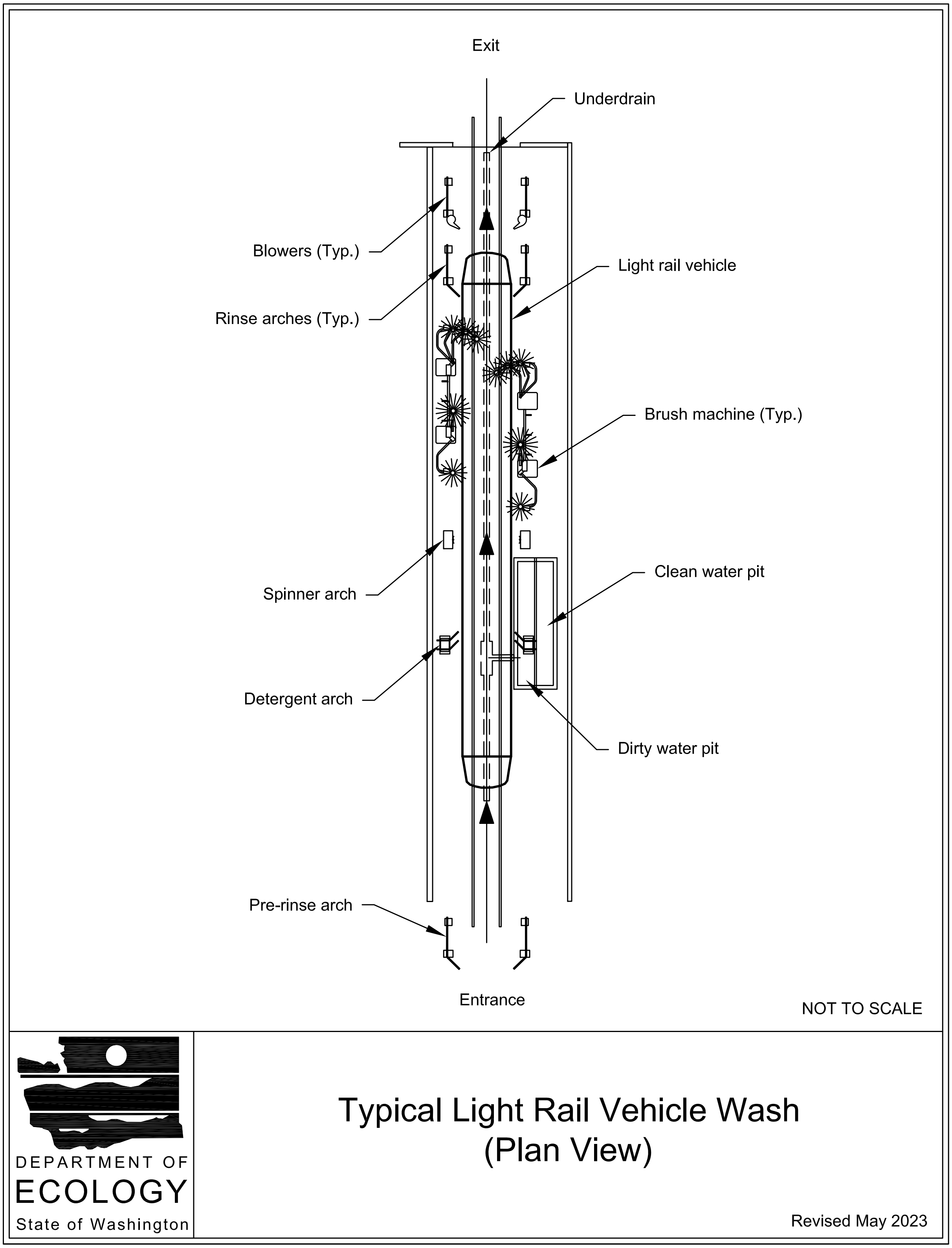
The following are details on the wash cycle steps:

1. **Pre-Rinse:** Vehicles are sprayed with water (either reused or fresh) upon entering the facility. Sprayers should be placed to maximize the surface area of the vehicle to be washed.
2. **Detergent:** Vehicles will next be sprayed with an approved detergent. Sprayers should be placed to maximize the surface area of the vehicle to be washed.
3. **Brush/Scrub:** Brushes will be placed along the wash track to scrub the vehicle to remove accumulated materials. Brushes should be placed to maximize the surface area of the vehicle to be washed.
4. **Final Rinse:** Vehicles will be sprayed with a final rinse. Sprayers should be placed to maximize the surface area of the vehicle to be washed. Vehicles will be rinsed at least once.
5. **Blowers:** After the final rinse, the LRV will travel through a set of blowers to dry the vehicle, reducing potentially contaminated wash water from leaving the facility.

Detergent Selection

- Minimize the use of water and detergents in washing operations when practicable.
- Use phosphate-free biodegradable detergents when practicable.
- Use the least hazardous effective cleaning products available.
- The selected detergent should meet requirements of the local county’s Certified Industrial Hygienists to protect wash facility operators and shall go through the approval process for the local jurisdiction associated with the washing facility’s wastewater discharge permit.

Figure 8.1: Typical Light Rail Vehicle Wash (Plan View)



8.4 Roads, Ditches, and Parking Lot Source Control BMPs

S405 BMPs for Deicing and Anti-Icing Operations - Airports

Refer to 40 CFR Part 449 for EPA effluent limitations guidelines and new source performance standards to control discharges of pollutants from airport deicing operations.

Description of Pollutant Sources: Operators use deicing and/or apply anti-icing compounds on airport runways, taxiways, and on aircraft to control ice and snow. Typically, ethylene glycol and propylene glycol are deicers used on aircraft. Deicers commonly used on runways, taxiways, and other hard surfaces include calcium magnesium acetate (CMA), calcium chloride, magnesium chloride, sodium chloride, urea, and potassium acetate. The deicing and anti-icing compounds become pollutants when conveyed to storm drains or to receiving water(s) after application. Leaks and spills of these chemicals can also occur during their handling and storage.

Pollutant Control Approach for Aircraft: Spent glycol discharges in aircraft application areas are regulated process wastewaters under Ecology's Industrial Stormwater General Permit. BMPs for aircraft deicers and/or anti-icers must be consistent with aviation safety and the operational needs of the aircraft operator.

Applicable BMPs for Aircraft:

- Conduct aircraft deicing or anti-icing applications in impervious containment areas. Collect spent aircraft deicer or anti-icer chemicals, such as glycol, draining from aircraft in deicing or anti-icing application areas and convey them to a sanitary sewer, treatment, or other approved disposal or recovery method. Divert deicing runoff from paved gate areas to appropriate collection areas or conveyances for proper treatment or disposal.
- Do not discharge spent deicer or anti-icer chemicals or stormwater contaminated with aircraft deicer or anti-icer chemicals from application areas, including gate areas, into storm drains. No discharge to surface water or groundwater, directly or indirectly, should occur.
- Transfer deicing and anti-icing chemicals on an impervious containment pad, or equivalent spill/leak containment area, and store in secondary containment areas. (See S428 BMPs for Storage of Liquids in Permanent Aboveground Tanks).

  Note this applicable containment BMP of aircraft de/anti-icing applications, and applicable treatment BMPs for de/anti-icer spent chemicals such as glycols.

Recommended Additional BMPs for Aircraft:

- Establish a centralized aircraft de/anti-icing facility, if practicable, or in designated areas of the tarmac equipped with separate collection drains for the spent deicer liquids.
- Consider installing an aircraft de/anti-icing chemical recovery system, or contract with a chemical recycler.

Applicable BMPs for Airport Runways/Taxiways:

- Avoid excessive application of all de/anti-icing chemicals. Do not apply more chemicals than necessary to achieve the necessary amount of ice removal or prevention. The chemicals could contaminate stormwater.
- Store and transfer de/anti-icing materials on an impervious containment pad or an equivalent containment area and/or under cover in accordance with S429 BMPs for Storage or Transfer (Outside) of Solid Raw Materials, Byproducts, or Finished Products. Consider other material storage and transfer approaches only if the de/anti-icer material will not contaminate stormwater.

Recommended Additional BMPs for Airport Runways/Taxiways:

- Include limits on toxic materials and phosphorus in the specifications for de/anti-icers, where applicable.
- Consider using anti-icing materials rather than deicers if it will result in less adverse environmental impact.
- Select cost-effective de/anti-icers that cause the least adverse environmental impact.

S406 BMPs for Streets and Highways

Description of Pollutant Sources: These BMPs apply to the maintenance and deicing/anti-icing of streets and highways. Deicing products can be conveyed during storm events to inlets/catch basins or to receiving waters after application. Leaks and spills of these products can also occur during their handling and storage. Equipment and processes using during maintenance can contribute pollutants such as oil and grease, suspended solids, turbidity, high pH, and metals.

Pollutant Control Approach: Apply good housekeeping practices, preventive maintenance, properly train employees, and use materials that cause less adverse effects on the environment.

Applicable BMPs:

Deicing and Anti-Icing Operations

- Adhere to manufacturer's guidelines and industry standards of use and application.
- Store and transfer deicing and anti-icing materials on impervious containment pads, or an equivalent spill/leak containment area in accordance with S429 BMPs for Storage or Transfer (Outside) of Solid Raw Materials, Byproducts, or Finished Products.
- Sweep/clean up accumulated deicing and anti-icing materials and grit from roads as soon as possible after the road surface clears.
- Minimize use in areas where runoff or spray from the roadway immediately enters sensitive areas such as fish-bearing streams.

Maintenance Operations

- Use drip pans or absorbents wherever concrete, asphalt, asphalt emulsion, paint product, and drips are likely to spill, such as beneath discharge points from equipment.
- Cover and contain nearby storm drains to keep runoff from entering the drainage system.
- Collect and contain all solids, slurry, and rinse water. Do not allow these to enter gutters, storm drains, or drainage ditches or onto the paved surface of a roadway or driveway.
- Designate an area onsite for washing hand tools and collect that water for disposal.
- Conduct all fueling of equipment in accordance with S419 BMPs for Mobile Fueling of Vehicles and Heavy Equipment.
- Do not use diesel fuel for cleaning or prepping asphalt tools and equipment.
- Sweep areas as frequently as needed. Collect all loose aggregate and dust for disposal. Do not hose down areas into storm drains.
- Store all fuel, paint, and other products on secondary containment.
- Conduct paint striping operations during dry weather.

Recommended Additional BMPs:

- Where feasible and practicable, use roadway deicing chemicals that cause the least adverse environmental impact. Apply only as needed using minimum quantities. Consider the Pacific Northwest Snowfighters Qualified Products List when selecting roadway de-icers and anti-icers.
- Intensify roadway and drainage structure cleaning in early spring to help remove particulates from road surfaces.
- Include limits on toxic metals in the specifications for de/anti-icers.
- Install catch basin inserts to collect excess sediment and debris as necessary. Inspect and maintain catch basin inserts to ensure they are working correctly.
- Research admixtures (e.g. corrosion inhibitors, surfactants) to determine what additional pollutants may be an issue. Verify with the local jurisdiction if there are any restrictions on admixtures.

S415 BMPs for Maintenance of Public and Private Utility Corridors and Facilities

Description of Pollutant Sources: Corridors and facilities at petroleum product pipelines, natural gas pipelines, water pipelines, electrical power transmission corridors, and rights-of-way can be sources of pollutants such as herbicides used for vegetation management, and eroded soil particles from unpaved access roads. At pump stations, waste materials generated during maintenance activities may be temporarily stored outside. Additional potential pollutant sources include the leaching of preservatives from wood utility poles, PCBs in older transformers, water removed from underground transformer vaults, and leaks/spills from petroleum pipelines. The following are potential pollutants: oil and grease, TSS, BOD, organics, PCBs, pesticides, and heavy metals.

Pollutant Control Approach: Implementation of spill control plans as well as control of fertilizer and pesticide applications, soil erosion, and site debris that can contaminate stormwater.

Applicable Operational BMPs:

- Minimize the amount of herbicides and other pesticides used to maintain access roads and facilities.
- Implement S411 BMPs for Landscaping and Lawn / Vegetation Management.
- Comply with WSDA Pesticide Regulations (see 1.2.16 Other Regulations and Programs).
- When removing water or sediments from electric transformer vaults, determine the presence of contaminants before disposing of the water and sediments.
    - This includes inspecting for the presence of oil or sheen, and determining from records or testing if the transformers contain PCBs.
    - If records or tests indicate that the sediments or water are contaminated above applicable levels, manage these media in accordance with applicable federal and state regulations, including the federal PCB rules (40 CFR 761) and the state MTCA cleanup regulations (Chapter 173-340 WAC).
    - Water removed from the vaults can be discharged in accordance with the federal regulations 40 CFR 761.79, and state regulations (Chapter 173-201A WAC and Chapter 173-200 WAC), or via the sanitary sewer if the requirements, including applicable permits, for such a discharge are met. (See also Requirements for Stormwater Discharges to Public Sanitary Sewers, Septic Systems, Dead-End Sumps, and Industrial Waste Treatment Systems and Ecology Requirements for Generators of Dangerous Wastes in 1.2.16 Other Regulations and Programs).
- Stabilize access roads or areas of bare ground with gravel, crushed rock, or another method to prevent erosion. Use and manage vegetation to minimize bare ground/soils that may be susceptible to erosion.
- Provide maintenance practices to prevent stormwater from accumulating and draining across and/or onto roadways. Convey stormwater through roadside ditches and culverts. The road should be crowned, outsloped, water barred, or otherwise left in a condition not conducive to erosion. Appropriately maintaining grassy roadside ditches discharging to surface waters is an effective way of removing some pollutants associated with sediments carried by stormwater.
- Maintain ditches and culverts at an appropriate frequency to ensure that plugging and flooding across the roadbed, with resulting overflow erosion, does not occur.

- Apply the appropriate BMPs in this Chapter for the storage of waste materials that can contaminate stormwater.

Recommended Operational BMPs:

- When selecting utility poles for a specific location, consider the potential environmental effects of the pole or poles during storage, handling, and end-use, as well as its cost, safety, efficacy, and expected life. Use wood products treated with chemical preservatives made in accordance with generally accepted industry standards such as the American Wood Preservers Association Standards (see http://www.awpa.com/standards/). Consider alternative materials or technologies if placing poles in or near an environmentally sensitive area, such as a wetland or a drinking water well. Alternative technologies include poles constructed with material(s) other than wood such as fiberglass composites, metal, or concrete. Consider other technologies and materials, such as sleeves or caissons for wood poles, when they are determined to be practicable and available.

- As soon as practicable remove all litter from wire cutting/replacing operations.

- Implement temporary erosion and sediment control in areas cleared of trees and vegetation and during the construction of new roads.

S416 BMPs for Maintenance of Roadside Ditches

Description of Pollutant Sources: Common road debris including eroded soil, oils, vegetative particles, and heavy metals can be sources of stormwater pollutants.

Pollutant Control Approach: Maintain roadside ditches to preserve the condition and capacity for which they were originally constructed, and to minimize bare or thinly vegetated ground surfaces. Maintenance practices should provide for erosion and sediment control (see S411 BMPs for Landscaping and Lawn / Vegetation Management).

Additional Regulations: Note that work in wet areas may be regulated by local, state, or federal regulations that impose additional obligations on the responsible party. Check with the appropriate authorities prior to beginning work in those areas.

Applicable Operational BMPs:

- Inspect roadside ditches regularly to identify sediment accumulations and localized erosion.

- Clean ditches on a regular basis, as needed. Keep ditches free of rubbish and debris.

- Vegetation in ditches often prevents erosion and cleanses runoff waters. Remove vegetation only when flow is blocked or excess sediments have accumulated. Conduct ditch maintenance (seeding, fertilizer application, harvesting) in late spring and/or early fall, where possible. This allows re-establishment of vegetative cover by the next wet season, thereby minimizing erosion of the ditch as well as making the ditch effective as a biofilter.

- Do not apply fertilizer unless needed to maintain vegetative growth.

- In the area between the edge of the pavement and the bottom of the ditch, commonly known as the "bare earth zone," use grass vegetation, wherever possible. Establish vegetation from the edge of the pavement, if possible, or at least from the top of the slope of the ditch.
- Maintain diversion ditches on top of cut slopes constructed to prevent slope erosion by intercepting surface drainage to retain their diversion shape and capability.
- Use temporary erosion and sediment control measures or re-vegetate as necessary to prevent erosion during ditch reshaping.
- Do not leave ditch cleanings on the roadway surfaces. Sweep, collect, and dispose of dirt and debris remaining on the pavement at the completion of ditch cleaning operations as described below:
    - Consider screening roadside ditch cleanings, not contaminated by spills or other releases and not associated with a runoff treatment BMP such as a biofiltration swale, to remove litter. Separate screenings into soil and vegetative matter (leaves, grass, needles, branches, etc.) categories. Compost or dispose of the vegetative matter in a municipal waste landfill. Consult with the jurisdictional health department to discuss use or disposal options for the soil portion. For more information, see Appendix 8-B: Management of Street Waste Solids and Liquids.
    - Roadside ditch cleanings contaminated by spills or other releases known or suspected to contain dangerous waste must be handled following the Dangerous Waste Regulations (Chapter 173 303 WAC). If testing determines materials are not dangerous waste but contaminants are present, consult with the jurisdictional health department for disposal options.
- Examine culverts on a regular basis for scour or sedimentation at the inlet and outlet, and repair as necessary. Give priority to those culverts conveying perennial and/or salmon-bearing streams and 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.

Recommended Treatment BMPs:

Install biofiltration swales and filter strips (see 6.8 Biofiltration BMPs) to treat roadside runoff wherever practicable and use engineered topsoils wherever necessary to maintain adequate vegetation. These systems can improve infiltration and stormwater pollutant control upstream of roadside ditches.

S417 BMPs for Maintenance of Stormwater Drainage Systems and Stormwater Management BMPs

Description of Pollutant Sources: Facilities include roadside catch basins on arterials and within residential areas, stormwater conveyance systems, detention BMPs such as ponds and vaults, oil/water separators, biofilters, settling basins, infiltration systems, and all other types of stormwater management BMPs presented in Chapter 6 - Runoff Treatment, Flow Control, and

LID BMP Library. Oil and grease, hydrocarbons, debris, heavy metals, sediments, and contaminated water are found in catch basins, oil and water separators, settling basins, etc.

Pollutant Control Approach: Provide maintenance and cleaning of debris, sediments, and other pollutants from stormwater collection, conveyance, and Runoff Treatment and Flow Control BMPs to maintain proper operation.

Applicable Operational BMPs:

Maintain stormwater management BMPs per the operations and maintenance (O&M) procedures presented in Appendix 6-A: BMP Maintenance Tables, in addition to the following BMPs:

- Inspect and clean stormwater management BMPs, conveyance systems, and catch basins as needed, and determine necessary O&M improvements.
- Promptly repair any deterioration threatening the structural integrity of stormwater facilities. These include replacement of clean-out gates, catch basin lids, and rock in emergency spillways.
- Ensure adequacy of storm sewer capacities and prevent heavy sediment discharges to the sewer system.
- Regularly remove debris and sludge from BMPs used for peak-rate control, treatment, etc. and discharge to a sanitary sewer if approved by the sewer authority, or truck to an appropriate local or state government approved disposal site.
- Clean catch basins when the depth of deposits reaches 60 percent of the sump depth as measured from the bottom of basin to the invert of the lowest pipe into or out of the basin. However, in no case should there be less than six inches clearance from the debris surface to the invert of the lowest pipe. Some catch basins (for example, WSDOT's *Catch Basin Type 1L* (WSDOT, 2011b)) may have as little as 12 inches sediment storage below the invert. These catch basins need frequent inspection and cleaning to prevent scouring. Where these catch basins are part of a stormwater collection and treatment system, the system owner/operator may choose to concentrate maintenance efforts on downstream control devices as part of a systems approach.
- 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 since there may be residual contaminants in the cleaning equipment. Do not jet material downstream into the public drainage system.
- Clean woody debris in a catch basin as frequently as needed to ensure proper operation of the catch basin.
- Post warning signs; “Dump No Waste - Drains to Groundwater,” “Streams,” “Lakes,” or emboss on or adjacent to all storm drain inlets where possible. See S442 BMPs for Labeling Storm Drain Inlets On Your Property.
- Disposal of sediments and liquids from the catch basins must comply with Appendix 8-B: Management of Street Waste Solids and Liquids.

S421 BMPs for Parking and Storage of Vehicles and Equipment

Description of Pollutant Sources: Public and commercial parking lots such as retail store, fleet vehicle (including rent-a-car lots and car dealerships), equipment sale and rental parking lots, and parking lot driveways, can be sources of toxic hydrocarbons and other organic compounds, including oils and greases, metals, and suspended solids.

Pollutant Control Approach: If the parking lot meets the site use thresholds used to determine if the site is expected to generate high concentrations of oil, as defined in Step 2: Determine if an Oil Control BMP is Required in 6.1.2 Choosing Your Runoff Treatment BMPs, provide oil removal equipment for the contaminated stormwater runoff.

Applicable Operational BMPs:

- If a parking lot must be washed, discharge the washwater to a sanitary sewer, if allowed by the local sewer authority, or other approved wastewater treatment system, or collect washwater for off-site disposal.
- Do not hose down the area to a storm sewer or receiving water. Vacuum sweep parking lots, storage areas, and driveways regularly to collect dirt, waste, and debris. Mechanical or hand sweeping may be necessary for areas where a vacuum sweeper cannot reach.
- Clean up vehicle and equipment fluid drips and spills immediately.
- Place drip pans below leaking vehicles (including inoperative vehicles and equipment) in a manner that catches leaks or spills, including employee vehicles. Drip pans must be managed to prevent overfilling and the contents disposed of properly.

Recommended Operational BMPs:

- Encourage employees to repair leaking personal vehicles.
- Encourage employees to carpool or use public transit through incentives.
- Encourage customers to use public transit by rewarding valid transit pass holders with discounts.
- Install catch basin inserts to collect excess sediment and oil if necessary. Inspect and maintain catch basin inserts to ensure they are working correctly.

Applicable Treatment BMPs:

Establishments subject to high-use intensity are significant sources of oil contamination of stormwater. Examples of potential high use areas include customer parking lots at fast food stores, grocery stores, taverns, restaurants, large shopping malls, discount warehouse stores, quick-lube shops, and banks.

Refer to Step 2: Determine if an Oil Control BMP is Required in 6.1.2 Choosing Your Runoff Treatment BMPs for the site use thresholds that determine if an oil control BMP is required, and for a list of oil control BMPs.

S430 BMPs for Urban Streets

Description of Pollutant Sources: Urban streets can be the source of vegetative debris, paper, fine dust, vehicle liquids, tire and brake wear residues, heavy metals (lead and zinc), soil particles, ice control salts, domestic wastes, lawn chemicals, and vehicle combustion products. Street surface contaminants contain significant concentrations of particle sizes less than 250 microns (Sartor and Boyd, 1972).

Pollutant Control Approach: Conduct efficient street sweeping where and when appropriate to minimize the contamination of stormwater. Do not wash street debris into storm drains.

Facilities not covered under the Industrial Stormwater General Permit may consider a minimum amount of water washing of streets. All facilities must comply with their local stormwater requirements for discharging to storm sewers. Municipal NPDES permittees are required to limit street wash water discharges and may have special conditions or treatment requirements.

Recommended BMPs:

- For maximum stormwater pollutant reductions on curbed streets and high volume parking lots, use efficient vacuum sweepers.

  Note: High-efficiency street sweepers utilize strong vacuums and the mechanical action of main and gutter brooms combined with an air filtration system that only returns clean air to the atmosphere (i.e., filters very fine particulates). They sweep dry and use no water since they do not emit any dust.

  High-efficiency vacuum sweepers have the capability of removing 80 percent or more of the accumulated street dirt particles whose diameters are less than 250 microns (Sutherland et al., 1998). This assumes pavements under good condition and reasonably expected accumulation conditions.

- For moderate stormwater pollutant reductions on curbed streets use regenerative air sweepers or tandem sweeping operations.

  Note: A tandem sweeping operation involves a single pass of a mechanical sweeper followed immediately by a single pass of a vacuum sweeper or regenerative air sweeper.

  - *A regenerative air sweeper blows air down on the pavement to entrain particles and uses a return vacuum to transport the material to the hopper.*
  - *These operations usually use water to control dust. This reduces their ability to pick up fine particulates.*

  These types of sweepers have the capability of removing approximately 25 to 50 percent of the accumulated street dirt particles whose diameters are less than 250 microns. (Sutherland et al., 1998). This assumes pavements under good conditions and typical accumulation conditions.

- For minimal stormwater pollutant reductions on curbed streets use mechanical sweepers.
    - *Note: The industry refers to mechanical sweepers as broom sweepers and uses the mechanical action of main and gutter brooms to throw material on a conveyor belt that transports it to the hopper.*
    - *These sweepers usually use water to control dust. This reduces their ability to pick up fine particulates.*

  Mechanical sweepers have the capability of removing only 10 to 20 percent of the accumulated street dirt particles whose diameters are less than 250 microns (Sutherland et al., 1998). This assumes pavements under good condition and the most favorable accumulation conditions.

- Conduct vacuum sweeping at optimal frequencies. Optimal frequencies are those scheduled sweeping intervals that produce the most cost-effective annual reduction of pollutants normally found in stormwater and can vary depending on tree cover, land use, traffic volume, receiving water, and rainfall patterns.
- Train operators in those factors that result in optimal pollutant removal. These factors include sweeper speed, brush adjustment and rotation rate, sweeping pattern, maneuvering around parked vehicles, and interim storage and disposal methods.
- Consider the use of periodic parking restrictions in low to medium density single-family residential areas to ensure the sweeper's ability to sweep along the curb.
- Establish programs for prompt vacuum sweeping, removal, and disposal of debris from special events that will generate higher than normal loadings.
- Do not sweep during rain events, if you can avoid it. The hopper on the sweeper will fill quickly with water from the street. Dispose of the combined water and solids at a decant facility, if possible.
- Disposal of street sweeping solids and liquids must comply with Appendix 8-B: Management of Street Waste Solids and Liquids.
- Consider developing ordinances that prohibit citizens from putting yard debris in the street gutters, or doing vehicle maintenance on the street.
- Provide incentives to property owners for installing permeable pavement parking areas and driveways.
- Consider installing catch basin inserts in high use areas to remove trash and yard debris before it enters the system.
- Implement a storm drain stenciling program to label and educate the public not to dump materials into storm drains or onto sidewalks, streets, parking lots, and gutters.
- Provide household hazardous waste collection and used oil recycling for citizens to avoid illegal dumping.

8.5 Soil Erosion, Sediment Control, and Landscaping Source Control BMPs

S407 BMPs for Dust Control at Disturbed Land Areas and Unpaved Roadways and Parking Lots

Note: Contact the local air quality authority for appropriate and required BMPs for dust control to implement at your project site. See the following web address to determine the air quality authority for the project site:

https://ecology.wa.gov/About-us/Our-role-in-the-community/Partnerships-committees/Clean-air-agencies

Description of Pollutant Sources: Dust can cause air and water pollution problems particularly at demolition sites and in arid areas where reduced rainfall exposes soil particles to transport by air.

Pollutant Control Approach: Minimize dust generation and apply environmentally friendly and government approved dust suppressant chemicals, if necessary.

Applicable Operational BMPs:

- Sprinkle or wet down soil or dust with water as long as it does not result in a wastewater discharge.
- Use only dust suppressant chemicals that are approved by the local jurisdiction and/or state government such as those listed in *Methods for Dust Control* (Ecology, 2016b).
- Avoid excessive and repeated applications of dust suppressant chemicals. Time the application of dust suppressants to avoid or minimize their wash-off by rainfall or human activity such as irrigation.
- Apply stormwater containment to prevent the conveyance of sediment into storm drains or receiving waters.
- Protect inlets/catch basins during application of dust suppressants.
- Ecology prohibits the use of motor oil for dust control. Take care when using lignin derivatives and other high BOD chemicals in areas susceptible to contaminating surface water or groundwater.
- Consult with Ecology and the local permitting authority on discharge permit requirements if the dust suppression process results in a wastewater discharge to the ground, groundwater, storm drain, or surface water.
- 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.

Recommended Additional Operational BMPs for Roadways and Other Trafficked Areas:

- Consider limiting use of off-road recreational vehicles on dust generating land.
- Consider graveling or paving unpaved permanent roads and other trafficked areas at municipal, commercial, and industrial areas.
- Consider paving or stabilizing shoulders of paved roads with gravel, vegetation, or local government approved chemicals.
- Encourage use of alternate paved routes, if available.
- Vacuum sweep fine dirt and skid control materials from paved roads soon after winter weather ends or when needed.
- Consider using pre-washed traction sand to reduce dust emissions.

Additional Recommended Operational BMPs for Dust Generating Areas:

- Prepare a dust control plan. Helpful references include: *Control of Open Fugitive Dust Sources* (Cowherd et al., 1988) and *Fugitive Dust Background Document and Technical Information Document for Best Available Control Measures* (USEPA, 1992).
- Limit exposure of soil (dust source) as much as feasible.
- Stabilize dust-generating soil by growing and maintaining vegetation, mulching, topsoiling, and/or applying stone, sand, or gravel.
- Apply windbreaks in the soil such as trees, board fences, tarp curtains, bales of hay, etc.

Note: Construction site dust control is covered in BMP C140: Dust Control.

S408 BMPs for Dust Control at Manufacturing Areas

Note: Contact the local air quality authority for appropriate and required BMPs for dust control to implement at your project site. See the following website to determine the air quality authority for the project site:

https://ecology.wa.gov/About-us/Our-role-in-the-community/Partnerships-committees/Clean-air-agencies

Description of Pollutant Sources: Industrial material handling activities can generate considerable amounts of dust that is typically removed using exhaust systems. Mixing cement and concrete products and handling powdered materials can also generate dust. Particulate materials that can cause air pollution include grain dust, sawdust, coal, gravel, crushed rock, cement, and boiler fly ash. Air emissions can contaminate stormwater. The objective of this BMP is to reduce the stormwater pollutants caused by dust generation and control.

Pollutant Control Approach: Prevent dust generation and emissions where feasible, regularly clean-up dust that can contaminate stormwater, and convey dust contaminated stormwater to proper treatment.

Applicable BMPs:

- Clean, as needed, powder material handling equipment and vehicles.
- Regularly sweep dust accumulation areas that can contaminate stormwater. Conduct sweeping using vacuum filter equipment to minimize dust generation and to ensure optimal dust removal.
- Use dust filtration/collection systems such as baghouse filters, cyclone separators, etc. to control vented dust emissions that could contaminate stormwater. Control of zinc dusts in rubber production is one example.
- Maintain on-site controls to prevent vehicle track-out.
- Maintain dust collection devices on a regular basis.

Recommended BMPs:

- In manufacturing operations, train employees to handle powders carefully to prevent generation of dust.
- Use water spray to flush dust accumulations to sanitary sewers where allowed by the local sewer authority or to other appropriate treatment system.
- Use approved dust suppressants such as those listed in *Methods for Dust Control* (Ecology, 2016b). Application of some products may not be appropriate in close proximity to receiving waters or conveyances close to receiving waters. For more information, check with Ecology or the local jurisdiction.

Recommended Treatment BMPs

Install sedimentation basins, wetponds, wetvaults, catch basin filters, vegetated filter strips, or equivalent sediment removal BMPs.

S411 BMPs for Landscaping and Lawn / Vegetation Management

Description of Pollutant Sources: Landscaping can include grading, soil transfer, vegetation planting, and vegetation removal. Examples include weed control on golf course lawns, access roads, and utility corridors and during landscaping; and residential lawn/plant care. Proper management of vegetation can minimize excess nutrients and pesticides.

Pollutant Control Approach: Maintain appropriate vegetation to control erosion and the discharge of stormwater pollutants. Prevent debris contamination of stormwater. Where practicable, grow plant species appropriate for the site, or adjust the soil properties of the site to grow desired plant species.

Applicable BMPs:

- Install engineered soil/landscape systems to improve the infiltration and regulation of stormwater in landscaped areas.
- Select the right plants for the planting location based on proposed use, available maintenance, soil conditions, sun exposure, water availability, height, sight factors, and space available.
- Ensure that plants selected for planting are not on the noxious weed list. For example, butterfly bush often gets planted as an ornamental but is actually on the noxious weed list.

  The Washington State Noxious Weed List can be found at the following webpage:

  https://www.nwcb.wa.gov/printable-noxious-weed-list
- Do not dispose of collected vegetation into waterways or storm sewer systems.
- Do not blow vegetation or other debris into the drainage system.
- Dispose of collected vegetation such as grass clippings, leaves, sticks by composting or recycling.
- Remove, bag, and dispose of class A and B noxious weeds in the garbage immediately.
- Do not compost noxious weeds as it may lead to spreading through seed or fragment if the composting process is not hot enough.
- Use manual and/or mechanical methods of vegetation removal (pincer-type weeding tools, flame weeders, or hot water weeders as appropriate) rather than applying herbicides, where practical.
- Use at least an 8 inch "topsoil" layer with at least 8% organic matter to provide a sufficient vegetation-growing medium.
  - Organic matter is the least water-soluble form of nutrients that can be added to the soil. Composted organic matter generally releases only between 2% and 10% of its total nitrogen annually, and this release corresponds closely to the plant growth cycle. Return natural plant debris and mulch to the soil, to continue recycling nutrients indefinitely.
- Select the appropriate turfgrass mixture for the climate and soil type.
  - Certain tall fescues and rye grasses resist insect attack because the symbiotic endophytic fungi found naturally in their tissues repel or kill common leaf and stem-eating lawn insects.

        - The fungus causes no known adverse effects to the host plant or to humans.
        - Tall fescues and rye grasses do not repel root-feeding lawn pests such as Crane Fly larvae.
        - Tall fescues and rye grasses are toxic to ruminants such as cattle and sheep
    - Endophytic grasses are commercially available; use them in areas such as parks or golf courses where grazing does not occur.
    - Local agricultural or gardening resources such as the Washington State University Extension office can offer advice on which types of grass are best suited to the area and soil type.
- Use the following seeding and planting BMPs, or equivalent BMPs, to obtain information on grass mixtures, temporary and permanent seeding procedures, maintenance of a recently planted area, and fertilizer application rates:
    - BMP C120: Temporary and Permanent Seeding
    - BMP C121: Mulching
    - BMP C123: Plastic Covering
    - BMP C124: Sodding
- Adjusting the soil properties of the subject site can assist in selection of desired plant species. Consult a soil restoration specialist for site-specific conditions.

Recommended Additional BMPs:

- Conduct mulch-mowing whenever practicable.
- Use native plants in landscaping. Native plants do not require extensive fertilizer or pesticide applications. Native plants may also require less watering.
- Use mulch or other erosion control measures on soils exposed for more than:
    - one week during the dry season (July 1 to September 30), or
    - 2 days during the wet season (October 1 to June 30).
- Till a topsoil mix or composted organic material into the soil to create a well-mixed transition layer that encourages deeper root systems and drought-resistant plants.
- Apply an annual topdressing application of 3/8 inches of compost. Amending existing landscapes and turf systems by increasing the percentage of organic matter and depth of topsoil can:
    - Substantially improve the permeability of the soil.
    - Increase the disease and drought resistance of the vegetation.
    - Reduce the demand for fertilizers and pesticides.

- Disinfect gardening tools after pruning diseased plants to prevent the spread of disease.
- Prune trees and shrubs in a manner appropriate for each species.
- If specific plants have a high mortality rate, assess the cause and replace with another more appropriate species.
- When working around and below mature trees, follow the most current American National Standards Institute (ANSI) ANSI A300 standards (see http://www.tcia.org/TCIA/BUSINESS/ANSI_A300_Standards_/TCIA/BUSINESS/A300_Standards/A300_Standards.aspx?hkey=202ff566-4364-4686-b7c1-2a365af59669) and International Society of Arboriculture (ISA) BMPs to the extent practicable (e.g. take care to minimize any damage to tree roots and avoid compaction of soil).
- Monitor tree support systems (stakes, guys, etc.).
    - Repair and adjust as needed to provide support and prevent tree damage.
    - Remove tree supports after one growing season or maximum of 1 year.
    - Backfill stake holes after removal.
- When continued, regular pruning (more than one time during the growing season) is required to maintain visual sight lines for safety or clearance along a walk or drive, consider relocating the plant to a more appropriate location.
- Make reasonable attempts to remove and dispose of class C noxious weeds.
- Re-seed bare turf areas until the vegetation fully covers the ground surface.
- Watch for and respond to new occurrences of especially aggressive weeds such as Himalayan blackberry, Japanese knotweed, morning glory, English ivy, and reed canary grass to avoid invasions.
- Plant and protect trees per BMP F6.62: Tree Retention and Tree Planting.
- Aerate lawns regularly in areas of heavy use where the soil tends to become compacted. Conduct aeration while the grasses in the lawn are growing most vigorously. Remove layers of thatch greater than ¾-inch deep.
- Set the mowing height at the highest acceptable level and mow at times and intervals designed to minimize stress on the turf. Generally mowing only 1/3 of the grass blade height will prevent stressing the turf.
    - Mowing is a stress-creating activity for turfgrass.
    - Grass decreases its productivity when mowed too short and there is less growth of roots and rhizomes. The turf becomes less tolerant of environmental stresses, more disease prone and more reliant on outside means such as pesticides, fertilizers, and irrigation to remain healthy.

Additional BMP Information:

- King County's *Best Management Practices for Golf Course Development and Operation* (King County, 1993) has additional BMPs for Turfgrass Maintenance and Operation.
- King County, Seattle Public Utilities, and the Saving Water Partnership have created the following natural lawn and garden care resources that include guidance on building healthy soil with compost and mulch, selecting appropriate plants, watering, using alternatives to pesticides, and implementing natural lawn care techniques.
    - *Natural Yard Care - Five steps to make your piece of the planet a healthier place to live* (King County and SPU, 2008)
    - *The Natural Lawn & Garden Series: Smart Watering* (Saving Water Partnership, 2006)
    - *Natural Lawn Care for Western Washington* (Saving Water Partnership, 2007)
    - *The Natural Lawn & Garden Series: Growing Healthy Soil; Choosing the Right Plants; and Natural Pest, Weed and Disease Control* (Saving Water Partnership, 2012)
- The International Society of Arboriculture (ISA) is a group that promotes the professional practice of arboriculture and fosters a greater worldwide awareness of the benefits of trees through research, technology, and education. ISA standards used for managing trees, shrubs, and other woody plants are the American National Standards Institute (ANSI) A300 standards. The ANSI A300 standards are voluntary industry consensus standards developed by the Tree Care Industry Association (TCIA) and written by the Accredited Standards Committee (ASC). The ANSI standards can be found on the ISA website: www.isa-arbor.com/education/publications/index.aspx
- Washington State University's *Gardening in Washington State* website at http://gardening.wsu.edu contains Washington State specific information about vegetation management based on the type of landscape.
- See the *Pacific Northwest Plant Disease Management Handbook* (Pscheidt and Ocamb, 2016) for information on disease recognition and for additional resources.

S425 BMPs for Soil Erosion and Sediment Control at Industrial Sites

Description of Pollutant Sources: Industrial activities on soil areas, exposed and disturbed soils, steep grading, etc. can be sources of sediments that can contaminate stormwater runoff.

Pollutant Control Approach: Limit the exposure of erodible soil, stabilize, or cover erodible soil where necessary to prevent erosion, and/or provide treatment for stormwater contaminated with TSS caused by eroded soil.

Applicable BMPs:

- Limit the exposure of erodible soil.
- Stabilize entrances/exits to prevent track-out. See BMP C105: Stabilized Construction Access.
- Stabilize or cover erodible soil to prevent erosion. Cover practice options include:
  - Use vegetative cover such as grass, trees, shrubs, on erodible soil areas.
  - Cover exposed areas with mats such as clear plastic, jute, synthetic fiber. See BMP C122: Nets and Blankets and BMP C123: Plastic Covering.
  - Preserve natural vegetation including grass, trees, shrubs, and vines when possible. See BMP C101: Preserving Natural Vegetation.
- If stabilizing or covering the erodible soil is not possible, then structural controls must be implemented. Structural practice options include:
  - Vegetated swales
  - BMP C200: Interceptor Dike and Swale
  - BMP C233: Silt Fence
  - BMP C207: Check Dams
  - BMP C232: Gravel Filter Berm
  - Sedimentation basin
  - Proper grading
  - Paving

For design information refer to 7.4 Construction Stormwater BMPs.

S435 BMPs for Pesticides and an Integrated Pest Management Program

Description of Pollutant Sources: Pesticides include herbicides, rodenticides, insecticides, fungicides, etc. Examples of pesticide uses include:

- Weed control on golf course lawns, access roads, utility corridors and landscaping.
- Sap stain and insect control on lumber and logs.
- Rooftop moss removal.
- Killing nuisance rodents.
- Fungicide application to patio decks.

It is possible to release toxic pesticides such as pentachlorophenol, carbamates, and organometallics to the environment by leaching and dripping from treated parts, container leaks, product misuse, and outside storage of pesticide contaminated materials and equipment. Poor management of pesticides can cause appreciable stormwater contamination and unintended impacts to non-targeted organisms.

Pollutant Control Approach: Control pesticide applications to prevent contamination of stormwater. Develop and implement an Integrated Pest Management (IPM) Plan. Carefully apply pesticides, in accordance with label requirements.

Applicable Operational BMPs:

- Train employees on proper application of pesticides and disposal practices.
- Follow manufacturers' application guidelines and label requirements.
- Do not apply pesticides in quantities that exceed the limits on the product's Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) label. Avoid excessive application of chemical.
- Conduct spray applications during weather conditions as specified in the label requirements and applicable local and state regulations. Do not apply during rain or immediately before expected rain (unless the label directs such timing).
- Clean up any spilled pesticides immediately. Do not hose down to a storm drain, conveyance ditch, or water body.
- Remove weeds/vegetation in stormwater ditches, stormwater facilities, and drainage systems by hand or other mechanical means and only use pesticides as a last resort.
- Flag all sensitive areas including wells, creeks, and wetlands prior to spraying.
- Post notices and delineate the spray area prior to the application, as required by the local jurisdiction, or by Ecology.
- Refer to S411 BMPs for Landscaping and Lawn / Vegetation Management and use pesticides only as a last resort.
- Conduct any pest control activity at the life stage when the pest is most vulnerable. For example, if it is necessary to use a Bacillus thuringiens application to control tent caterpillars, apply it to the material before the caterpillars cocoon or it will be ineffective. Any method used should be site-specific and not used wholesale over a wide area.
- Mix pesticides and clean the application equipment under cover in an area where accidental spills will not enter surface or ground waters, and will not contaminate the soil.
- The pesticide application equipment must be capable of immediate shutoff in the event of an emergency.
- Implement a pesticide-use plan and include at a minimum:

- A list of selected pesticides and their specific uses.
- Brands and formulations of the pesticides.
- Application methods and quantities to be used.
- Equipment use and maintenance procedures.
- Safety, storage, and disposal methods.
- Monitoring, record keeping, and public notice procedures. All procedures shall conform to the requirements of Chapter 17.21 RCW and Chapter 16-228 WAC.

- Develop and implement an Integrated Pest Management (IPM) program if pests are present. The following steps are adapted from *Least Toxic Pest Management for Lawns* (Daar, 1992).
    - **Step One:** Correctly identify problem pests and understand their life cycle.
        - 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 only a problem during certain seasons, or can only be treated effectively in certain phases of the life cycle.
    - **Step Two:** Establish tolerance thresholds for pests.
        - 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.
    - **Step Three:** Monitor to detect and prevent pest problems.
        - Monitor regularly to anticipate and prevent major pest outbreaks.
        - Conduct a visual evaluation of the lawn or landscape's 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 European crane fly.
    - **Step Four:** Modify the maintenance program to promote healthy plants and discourage pests.
        - Review your landscape maintenance practices to see if they can be modified to prevent or reduce the problem.

        - 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 waterings in the summer may reduce the number of crane-fly larvae that survive.
    - **Step Five:** If pests exceed the tolerance thresholds:
        - Consider the most effective management options concurrent with reducing impacts to the environment. This may mean chemical pesticides are the best option in some circumstances.
        - Consider the use of physical, mechanical, or biological controls.
        - Study to determine what products are available and choose a product that is the least toxic and has the least non-target impact.
    - **Step Six:** Evaluate and record the effectiveness of the control, and modify maintenance practices to support lawn or landscape 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 next year for the same problems.

Recommended Additional Operational BMPs:

- Choose the least toxic pesticide available that is capable of reducing the infestation to acceptable levels. The pesticide should readily degrade in the environment and/or have properties that strongly bind it to the soil.
- Choose pesticides categorized by EPA as reduced risk. For example, the herbicide imazamox.
- When possible, apply pesticides during the dry season so that the pesticide residue is degraded prior to the next rain event.
- If possible, do not spray pesticides within 100 feet of water bodies. Spraying pesticides within 100 feet of water bodies including any drainage ditch or channel that leads to open water may have additional regulatory requirements beyond just following the pesticide product label. Additional requirements may include:
    - Obtaining a discharge permit from Ecology.
    - Obtaining a permit from the local jurisdiction.

    - Using an aquatic labeled pesticide and adjuvant.

- Use manual pest control strategies such as physically scraping moss from rooftops, high-pressure sprayers to remove moss, and rodent traps.
- Consider alternatives to the use of pesticides such as covering or harvesting weeds, substitute vegetative growth, and manual weed control/moss removal.
- Consider the use of soil amendments, such as compost, that are known to control some common diseases in plants, such as Pythium root rot, ashy stem blight, and parasitic nematodes.
- Once a pesticide is applied, evaluate its effectiveness for possible improvement. Records should be kept showing the effectiveness of the pesticides applied.
- Follow the FIFRA label requirements for disposal. If the FIFRA label does not have disposal requirements, the rinseate from equipment cleaning and/or from triple-rinsing of pesticide containers should be used as product or recycled into product.
- Develop an adaptive management plan and annual evaluation procedure including: (adapted from (Daar, 1992))
    - A review of the effectiveness of pesticide applications.
    - Impact on buffers and sensitive areas, including potable wells. If individual or public potable wells are located in the proximity of commercial pesticide applications, contact the regional Ecology hydrogeologist to determine if additional pesticide application control measures are necessary.
    - Public concerns.
    - Recent toxicological information on pesticides used/proposed for use.

Additional Information

For more information, refer to the Pesticide Information Center Online (PICOL) databases at the following web address:

http://cru66.cahe.wsu.edu/LabelTolerance.html.

Washington pesticide law requires most businesses that commercially apply pesticides to the property of another to be licensed as a Commercial Applicator from the Washington State Department of Agriculture.

S444 BMPs for the Storage of Dry Pesticides and Fertilizers

Description of Pollutant Sources: Pesticides such as pentachlorophenol, carbamates, and organometallics can be released to the environment as a result of container leaks and outside storage of pesticide-contaminated materials and equipment. Inappropriate management of pesticides or fertilizers can result in stormwater contamination. Runoff contaminated by pesticides and fertilizers can severely degrade streams and lakes and adversely affect fish and other aquatic life.

Pollutant Control Approach: Store fertilizer and pesticide properly to prevent stormwater contamination.

Applicable Structural BMPs:

Store pesticides and fertilizers in enclosed impervious containment areas that prevent precipitation or unauthorized personnel from coming into contact with the materials.

Applicable Operational BMPs:

- Containers and bags must be covered, intact, and off the ground.
- Store all material so that it cannot come into contact with water.
- Immediately clean up any spilled fertilizer or pesticides.
- Keep pesticide and fertilizer contaminated waste materials in designated covered and contained areas, and dispose of properly.
- Store and maintain spill cleanup materials near the storage area.
- Sweep paved storage areas as needed. Collect and dispose of spilled materials. Do not hose down the area.
- Do not discharge pesticide contaminated stormwater or spills/leaks of pesticides to storm sewers or to the sanitary sewer. Contaminated stormwater must be collected and disposed of properly. Unused or spilled/leaked pesticides must be disposed of according to the label.
- Comply with WAC 16-228-1220 and Chapter 16-229 WAC.

S449 BMPs for Nurseries and Greenhouses

Description of Pollutant Sources: These BMPs are for use by commercial container plant, greenhouse grown, and cut foliage production operations. Common practices at nurseries and greenhouses can cause elevated levels of phosphorus, nitrogen, sediment, bacteria, and organic material which can contribute to the degradation of water quality.

Pollutant Control Approach: Minimize the pollutants that leave the site by controlling the placement of materials, stabilizing the site, and managing irrigation water.

Applicable Operational BMPs:

- Establish nursery composting areas, soil storage, and mixing areas at least 100 feet away from any stream or other surface water body and as far away as possible from drainage systems.
- Do not dispose of collected vegetation into waterways or storm sewer systems.
- Do not blow, sweep, or otherwise allow vegetation or other debris into the drainage system.
- Regularly clean up spilled potting soil to prevent its movement, especially if fertilizers and pesticides are incorporated. (Haver, 2014)

- Use soil mixing and layering techniques with composted organic material to reduce herbicide use and watering.
- Utilize soil incorporated with fertilizers and / or pesticides immediately; do not store for extended periods. (Haver, 2014)
- Cover soil storage and compost storage piles. Refer to S429 BMPs for Storage or Transfer (Outside) of Solid Raw Materials, Byproducts, or Finished Products.
- Dispose of pathogen-laced potting substrate and diseased plants appropriately.
- Place plants on gravel, geotextile, or weed cloth to allow infiltration and minimize erosion, including inside greenhouse structures. (Haver, 2014)
- Properly reuse, recycle, or dispose of used polyfilm, containers, and other plastic-based products so that they do not collect stormwater. (FDACS, 2014)
- Evaluate and manage irrigation to reduce runoff, sediment transport, and erosion.
    - Place irrigation inputs to keep moisture primarily in the plant's root zone. This will significantly reduce nutrient related impacts from fertilizers. (FDACS, 2014)
    - Avoid over-irrigating. This may exceed the soil's water-holding capacity and lead to runoff or leaching. (FDACS, 2014)
    - Consider and adjust as needed the uniformity of application, the amount of water retained within the potting substrate, and the amount of water that enters containers compared to that which exits the containers and / or falls between containers. (FDACS, 2014)
    - Consolidate containers and turn off irrigation in areas not in production. This may require individual on / off valves at each sprinkler head. (Haver, 2014)
    - Based on the stage of plant growth, space containers and flats as close as possible to minimize the amount of irrigation water that falls between containers. (FDACS, 2014)
    - Group plants of similar irrigation needs together. (FDACS, 2014)
    - Consider minimizing water losses by using cyclic irrigation (multiple applications of small amounts). (FDACS, 2014)
    - Consider using sub-irrigation systems (e.g. capillary mat, ebb-and-flow benches, and trays or benches with liners); these systems can conserve water and reduce nutrient loss, particularly when nutrients are supplied in irrigation water that is reused. (FDACS, 2014)
    - Refer to S450 BMPs for Irrigation for additional BMP considerations.
- Refer to S443 BMPs for Fertilizer Application and S435 BMPs for Pesticides and an Integrated Pest Management Program.

Applicable Structural BMPs:

- Use windbreaks or other means (e.g. pot in pot) to minimize plant blowover. (FDACS, 2014)
- Cover potting areas with a permanent structure to minimize movement of loose soil. Use a temporary structure if a permanent structure is not feasible. (Haver, 2014)
- Control runoff from central potting locations that have a watering station used to irrigate plants immediately after potting. Implement one of the following actions:
    - Collect runoff in a small basin and reuse the runoff.
    - Route runoff through an onsite vegetative treatment area.
    - Use a graveled area and allow runoff to infiltrate.
- Surround soil storage and compost storage areas with a berm or wattles.
- Utilize a synthetic (geotextile) groundcover material to stabilize disturbed areas and prevent erosion in areas where vegetative cover is not an option. (FDACS, 2014)
- In areas with a large amount of foot traffic, use appropriate aggregate such as rock and gravel for stabilization. (FDACS, 2014)
- Store potting substrate that contains fertilizer in a dedicated area with an impermeable base. If the storage area is not under a roof to protect it from rainfall, manage runoff by directing it to a stormwater treatment area. (FDACS, 2014)

S450 BMPs for Irrigation

Description of Pollutant Sources: Irrigation consists of discharges from irrigation water lines, landscape irrigation, and lawn or garden watering. Excessive watering can lead to discharges of chlorinated potable water runoff into drainage systems; it can also cause erosion; and negatively affect plant health. Improper irrigation can encourage pest problems, leach nutrients, and make a lawn completely dependent on artificial watering. Mosquito breeding habitats may form through excessive watering.

Pollutant Control Approach: Limit the amount and location of watering to prevent runoff and discharges to drainage systems.

Applicable Operational BMPs:

- Irrigate with the minimum amount of water needed. Never water at rates that exceed the infiltration rate of the soil.
- Maintain all irrigation systems so that irrigation water is applied evenly and where it is needed.
- Ensure sprinkler systems do not overspray vegetated areas resulting in excess water discharging into the drainage system.

- Inspect irrigated areas for excess watering. Adjust watering times and schedules to ensure that the appropriate amount of water is being used to minimize runoff. Consider factors such as soil structure, grade, time of year, and type of plant material in determining the proper amounts of water for a specific area.
- Inspect irrigated areas regularly for signs of erosion and/or discharge.
- Place sprinkler systems appropriately so that water is not being sprayed on impervious surfaces instead of vegetation.
- Repair broken or leaking sprinkler nozzles as soon as possible.
- Appropriately irrigate lawns based on the species planted, the available water holding capacity of the soil, and the efficiency of the irrigation system.
    - The depth from which a plant normally extracts water depends on the rooting depth of the plant. Appropriately irrigated lawn grasses normally root in the top 6 to 12 inches of soil; lawns irrigated on a daily basis often root in only the top 1 inch of soil.
- Do not irrigate plants during or immediately after fertilizer application. The longer the period between fertilizer application and irrigation, the less fertilizer runoff occurs.
- Do not irrigate plants during or immediately after pesticide application (unless the pesticide label directs such timing).
- Reduce frequency and/or intensity of watering as appropriate for the wet season (October 1 to June 30).
- Place irrigation systems to ensure that plants receive water where they need it. For example, do not place irrigation systems downgradient of plant's root zones on hillsides.

Recommended Operational BMPs:

- Add a tree bag or slow-release watering device (e.g., bucket with a perforated bottom) for watering newly installed trees when irrigation system is not present.
- Water deeply, but infrequently, so that the top 6 to 12 inches of the root zone is moist.
- Use soaker hoses or spot water with a shower type wand when an irrigation system is not present.
    - Pulse water to enhance soil absorption, when feasible.
    - Pre-moisten soil to break surface tension of dry or hydrophobic soils/mulch, followed by several more passes. With this method, each pass increases soil absorption and allows more water to infiltrate prior to runoff.
- Identify trigger mechanisms for drought-stress (e.g., leaf wilt, leaf senescence, etc.) of different species and water immediately after initial signs of stress appear.
- Water during drought conditions or more often if necessary to maintain plant cover.
- Adjust irrigation frequency and/or intensity as appropriate after plant establishment.

- Annually inspect irrigation systems to ensure:
    - That there are no blockages of sprayer nozzles.
    - Sprayer nozzles are rotating as appropriate.
    - Sprayer systems are still aligned with the plant locations and root zones.
- Consult with the local water utility, Conservation District, or Cooperative Extension office to help determine optimum irrigation practices.
- Do not use chemigation and fertigation in irrigation systems. This will help avoid over-application of pesticides and fertilizers.

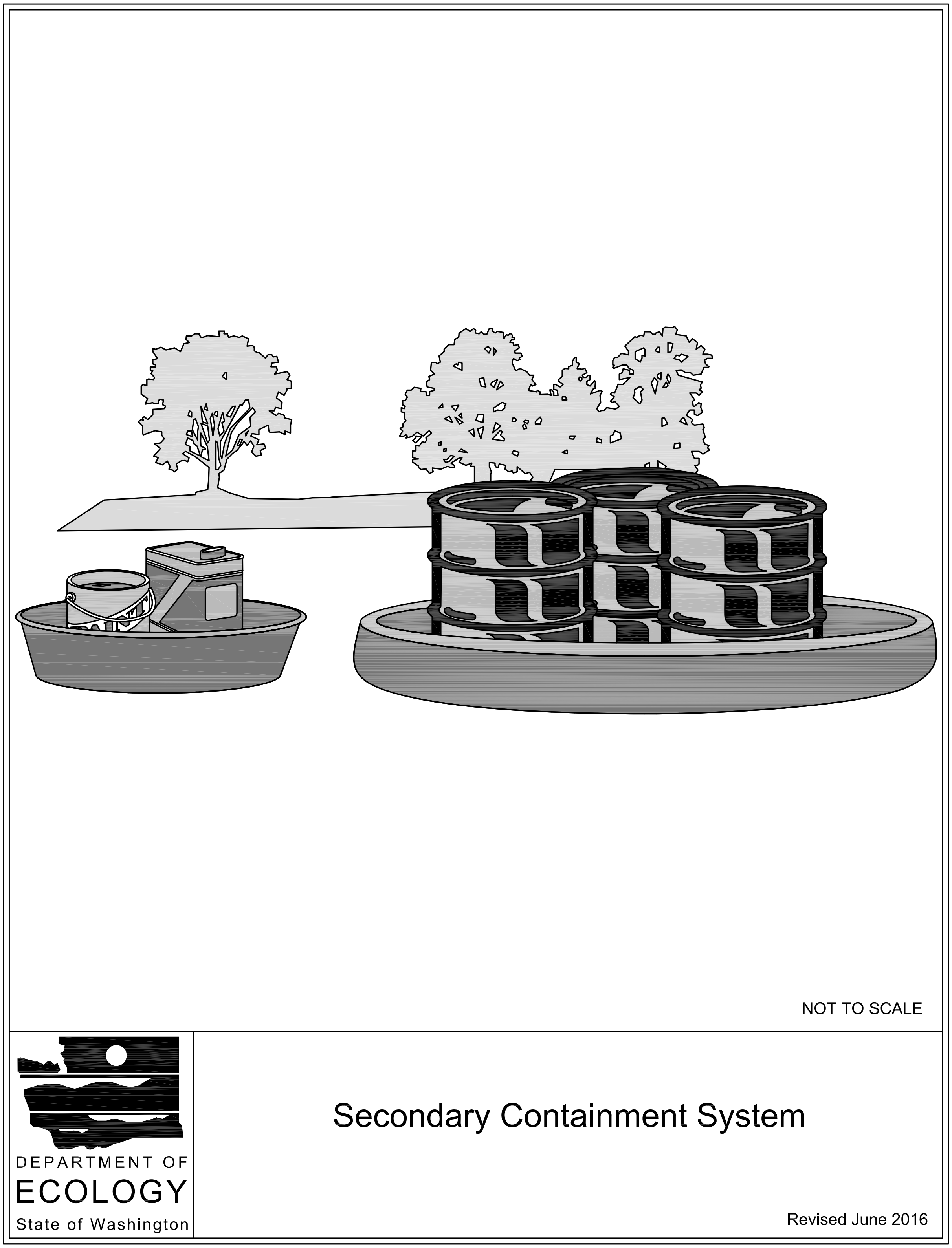
8.6 Storage and Stockpiling Source Control BMPs

S427 BMPs for Storage of Liquid, Food Waste, or Dangerous Waste Containers

Description of Pollutant Sources: Steel and plastic drums with volumetric capacities of 55 gallons or less are typically used at industrial facilities for container storage of liquids and powders. The BMPs specified below apply to container(s) located outside a building. Use these BMPs when temporarily storing potential pollution generating materials or wastes. These BMPs do not apply when Ecology has permitted the business to store the wastes (see Standards for Solid Waste Containers in 1.2.16 Other Regulations and Programs). Leaks and spills of pollutant materials during handling and storage are the primary sources of pollutants. Oil and grease, acid/alkali pH, BOD, and COD are potential pollutant constituents.

Pollutant Control Approach: Store containers in impervious containment under a roof or other appropriate cover, or in a building. For storage areas on-site for less than 30 days, consider using a portable temporary secondary system like that shown in Figure 8.2: Secondary Containment System in lieu of a permanent system as described above.

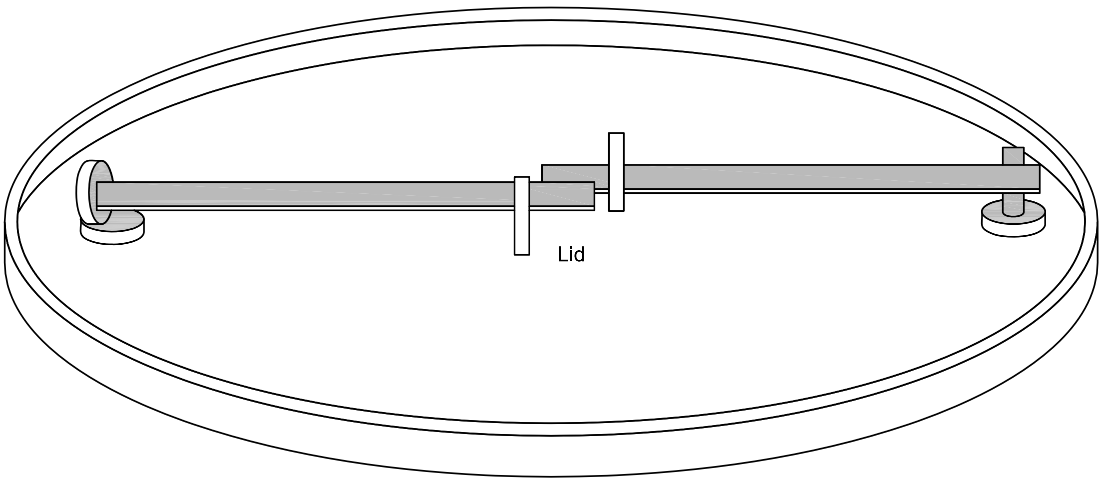
Figure 8.2: Secondary Containment System



Applicable Operational BMPs:

- Place tight-fitting lids on all containers.
- Label all containers appropriately. Store containers so that the labels are clearly visible..
- Place drip pans beneath all mounted container taps and at all potential drip and spill locations during filling and unloading of containers.
- Inspect container storage areas regularly for corrosion, structural failure, spills, leaks, overfills, and failure of piping systems. Check containers daily for leaks/spills. Replace containers, and replace and tighten bungs in drums as needed.
- Empty drums containing residues should be stored to prevent stormwater from entering drum closures. Cover or tilt drums to prevent stormwater from accumulating on the top of empty drums and around drum closures.
- Store containers that do not contain free liquids in a designated sloped area with the containers elevated or otherwise protected from stormwater run-on. Comply with local fire code.
- Secure drums when stored in an area where unauthorized persons may gain access in a manner that prevents accidental spillage, pilferage, or any unauthorized use (see Figure 8.3: Locking System for Drum Lid).

Figure 8.3: Locking System for Drum Lid



NOT TO SCALE

DEPARTMENT OF ECOLOGY
State of Washington

Locking System for Drum Lid

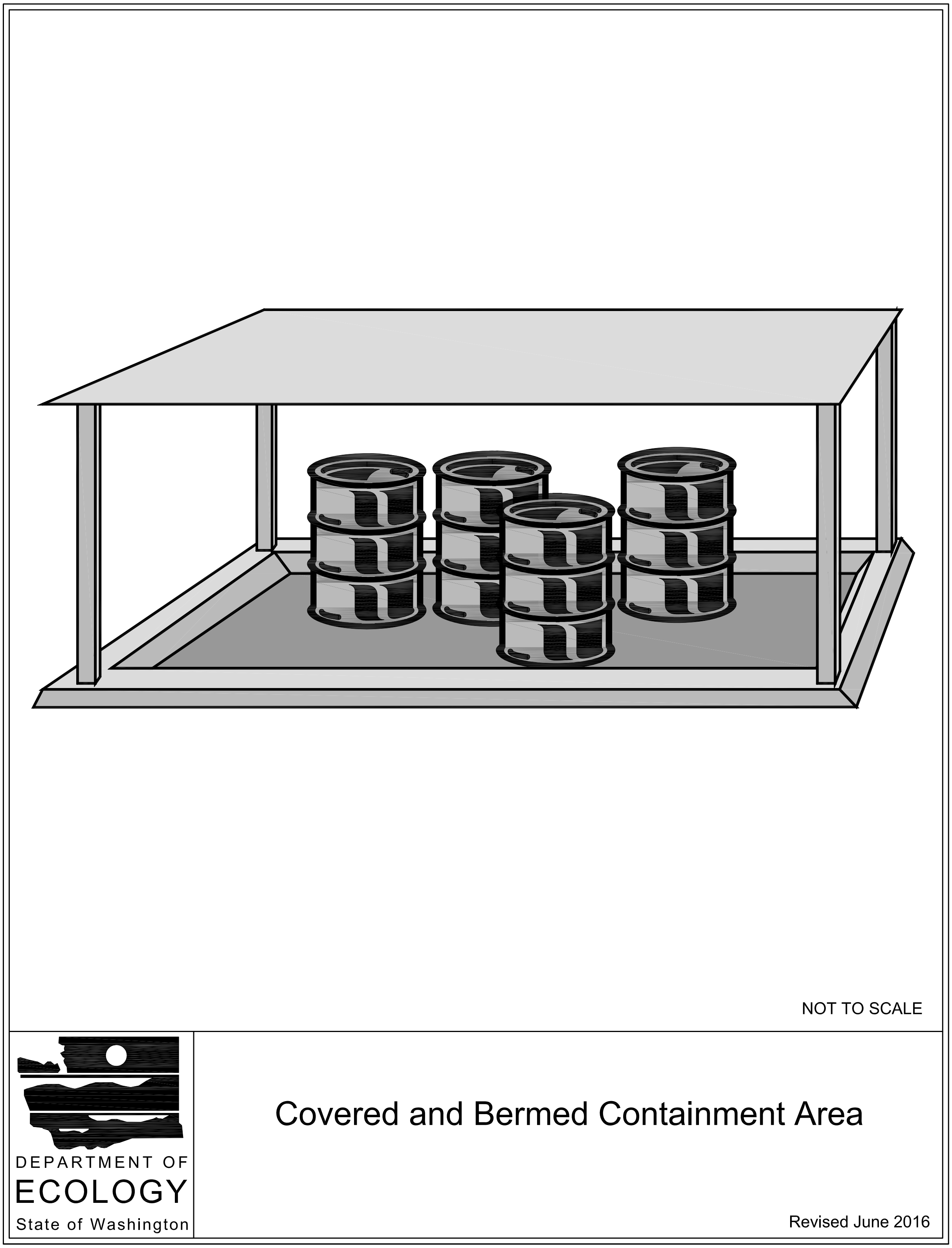
Revised June 2016

- If the material is a dangerous waste, the business owner must comply with any additional Ecology requirements as specified in Ecology Requirements for Generators of Dangerous Wastes within 1.2.16 Other Regulations and Programs.
- Storage of flammable, ignitable, and reactive chemicals and materials must comply with the stricter of local zoning codes, local fire codes, the Uniform Fire Code (UFC), UFC standards, or the National Electric Code.
- Have spill kits or cleanup materials near container storage areas.
- Clean up all spills immediately.
- Cover dumpsters, or keep them under cover, such as a lean-to, to prevent the entry of stormwater. Keep dumpster lids closed.
- Replace or repair leaking garbage dumpsters, or install waterproof liners.
- Drain dumpsters and/or dumpster pads to sanitary sewer where approved by the sewer authority.
- When collection trucks directly pick up roll-containers, ensure a filet is on both sides of the curb to facilitate moving the dumpster.

Applicable Structural Source Control BMPs:

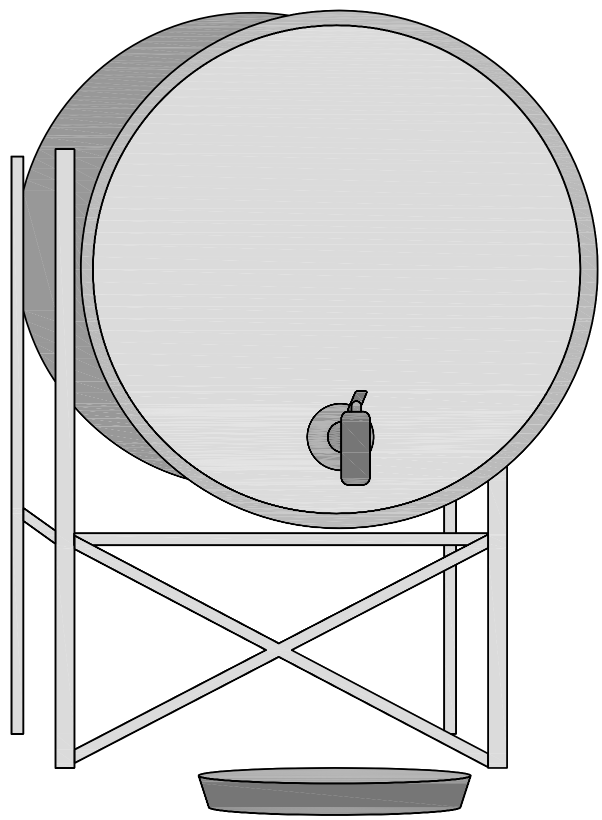
- Keep containers with dangerous waste, food waste, or other potential pollutant liquids inside a building unless this is not feasible due to site constraints or Uniform/International Fire Code requirements.
- Store containers in a designated area which is covered, bermed, diked, or paved and impervious in order to contain leaks and spills (see Figure 8.4: Covered and Bermed Containment Area). Slope the secondary containment to drain into a dead-end sump for the collection of leaks and small spills.
- For liquid materials, surround the containers with a dike as illustrated in Figure 8.4: Covered and Bermed Containment Area. The dike must be of sufficient height to provide a volume of either 10 percent of the total enclosed container volume or 110 percent of the volume contained in the largest container, whichever is greater.

Figure 8.4: Covered and Bermed Containment Area



- Where material is temporarily stored in drums, use a containment system as illustrated, in lieu of the above system (see Figure 8.2: Secondary Containment System).
- Place containers mounted for direct removal of a liquid chemical for use by employees inside a containment area as described above. Use a drip pan during liquid transfer (see Figure 8.5: Mounted Container with Drip Pan).

Figure 8.5: Mounted Container with Drip Pan



*Note that the secondary containment is not shown in this figure

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Mounted Container with Drip Pan

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Applicable Treatment BMP:

Note this treatment BMP is for contaminated stormwater from drum storage areas.

- To discharge contaminated stormwater, pump it from a dead-end sump or catchment and dispose of appropriately.

S428 BMPs for Storage of Liquids in Permanent Aboveground Tanks

Description of Pollutant Sources: Aboveground tanks containing liquids (excluding uncontaminated water) may be equipped with a valved drain, vent, pump, and bottom hose connection. Aboveground tanks may be heated with steam heat exchangers equipped with steam traps, if required. Leaks and spills can occur at connections and during liquid transfer. Oil and grease, organics, acids, alkalis, and heavy metals in tank water and condensate drainage can also cause stormwater contamination at storage tanks.

Pollutant Control Approach: Install secondary containment or a double-walled tank. Slope the containment area to a drain with a sump. Operators may need to discharge stormwater collected in the containment area to a Runoff Treatment BMP such as BMP T5.100: API (Baffle type) Separator or BMP T5.110: Coalescing Plate (CP) Separator, or an equivalent BMP. Add safeguards against accidental releases including protective guards around tanks to protect against vehicle or forklift damage, and tagging valves to reduce human error. *Tank water and condensate discharges are process wastewater that may need an NPDES Permit.*

Applicable Operational BMPs:

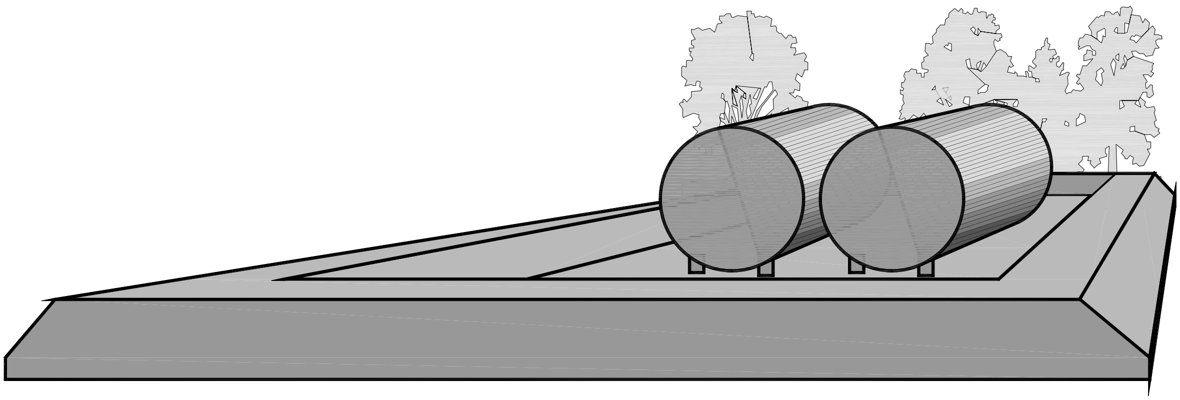
- Inspect the tank containment areas regularly for leaks/spills, cracks, corrosion, etc. to identify problem components such as fittings, pipe connections, and valves.
- Place adequately sized drip pans beneath all mounted taps and drip/spill locations during filling/unloading of tanks. Operators may need valved drain tubing in mounted drip pans.
- Vacuum sweep and clean the tank storage area regularly, if paved.
- Replace or repair tanks that are leaking, corroded, or otherwise deteriorating.
- Storage of flammable, ignitable, and reactive chemicals and materials must comply with the stricter of local zoning codes, local fire codes, the Uniform Fire Code (UFC), UFC standards, or the National Electric Code.

Applicable Structural BMPs:

- Locate permanent tanks in impervious (Portland cement concrete or equivalent) secondary containment surrounded by dikes as illustrated in Figure 8.6: Above-Ground Tank Storage, or use UL approved double-walled tanks. The dike must be of sufficient height to provide a containment volume of either 10 percent of the total enclosed tank volume or 110 percent of the volume contained in the largest tank, whichever is greater.

- Slope the secondary containment to drain to a normally closed valve, for the collection of small spills.
- Include a tank overfill protection system to minimize the risk of spillage during loading.

Figure 8.6: Above-Ground Tank Storage



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Above-Ground Tank Storage

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Applicable Treatment BMPs:

- Depending on the kind of liquid being stored, the potential and type of stormwater contamination will vary and may require specialized treatment.
- For an uncovered tank containment area, equip the outlet from the spill-containment sump with a normally closed shutoff valve. Operators may open this valve manually or automatically, only to convey contaminated stormwater to approved treatment or disposal, or to convey uncontaminated stormwater to a storm sewer. Evidence of contamination can include the presence of visible sheen, color, or turbidity in the runoff, or existing or historical operational problems at the facility. Use simple pH tests with litmus or pH paper for areas subject to acid or alkaline contamination.
- At petroleum tank farms, convey stormwater contaminated with floating oil or debris in the contained area to a sanitary sewer with the sewer authority's approval or through BMP T5.100: API (Baffle type) Separator or BMP T5.110: Coalescing Plate (CP) Separator, or other approved treatment prior to discharge to the storm drain or surface water.

S429 BMPs for Storage or Transfer (Outside) of Solid Raw Materials, Byproducts, or Finished Products

Description of Pollutant Sources: Some pollutant sources stored outside in large piles, stacks, etc. at commercial or industrial establishments include:

- Solid raw materials
- Byproducts
- Gravel
- Sand
- Salts
- Topsoil
- Compost
- Logs
- Sawdust
- Wood chips
- Lumber
- Concrete
- Metal products

Contact between outside bulk materials and stormwater can cause leachate, and erosion of the stored materials. Contaminants may include TSS, BOD, organics, and dissolved salts (sodium, calcium, and magnesium chloride, etc.).

Pollutant Control Approach: Provide impervious containment with berms, dikes, etc., and/or cover to prevent run-on and discharge of leachate pollutant(s) and TSS.

Applicable Operational BMPs:

- Do not hose down the contained stockpile area to a storm drain or a conveyance to a storm drain, or to a receiving water.
- Maintain contributing drainage areas in and around storage of solid materials with a minimum slope of 1.5 percent to prevent pooling and minimize leachate formation. Areas should be sloped to drain stormwater to the perimeter for collection or to internal drainage "alleyways" where no stockpiled material exists.
- Sweep paved storage areas regularly for collection and disposal of loose solid materials.
- If and when feasible, collect and recycle water-soluble materials (leachates).
- Stock cleanup materials, such as brooms, dustpans, and vacuum sweepers near the storage area.

Applicable Structural BMPs:

For stockpiles less than 5 cubic yards, place temporary plastic sheeting (polyethylene, polypropylene, hypalon, or equivalent) over the material as shown in Figure 8.8: Material Covered with Plastic Sheeting.

The source control BMP options listed below are applicable to:

- Stockpiles greater than 5 cubic yards of erodible or water soluble materials such as:
    - Soil
    - Road deicing salts
    - Compost
    - Unwashed sand and gravel
    - Sawdust
- Outside storage areas for solid materials such as:
    - Logs
    - Bark
    - Lumber
    - Metal products

Choose one or more of the following Source Control BMPs:

- Store in a building or a paved and bermed covered area as shown in Figure 8.7: Covered Storage Area for Bulk Solids.
- Place temporary plastic sheeting (polyethylene, polypropylene, hypalon, or equivalent) over the material as shown in Figure 8.8: Material Covered with Plastic Sheeting.
- Pave the area 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 runoff to treatment. Slope the paved area in a manner that minimizes the contact between stormwater (e.g., pooling) and leachable materials in compost, logs, bark, wood chips, etc.
- For large uncovered stockpiles, implement containment practices at the perimeter of the site and at any catch basins as needed to prevent erosion and discharge of the stockpiled material off-site or to a storm drain. Ensure that no direct discharge of contaminated stormwater to catch basins exists without conveying runoff through an appropriate treatment BMP.

Figure 8.7: Covered Storage Area for Bulk Solids

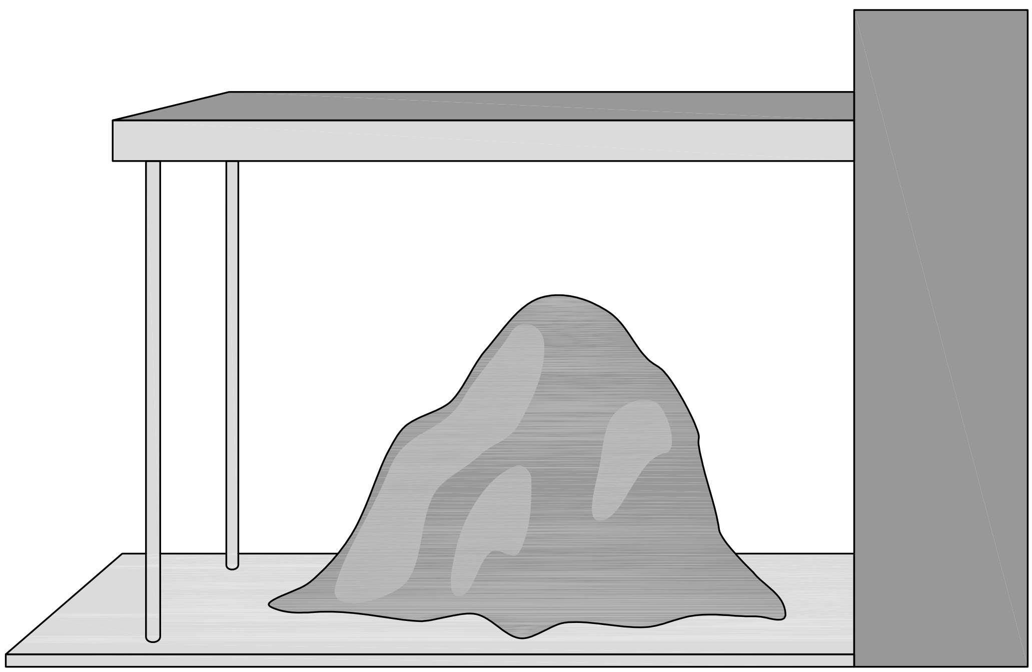
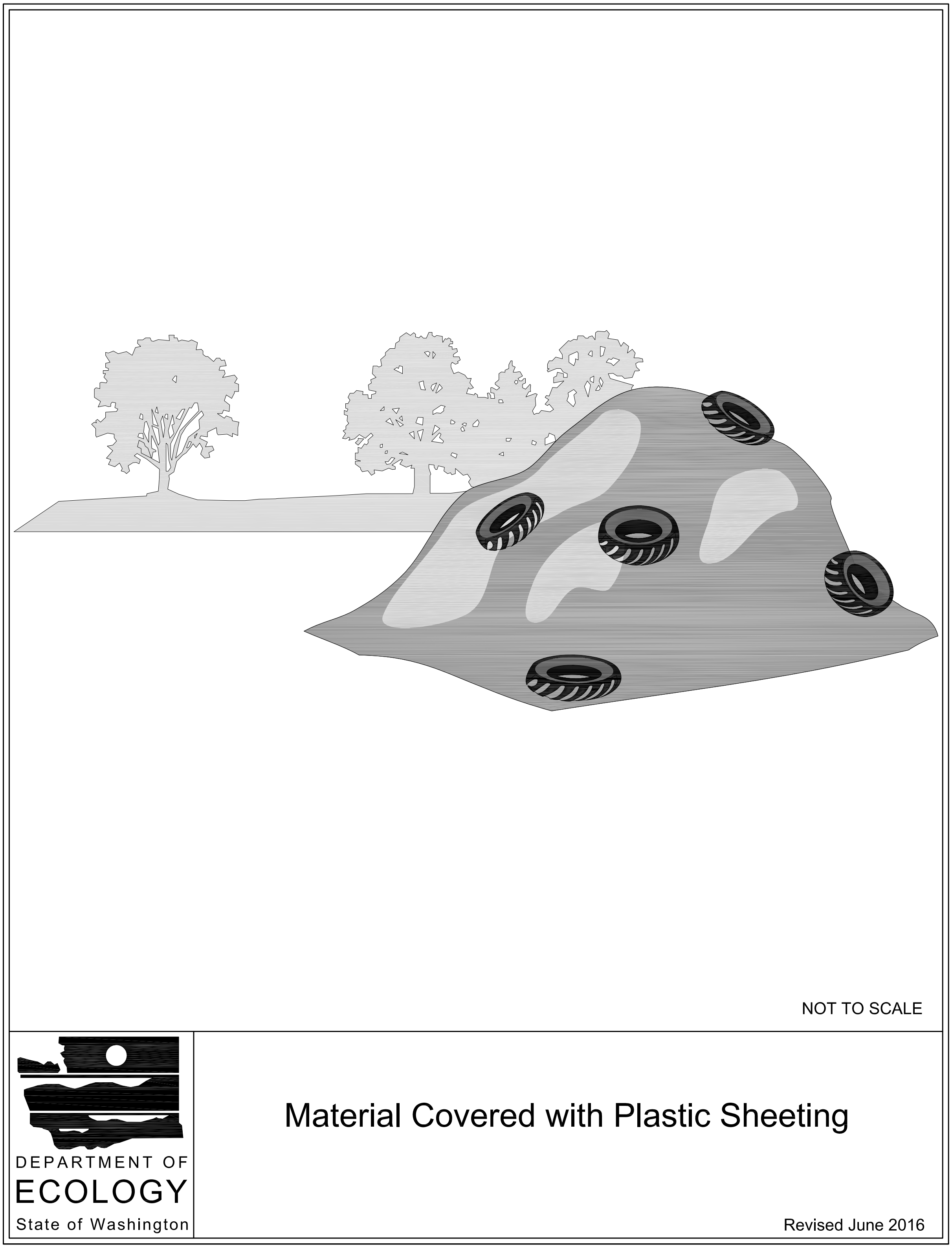


Figure 8.8: Material Covered with Plastic Sheeting



Applicable Treatment BMPs:

Convey contaminated stormwater from the stockpile area to:

- BMP T10.10: Wetponds - Basic and Large,
- BMP T5.72: Wetvaults,
- BMP T6.10: Presettling Basin,
- a Manufactured Treatment Device (see 6.11 Manufactured Treatment Devices as BMPs), or
- other appropriate Runoff Treatment BMP depending on the contamination.

S445 BMPs for Temporary Fruit Storage

Description of Pollutant Sources: This activity applies to businesses that temporarily store fruits and vegetables outdoors prior to or after packing, processing, or sale, or that crush, cut, or shred fruits or vegetables for wines, frozen juices, and other food and beverage products.

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 biochemical oxygen demand (BOD), and color. These pollutants must not be discharged to the drainage system or directly into receiving waters.

Pollutant Control Approach: Store and process fruits and vegetables indoors or under cover whenever possible. Educate employees about proper procedures. Cover and contain operations and apply good housekeeping and preventive maintenance practices to prevent the contamination of stormwater.

Applicable Operational BMPs:

- Educate employees on the benefits of keeping a clean storage area.
- Keep fruits, vegetables, and grains stored outside for longer than a day in plastic bins or in bins lined with plastic. The edge of the plastic liner should be higher than the amount of fruit stored or should drape over the side of the bin.
- Dispose of rotten fruit, vegetables, and grains in a timely manner (typically, within a week).
- Make sure all outside materials that have the potential to leach or spill to the drainage system are covered, contained, or moved to an indoor location. For fruits, vegetables, and grains stored outside for a week or more, cover with a tarp or other waterproof material. Make sure coverings are secured from wind.
- Minimize the use of water when cleaning produce to avoid excess runoff.
- Sweep or shovel storage and processing areas daily to collect dirt and fruit and vegetable fragments for proper disposal. Keep hosing to a minimum.

- Keep cleanup materials, such as brooms and dustpans, near the storage area.
- If a holding tank is used for the storage of wastewater, pump out the contents before the tank is full and dispose of wastewater to a sanitary sewer or approved wastewater treatment system.

Applicable Structural BMPs:

- Enclose the processing area in a building or shed, or cover the area with provisions for stormwater run-on prevention. Alternatively, pave and slope the area to drain to the sanitary sewer, holding tank, or process treatment system collection drain.

Optional Structural BMPs:

- Cover outdoor storage areas for fruits and vegetables.
- Use a containment curb, dike, or berm to prevent off-site runoff from storage or processing areas and to prevent stormwater run-on.

8.7 Transfer of Liquid or Solid Materials Source Control BMPs

S409 BMPs for Fueling At Dedicated Stations

Description of Pollutant Sources: A fueling station is a facility dedicated to the transfer of fuels from a stationary pumping station to mobile vehicles or equipment. It includes above or underground fuel storage facilities. Fueling may occur at:

- General service gas stations
- 24-hour convenience stores
- Construction sites
- Maintenance yards
- Warehouses
- Car washes
- Manufacturing establishments
- Port facilities
- Marinas
- Boatyards
- Businesses with fleet vehicles.

Typical causes of stormwater contamination at fueling stations include leaks/spills of fuels, lubrication oils, radiator coolants, and vehicle washwater.

Pollutant Control Approach: New or substantially remodeled* fueling stations must be constructed on an impervious concrete pad under a roof to keep out rainfall and stormwater run-on. The facility must use a runoff treatment BMP for contaminated stormwater and wastewaters in the fueling containment area.

** Substantial remodeling includes (but is not limited to) replacing the canopy, or relocating or adding one or more fuel dispensers in such a way that modifies the Portland cement concrete (or equivalent) paving in the fueling area.*

Applicable Operational BMPs:

- Prepare an emergency spill response and cleanup plan (spill plan) per S426 BMPs for Spills of Oil and Hazardous Substances.
- Train employees on the proper use of fuel dispensers and on the spill plan.
- Have a designated trained person(s) available either on site or on call at all times to promptly and properly implement the spill plan and immediately cleanup all spills.
- 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 fully stocked at all times.
- The person conducting the fuel transfer must be present at the fueling pump during fuel transfer, particularly at unattended or self-serve stations.
- Keep suitable cleanup materials, such as dry adsorbent materials, on site to allow prompt cleanup of a spill.
- Do not use dispersants to clean up spills or sheens, unless properly removed for disposal following application. Dispersants are not allowed to enter storm drains, surface waters, treatment systems, or sanitary sewers.
- Post signs in accordance with the requirements in the International Fire Code (IFC). For example, post “No Topping Off” signs (topping off gas tanks causes spillage and vents gas fumes to the air).
- Make sure that the automatic shut-off on the fuel nozzle is functioning properly.
- Refer to S439 BMPs for In-Water and Over-Water Fueling for BMPs for in-water or over-water fueling operations

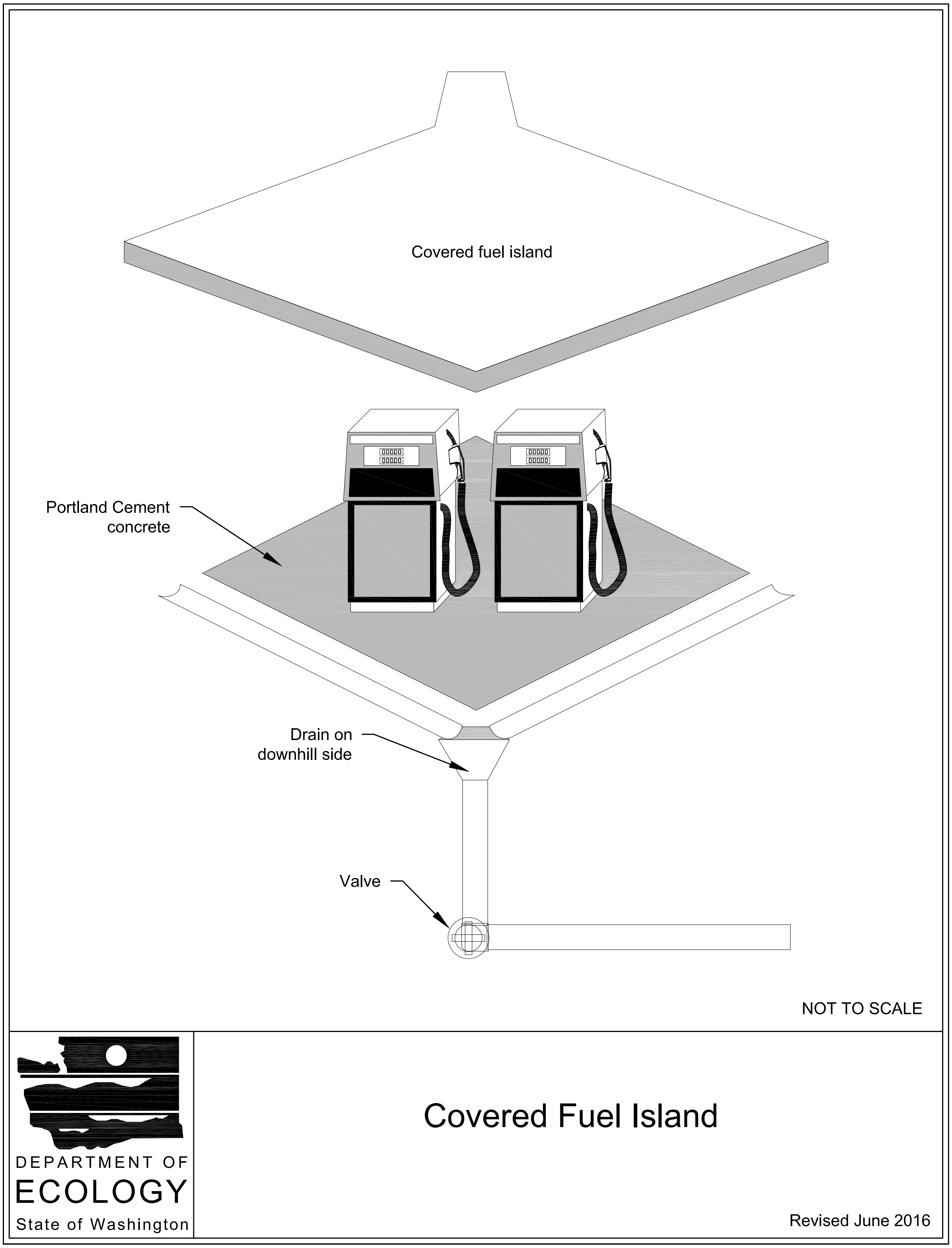
Applicable Structural Source Control BMPs:

For new or substantially remodeled fueling stations:

- Design the fueling island to:
    - Minimize stormwater contamination.
    - Control spills (dead-end sump or spill control separator in compliance with the IFC).
    - Collect stormwater and/or wastewater and direct it to an appropriate treatment system.
- Slope the concrete containment pad around the fueling island toward drains; either trench drains, catch basins and/or a dead-end sump. The slope of the drains shall not be less than 1 percent in accordance with the IFC.
- Drains from containment pads must have a normally closed shutoff valve. The valve may be opened to convey contaminated stormwater to oil removal treatment such as an API or CP oil/water separator (see 6.14 Oil and Water Separator BMPs), catchbasin insert, or equivalent treatment, and then to a basic treatment BMP (as described in 6.1.2 Choosing Your Runoff Treatment BMPs) or to a sanitary sewer, if approved by the sewer authority. Discharges from treatment systems to storm sewer or surface water or to the ground must not display ongoing or recurring visible sheen and must not contain a significant amount of oil and grease.
- The spill control capacity must be sized in compliance with the IFC. The spill control capacity may be acquired by either an underground system including a sump, or an above ground containment area consisting of a containment pad with berms.

  The fueling island may be designed as a spill containment pad with a sill or berm raised to a minimum of four inches to prevent the runoff of spilled liquids and to prevent run-on of stormwater from the surrounding area. All stormwater collected on the containment pad must discharge to treatment with a normally closed valve downstream of the treatment.
- The fueling pad must be paved with Portland cement concrete, or equivalent. Ecology does not consider asphalt an equivalent material.
- The fueling island must have a roof or canopy to prevent the direct entry of precipitation onto the spill containment pad (see Figure 8.9: Covered Fuel Island). The roof or canopy should, at a minimum, cover the spill containment pad (within the grade break or fuel dispensing area) and preferably extend 3 feet on each side for roofs and canopies 10 feet or less in height and 5 feet on each side for roofs and canopies greater than 10 feet in height. Overhangs reduce the introduction of windblown rain. Measure the overhang relative to the berm or other hydraulic grade break for the spill containment pad.

Figure 8.9: Covered Fuel Island



- Convey all roof drains to storm drains outside the fueling containment area.
- Convey stormwater collected on the fuel island containment pad to a sanitary sewer system, if approved by the sanitary authority, or to an approved treatment system such as an oil/water separator and a basic treatment BMP. (Basic treatment BMPs are listed in 6.1.2 Choosing Your Runoff Treatment BMPs). Discharges from treatment systems to storm drains or surface water or to the ground must not display ongoing or recurring visible sheen and must not contain oil and grease.
- Alternatively, collect stormwater from the fuel island containment pad and hold for proper off-site disposal.
- Approval from the local sewer authority is required for conveyance of any fuel-contaminated stormwater to a sanitary sewer. The discharged stormwater must comply with pretreatment regulations (WAC 173-216-060). These regulations prohibit discharges that could "cause fire or explosion”. State and federal pretreatment regulations define an explosive or flammable mixture, based on a flash point determination of the mixture. Stormwater could be conveyed to a sanitary sewer system if it is determined not to be explosive.
- 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. Alternatively, cover nearby storm drains during the filling process and use drip pans under all hose connections.

Additional BMP for Vehicles 10 Feet in Height or Greater

A roof or canopy may not be feasible at fueling stations that regularly fuel vehicles that are 10 feet in height or greater, particularly at industrial or WSDOT sites. At those types of fueling facilities, the following BMPs apply, as well as the applicable BMPs and fire prevention (IFC requirements) of this BMP for fueling stations:

- If a roof or canopy is impractical, the concrete fueling pad must be equipped with emergency spill control including a shutoff valve for drainage from the fueling area. Maintain the valve in the closed position in the event of a spill. Clean up spills and dispose of materials off-site in accordance with S426 BMPs for Spills of Oil and Hazardous Substances.
- The valve may be opened to convey contaminated stormwater to a sanitary sewer, if approved by the sewer authority, or to oil removal treatment such as an API or CP oil/water separator (see 6.14 Oil and Water Separator BMPs), catchbasin insert, or equivalent treatment, and then to a basic treatment BMP (as described in 6.1.2 Choosing Your Runoff Treatment BMPs). Discharges from treatment systems to storm sewer or surface water or to the ground must not display ongoing or recurring visible sheen and must not contain a significant amount of oil and grease.

S412 BMPs for Loading and Unloading Areas for Liquid or Solid Material

Description of Pollutant Sources: Operators typically conduct loading/unloading of liquid and solid materials at industrial and commercial facilities at shipping and receiving, outside storage, fueling areas, etc. Materials transferred can include products, raw materials, intermediate products, waste materials, fuels, scrap metals, etc. Leaks and spills of fuels, oils, powders, organics, heavy metals, salts, acids, alkalis, etc. during transfer may cause stormwater contamination. Spills from hydraulic line breaks are a common problem at loading docks.

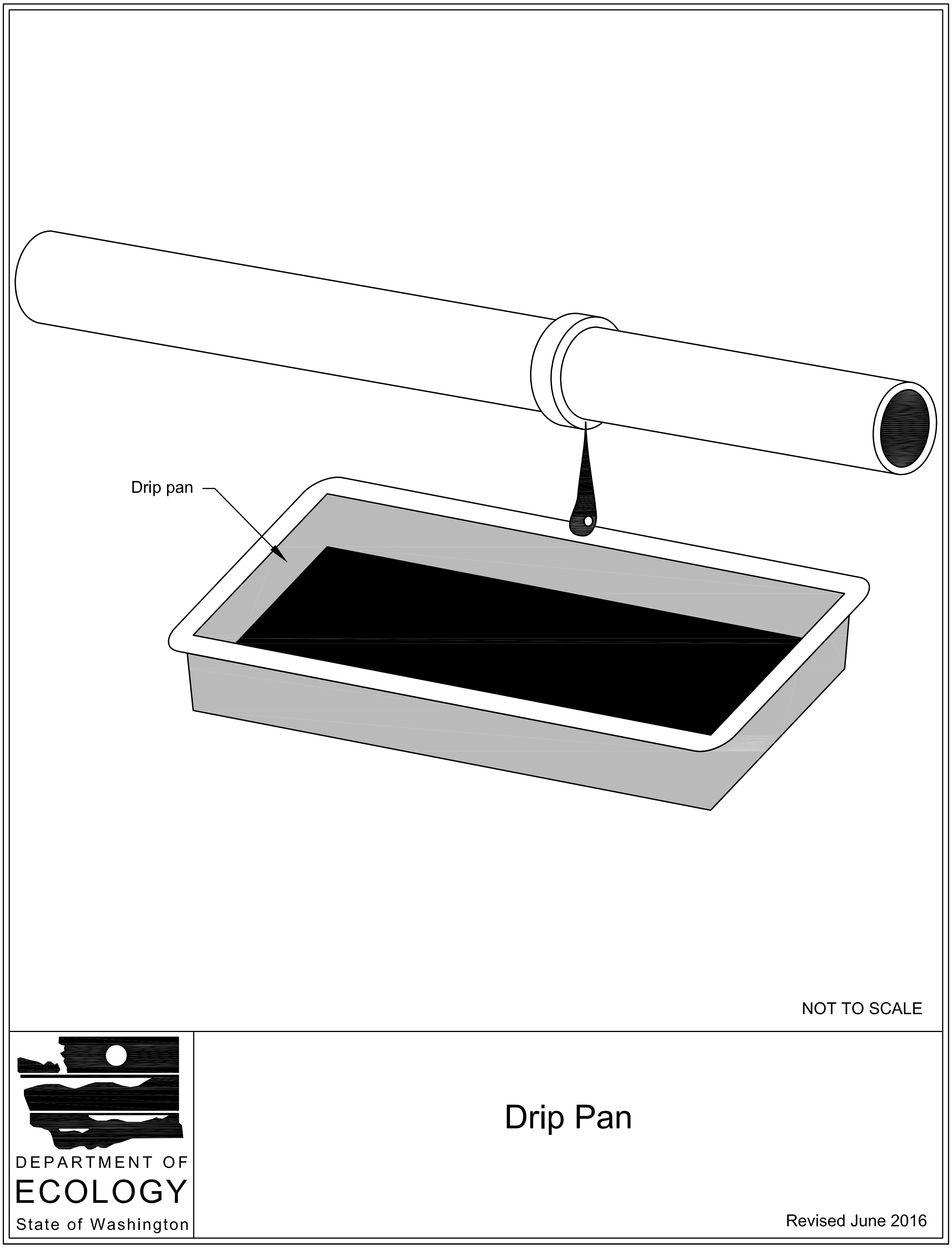
Pollutant Control Approach: Cover and contain the loading/unloading area where necessary to prevent run-on of stormwater and runoff of contaminated stormwater.

Applicable Operational BMPs:

At All Loading/ Unloading Areas

- A significant amount of debris can accumulate at outside, uncovered loading/unloading areas. Sweep these surfaces frequently to remove loose material that could contaminate stormwater. Sweep areas temporarily covered after removal of the containers, logs, or other material covering the ground.
- Place drip pans, or other appropriate temporary containment device, at locations where leaks or spills may occur such as hose connections, hose reels, and filler nozzles. Always use drip pans when making and breaking connections (see Figure 8.10: Drip Pan). Check loading/unloading equipment such as valves, pumps, flanges, and connections regularly for leaks and repair as needed.

Figure 8.10: Drip Pan



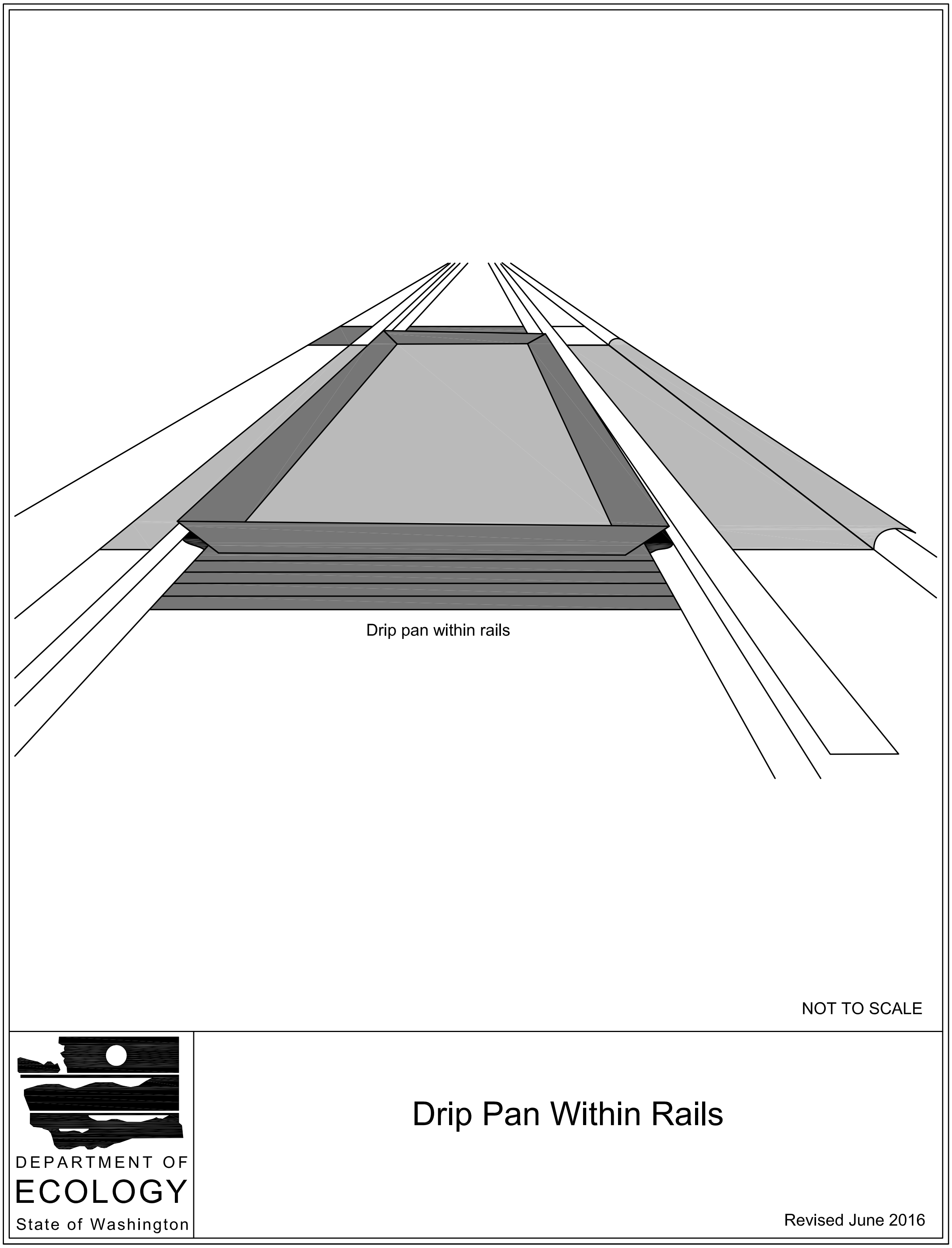
At Tanker Truck and Rail Transfer Areas to Above/Below-ground Storage Tanks

- To minimize the risk of accidental spillage, prepare an "Operations Plan" that describes procedures for loading/unloading. Train employees in its execution and post it or otherwise have it readily available to all employees.
- Report spills of reportable quantities to Ecology.
- Prepare and implement an Emergency Spill Cleanup Plan for the facility (See S426 BMPs for Spills of Oil and Hazardous Substances) which includes the following BMPs:
    - Ensure the cleanup of liquid/solid spills in the loading/unloading area immediately, if a significant spill occurs, and, upon completion of the loading/unloading activity, or, at the end of the working day.
    - Retain and maintain an appropriate oil spill cleanup kit on-site for rapid cleanup of material spills. (See S426 BMPs for Spills of Oil and Hazardous Substances).
    - Ensure that an employee trained in spill containment and cleanup is present during loading/unloading.

At Rail Transfer Areas to Above/Below-ground Storage Tanks

Install a drip pan system as illustrated (see Figure 8.11: Drip Pan Within Rails) within the rails to collect spills/leaks from tank cars and hose connections, hose reels, and filler nozzles.

Figure 8.11: Drip Pan Within Rails



Loading/Unloading from/to Marine Vessels

Facilities and procedures for the loading or unloading of petroleum products must comply with Coast Guard requirements specified in Coast Guard Requirements for Marine Transfer of Petroleum Products within 1.2.16 Other Regulations and Programs.

Transfer of Small Quantities from Tanks and Containers

Refer to S428 BMPs for Storage of Liquids in Permanent Aboveground Tanks and S427 BMPs for Storage of Liquid, Food Waste, or Dangerous Waste Containers for requirements related to the transfer of small quantities from tanks and containers, respectively.

Applicable Structural Source Control BMPs:

At All Loading/ Unloading Areas

- Consistent with Uniform Fire Code requirements (see Uniform Fire Code Requirements within 1.2.16 Other Regulations and Programs) and to the extent practicable, conduct unloading or loading of solids and liquids in a manufactured building, under a roof, lean-to, or other appropriate cover.
- Berm, dike, and/or slope the loading/unloading area to prevent run-on of stormwater and to prevent the runoff or loss of any spilled material from the area.
- Place curbs along the edge of the loading/unloading areas, or slope the edge such that the stormwater can flow to an internal storm sewer system that leads to an approved treatment BMP. Avoid draining directly to the surface water from loading/unloading areas.
- Pave and slope loading/unloading areas to prevent the pooling of water. Minimize the use of catch basins and drain lines within the interior of the paved area or place catch basins in designated “alleyways” that are not covered by material, containers, or equipment.
- Retain on-site the necessary materials for rapid cleanup of spills.

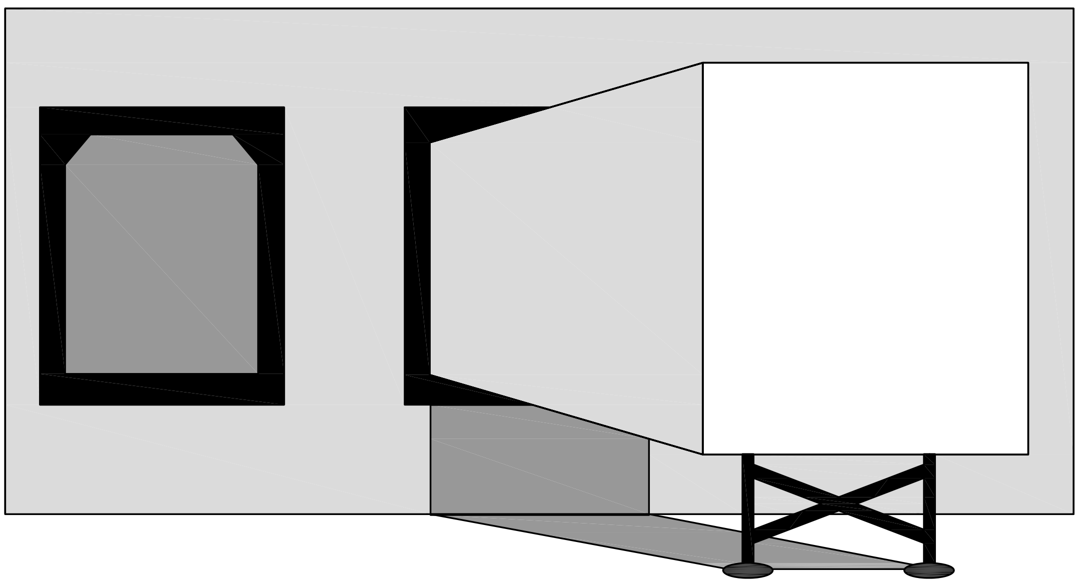
Recommended Structural Source Control BMPs:

For the transfer of pollutant liquids in areas that cannot contain a catastrophic spill, install an automatic shutoff system in case of unanticipated off-loading interruption (e.g. coupling break, hose rupture, overfill, etc.).

At Loading and Unloading Docks

- Install/maintain overhangs, or door skirts that enclose the trailer end (see Figure 8.12: Loading Dock with Door Skirt and Figure 8.13: Loading Dock with Overhang) to prevent contact with rainwater.
- Design the loading/unloading area with berms, sloping, etc., to prevent the run-on of stormwater.

Figure 8.12: Loading Dock with Door Skirt



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Loading Dock with Door Skirt

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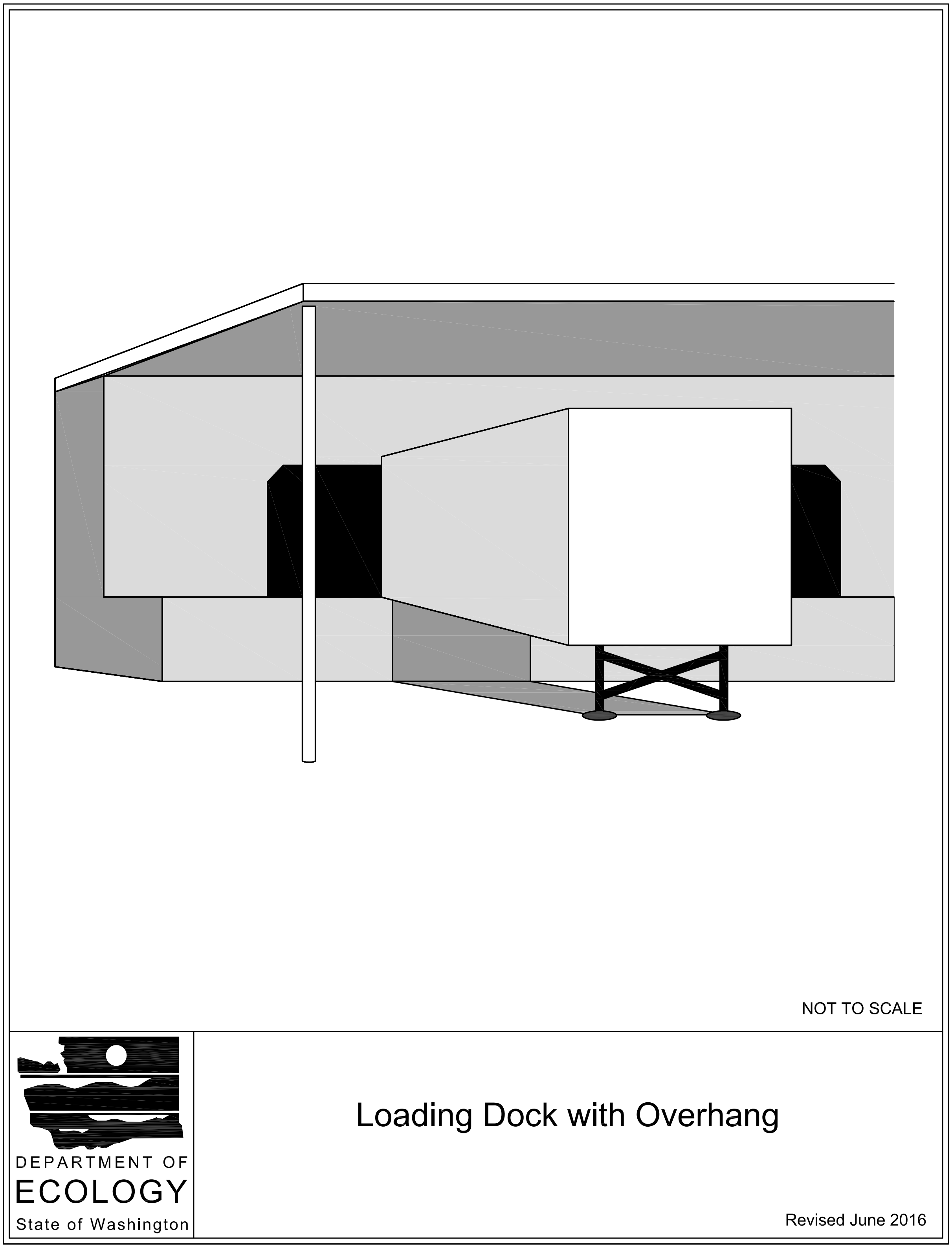
Figure 8.13: Loading Dock with Overhang



At Tanker Truck Transfer Areas to Above/Below-Ground Storage Tanks

- Pave the area on which the transfer takes place. If any transferred liquid, such as gasoline, is reactive with asphalt, pave the area with Portland cement concrete.
- Slope, berm, or dike the transfer area to a dead-end sump, spill containment sump, an oil/water separator, or other spill control device. The minimum spill retention time should be 15 minutes at the greater flow rate of the highest fuel dispenser nozzle through-put rate, or the peak flow rate of the 6-month, 24-hour storm event over the surface of the containment pad, whichever is greater. The capacity of the spill containment sump should be a minimum of 50 gallons with adequate additional capacity provided for grit sedimentation.

S419 BMPs for Mobile Fueling of Vehicles and Heavy Equipment

Description of Pollutant Sources: Mobile fueling, also known as fleet fueling, wet fueling, or wet hosing, is the practice of filling fuel tanks of vehicles by tank trucks that are driven to the yards or sites where the vehicles to be fueled are located. Diesel fuel is categorized as a Class II Combustible Liquid, whereas gasoline is categorized as a Flammable Liquid.

Note that some local fire departments may have restrictions on mobile fueling practices.

Historically organizations conducted mobile fueling for off-road vehicles operated for extended periods in remote areas. This includes construction sites, logging operations, and farms. Some organizations conduct mobile fueling of on-road vehicles commercially in the state of Washington.

Pollutant Control Approach: Fueling operators need proper training of fueling operations, the use of spill/drip control, and fuel transfer procedures.

Applicable Operational BMPs:

Organizations and individuals conducting mobile fueling operations must implement the BMPs in the following list. The operating procedures for the driver/operator should be simple, clear, effective, and their implementation verified by the organization liable for environmental and third party damage.

- Ensure that the local fire department approves all mobile fueling operations. Comply with local and Washington State fire codes.
- In fueling locations that are in close proximity to sensitive aquifers, designated wetlands, wetland buffers, or other waters of the State, approval by local jurisdictions is necessary to ensure compliance with additional local requirements.
- Ensure compliance with all 49 CFR 178 requirements for all fuel delivery vehicles or containers. Documentation from a Department of Transportation (DOT) Registered Inspector provides proof of compliance.
- Ensure the presence and the constant observation/monitoring of the driver/operator at the fuel transfer location at all times during fuel transfer and ensure implementation of the following procedures at the fuel transfer locations:

    - Locate the point of fueling at least 25 feet from the nearest storm sewer or inside an impervious containment with a volumetric holding capacity equal to or greater than 110 percent of the fueling tank volume, or covering the storm sewer to ensure no inflow of spilled or leaked fuel. Covers are not required for storm sewers that convey the inflow to a spill control separator approved by the local jurisdiction and the fire department. Potential spill/leak conveyance surfaces must be impervious and in good repair. Do not remove the drain cover if sheen is present. Properly collect and dispose of any contaminated material.
    - Place a drip pan, or an absorbent pad under each fueling location prior to and during all dispensing operations. The pan (must be liquid tight) and the absorbent pad must have a capacity of at least 5 gallons. There is no need to report spills retained in the drip pan or the pad.
    - Manage the handling and operation of fuel transfer hoses and nozzle, drip pan(s), and absorbent pads as needed to prevent spills/leaks of fuel from reaching the ground, storm sewer, and receiving waters.
    - Avoid extending the fueling hoses across a traffic lane without fluorescent traffic cones, or equivalent devices, conspicuously placed to block all traffic from crossing the fuel hose.
    - 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" the fuel receiving equipment.
- Provide the driver/operator of the fueling vehicle with:
    - Adequate flashlights or other mobile lighting to view fuel fill openings with poor accessibility. Consult with local fire department for additional lighting requirements.
    - Two-way communication with his/her home base.
- Train the driver/operator annually in spill prevention and cleanup measures and emergency procedures. Make all employees aware of the significant liability associated with fuel spills.
- The responsible manager shall properly sign and date the fueling operating procedures. Distribute procedures to the operators, retain them in the organization files, and make them available in the event an authorized government agency requests a review.
- Immediately notify the local fire department (911), the appropriate regional office of the Department of Ecology, and the local jurisdiction in the event of any spill entering surface or ground waters. Establish a "call down list" to ensure the rapid and proper notification of management and government officials should any significant amount of product be lost off-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 spillage into the environment.
- In all fueling vehicles, maintain a minimum of the following spill cleanup materials and have them readily available for use:

    - Non-water absorbents capable of absorbing at least 15 gallons of fuel.
    - A storm drain plug or cover kit.
    - A non-water absorbent containment boom of a minimum 10 feet in length with a 12-gallon minimum absorbent capacity.
    - A non-spark generating shovel (a steel shovel could generate a spark and cause an explosion in the right environment around a spill).
    - Two, five-gallon buckets with lids.
- Use automatic shutoff nozzles for dispensing the fuel. Replace automatic shut-off nozzles as recommended by the manufacturer.
- Maintain and replace equipment on fueling vehicles, particularly hoses and nozzles, at established intervals to prevent failures.
- Immediately remove and properly dispose of soils with visible surface contamination to prevent the spread of chemicals to groundwater or receiving water via stormwater runoff.
- Do not use dispersants to clean up spills or sheens unless properly removed for disposal following application. Dispersants are prohibited from use for spills on water or where the dispersant may enter storm drains, surface waters, treatment systems, or sanitary sewers.

Applicable Structural Source Control BMPs:

Include the following fuel transfer site components:

- Automatic fuel transfer shut-off nozzles.
- An adequate lighting system at the filling point.

S426 BMPs for Spills of Oil and Hazardous Substances

Description of Pollutant Sources: Washington Administrative Code requires owners or operators of facilities engaged in drilling, producing, gathering, storing, processing, transferring, distributing, refining, or consuming oil and/or oil products to have a Spill Prevention and Emergency Cleanup Plan (SPECP). The SPECP is required if the above ground storage capacity of the facility is 1,320 gallons or more of oil. Additionally, the SPECP is required if the facility, due to its location, could reasonably be expected to discharge oil in harmful quantities, as defined in 40 CFR Part 110, into or upon the navigable waters of the United States or adjoining shorelines {40 CFR 112.1 (b)}. Onshore and offshore facilities, which, due to their location, could not reasonably be expected to discharge oil into or upon the navigable waters of the United States or adjoining shorelines are exempt from these regulations {40 CFR 112.1(d)(1)(i)}. State Law requires owners of businesses that produce dangerous wastes to have a SPECP. These businesses should refer to Washington State/Federal Emergency Spill Cleanup Requirements (see 1.2.16 Other Regulations and Programs). The federal definition of oil is oil of any kind or any form, including, but not limited to petroleum, fuel oil, sludge, oil refuse, and oil mixed with wastes other than dredged spoil.

Pollutant Control Approach: Maintain, update, and implement a Spill Prevention and Emergency Cleanup Plan.

Applicable Operational BMPs:

The businesses and public agencies identified in Appendix 8-A: Urban Land Uses and Pollutant Generating Sources required to prepare and implement a Spill Prevention and Emergency Cleanup Plan shall implement the following:

- Prepare a Spill Prevention and Emergency Cleanup Plan (SPECP), which includes:
  - A description of the facility including the owner's name and address.
  - The nature of the activity at the facility.
  - The general types of chemicals used or stored at the facility.
  - A site plan showing the location of storage areas for chemicals, the locations of storm drains, the areas draining to them, and the location and description of any devices to stop spills from leaving the site such as positive control valves.
  - Cleanup procedures.
  - Notification procedures used in the event of a spill, such as notifying key personnel. Agencies such as Ecology, local fire department(s), Washington State Patrol, and the local sewer authority, shall be notified.
  - The name of the designated person with overall spill cleanup and notification responsibility.
- Train key personnel in the implementation of the SPECP. Prepare a summary of the plan and post it at appropriate points in the building, identifying the spill cleanup coordinators, location of cleanup kits, and phone numbers of regulatory agencies to contact in the event of a spill.
- Update the SPECP regularly.
- Immediately notify Ecology, the local jurisdiction, and the local sewer authority if a spill may reach sanitary or storm sewers, groundwater, or surface water, in accordance with federal and Ecology spill reporting requirements.
- Immediately clean up spills. Do not use emulsifiers for cleanup unless there is an appropriate disposal method for the resulting oily wastewater. Do not wash absorbent material down a floor drain or into a storm sewer.
- Locate emergency spill containment and cleanup kit(s) in high-potential spill areas. The contents of the kit shall be appropriate for the type and quantities of chemical liquids stored at the facility.

Recommended Additional Operational BMP:

Spill kits should include appropriately lined drums, absorbent pads, and granular or powdered materials for neutralizing acids or alkaline liquids where applicable. In fueling areas, package absorbent material in small bags for easy use and make available small drums for storage of absorbent and/or used absorbent. Deploy spill kits in a manner that allows rapid access and use by employees.

S439 BMPs for In-Water and Over-Water Fueling

Description of Pollutant Sources: BMPs in this section apply to businesses and public agencies that operate a facility used for the transfer of fuels from a stationary pumping 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.

Typically, stormwater contamination at fueling stations is caused by leaks or spills of fuels, lubrication oils, and fuel additives. These materials contain organic compounds, oil and grease, and metals that can be harmful to humans and aquatic life.

Most fuel dock spills are small and result from overfilling boat fuel tanks, burps from air vent lines, and drips from the pump nozzle as it is being returned to the pump.

Pollutant Control Approach: Provide employees with proper training and use spill control devices to prevent the discharge of pollutants in the receiving water or the drainage system.

Applicable Operational BMPs

Applicable Operational BMPs for Fuel Docks

General

- Facilities and procedures for the loading or unloading of petroleum products must comply with U.S. Coast Guard requirements. Refer to guidance in Coast Guard Requirements for Marine Transfer of Petroleum Products in 1.2.16 Other Regulations and Programs.

Training and Fueling Dock Supervision

- Train staff on proper fueling procedures. Document training and maintain records.
- Have a trained employee supervise the fuel dock during fueling activities.
- Do not allow self-service on a marina dock without some means of controlling the dock activity. According to *NFPA 30A: Code for Motor Fuel Dispensing Facilities and Repair Garages*, each facility must have an attendant on duty to supervise, observe, and “control” the operation when open for business. This can be done via camera, intercom, and shutoff abilities in the office. However, this can lead to complacency and nothing can replace having an attendant on the dock to attend to emergencies when they occur. (NFPA, 2012)

Fueling Dock Setup, Maintenance, and Inspection

- Install a tank and leak detection monitoring system that shuts off the pump and fuel line when a leak is sensed.
- Install personal watercraft floats at fuel docks to stabilize personal watercraft/jet skis while refueling.
- Provide a spill containment equipment storage area where materials are easily accessible and clearly marked.
- Use automatic shut-off nozzles and promote the use of "whistles" and fuel/air separators on air vents or tank stems of inboard fuel tanks to reduce the amount of fuel spilled into receiving waters during fueling of boats.
- Post readable refueling directions, BMPs, and emergency protocols.
- Always have a "Spills Aren't Slick" sign with emergency spill reporting numbers clearly visible. Marinas on land leased from the Washington Department of Natural Resources (DNR) are required to post these signs.
- Display "No Smoking" signs on fuel docks.
- Create a regular inspection, maintenance, and replacement schedule for fuel hoses, pipes, and tanks. Have staff walk the dock fuel lines from dispenser to tank to look for signs of leakage at joints and determine hose condition from end to end.

Fueling Practices

- Discourage operators from "topping off" (no more than 90% capacity). Fuel expands and can slosh out of the vent when temperatures rise or waters become choppy.
- When handing over the nozzle, wrap an absorbent pad around the nozzle end or plug inside the nozzle end to prevent fuel in the nozzle from spilling.
- Have the boat operator place an absorbent pad or suction cup bottle under the vent(s) to capture fuel spurts from the vent.
- Never block open the fuel nozzle trigger and always disable hands-free clips to ensure the boater remains with the nozzle to prevent overfilling. Hands-free clips are not allowed in Washington, per WAC 296-24-33015.
- Always keep the nozzle tip pointing up and hang the nozzle vertically when not in use.
- During fueling operations, visually monitor the liquid level indicator to prevent the tank from being overfilled.
- The maximum amount of product received must not exceed 95 percent capacity of the receiving tank.

Spill cleanup

- See S426 BMPs for Spills of Oil and Hazardous Substances.
- Manage petroleum-contaminated booms, pads, and absorbents in a designated collection container and properly dispose of these materials (see S427 BMPs for Storage of Liquid, Food Waste, or Dangerous Waste Containers).
- Ensure customers do not use soaps in the event of a spill. Use oil absorbent booms or pads instead.

Applicable Operational BMPs for Fueling by Portable Container

- Have boats fuel on shore or at a fuel dock rather than transport fuel from an upland facility to the boats. Only use hand-held fueling containers or "jerry cans" when necessary or when on shore or at dock fueling is not practical.
- Always refill portable fuel containers on the pavement or dock to ensure a good electrical ground. While the deck of the boat may seem stable, static electricity can build up and cause a spark.
- On the dock, put an absorbent pad under the container and wrap an absorbent pad around the fuel fill — this can easily be done by putting a hole in the pad.
- Ensure the nozzle stays in contact with the tank opening.
- When transferring fuel from a portable can, use a fuel siphon with a shut-off feature. If a siphon is not available, a nozzle/spout with a shut off is a good alternative.
- Since fueling boats with a portable container can take time, make sure the container is comfortable to carry, hold, and balance.
- Use a high flow funnel. Funnels can help prevent spills by making a larger opening for fueling.
- Place a plug of absorbent pad or paper towel in the nozzle when not in use to capture any extra drops that accumulate.
- Fuel slowly and pour deliberately, and watch the container (especially the nozzle mechanism) for signs of wear.
- Store portable fuel tanks out of direct sunlight and keep in a cool, dry place to minimize condensation.

8.8 Other Source Control BMPs

S401 BMPs for the Building, Repair, and Maintenance of Boats and Ships

Description of Pollutant Sources: Sources of pollutants for the building, repair, and maintenance of boats and ships at boatyards, shipyards, ports, and marinas include pressure washing, surface preparation, paint removal, sanding, painting, engine maintenance and repairs, and material handling and storage, if conducted outdoors.

Potential pollutants include spent abrasive grits, solvents, oils, ethylene glycol, washwater, paint over-spray, cleaners/detergents, anti-corrosion compounds, paint chips, scrap metal, welding rods, resins, glass fibers, dust, and miscellaneous trash. Pollutant constituents include suspended solids, oil and grease, organics, copper, lead, tin, and zinc.

Pollutant Control Approach: Apply good housekeeping, conduct routine preventive maintenance, and cover and contain BMPs in and around work areas.

NPDES Permit Requirements: Ecology's statewide Boatyard General Permit applies to boatyards that discharge stormwater runoff from areas with industrial activity directly to the ground, to a surface waterbody, or to a storm sewer system that drains to a surface waterbody. This general permit also regulates wastewater from pressure washing in boatyards. All boatyards in the state must apply for coverage under this permit and must comply with all conditions specified in this permit, as applicable to their facility, unless exempted. Ecology may require coverage under an individual NPDES permit for large boatyards and shipyards in Washington State not covered by the Boatyard General Permit or Industrial Stormwater General Permit (ISGP).

Applicable Operational BMPs:

- Clean regularly all accessible work, service, and storage areas to remove debris, spent sandblasting material, and any other potential stormwater pollutants.
- Whenever the boat is in the water, avoid the use of soaps, detergents and other chemicals that need to be rinsed or hosed off. If necessary, consider applying sparingly so that a sponge, towel or rag can be used to remove residuals. Consider instead washing the boat in a suitable controlled area (see S431 BMPs for Washing and Steam Cleaning Vehicles / Equipment / Building Structures) while it is out of the water.
- Sweep rather than hose debris on the dock. Collect and convey hose water to treatment if hosing is unavoidable,
- Collect spent abrasives regularly and store them under cover to await proper disposal.
- Dispose of greasy rags, oil filters, air filters, batteries, spent coolant, and degreasers properly.
- Drain oil filters before disposal or recycling.
- Immediately repair or replace leaking connections, valves, pipes, hoses, and other equipment that may cause the contamination of stormwater.
- Use drip pans, drop cloths, tarpaulins, or other protective devices in all paint mixing and solvent operations, unless carried out in impervious contained and covered areas.
- Convey sanitary sewage to pump-out stations, portable on-site pump-outs, commercial mobile pump-out facilities, or other appropriate onshore facilities.
- Maintain automatic bilge pumps in a manner that will prevent automatic pumping of waste material into surface water.
- Prohibit uncontained spray painting, blasting or sanding activities over open water.

- Do not dump or pour waste materials down floor drains, sinks, or outdoor storm drain inlets that discharge to surface water. Plug floor drains connected to storm drains or to surface water. If necessary, install a regularly operated sump pump.
- Prohibit outside spray-painting, blasting, or sanding activities during windy conditions that render containment ineffective.
- Do not burn paint and/or use spray guns on topsides or above decks.
- Immediately clean up any spillage on the pier, wharf, boat, ship deck, or adjacent surface areas and dispose of the wastes properly.
- Apply source control BMPs for other activities conducted at the marina, boat yard, shipyard, or port facility (see S409 BMPs for Fueling At Dedicated Stations, S431 BMPs for Washing and Steam Cleaning Vehicles / Equipment / Building Structures, and S426 BMPs for Spills of Oil and Hazardous Substances).
- Locate spill kits so they are readily accessible on all piers and docks.

Applicable Structural Source Control BMPs:

- Use fixed platforms with appropriate plastic or tarpaulin barriers as work surfaces and for containment when performing work on a vessel in the water to prevent blast material or paint overspray from contacting stormwater or the surface water. Keep the use of such platforms to a minimum, and do not perform extensive repair, modification, surface preparation, or coating while the boat is in the water (anything in excess of 25 percent of the surface area of the vessel above the waterline).
- Use plastic or tarpaulin barriers beneath the hull and between the hull and dry dock walls to contain and collect waste and spent materials. Clean and sweep regularly to remove debris.
- Enclose, cover, or contain blasting and sanding activities to the maximum extent practicable to prevent abrasives, dust, and paint chips, from reaching storm sewers or receiving waters. Use plywood and/or plastic sheeting to cover open areas between decks when sandblasting (scuppers, railings, freeing ports, ladders, and doorways).
- Direct deck drainage to a collection system sump for settling and/or additional treatment.
- Store cracked batteries in covered secondary containers.

Recommended Additional Operational BMPs:

- Consider recycling paint, paint thinner, solvents, used oils, oil filters, pressure wash wastewater, and any other recyclable materials.
- Perform paint and solvent mixing, fuel mixing, etc., on shore.

S402 BMPs for Commercial Animal Handling Areas

Description of Pollutant Sources: Animals at racetracks, kennels, fenced pens, veterinarians, and businesses that provide boarding services for horses, dogs, cats, etc., can generate pollutants from the following activities: manure deposits, animal washing, grazing, and any other animal handling activity that could contaminate stormwater. Pollutants can include coliform bacteria, nutrients, and total suspended solids. Individual stormwater permits covering commercial animal handling facilities include additional applicable source controls.

Pollutant Control Approach: To prevent, to the maximum extent practicable, the discharge of contaminated stormwater from animal handling and keeping areas.

Applicable Operational BMPs

- Regularly sweep and clean animal keeping areas to collect and properly dispose of droppings, uneaten food, and other potential stormwater contaminants.
- Do not hose down areas that contain potential stormwater contaminants where they drain to storm drains or to receiving waters.
- Do not discharge any washwater to storm drains or to receiving waters without proper treatment.
- If the operator keeps animals in unpaved and uncovered areas, the ground must have either vegetative cover or some other type of ground cover such as mulch.
- Surround the area where animals are kept with a fence or other means to prevent animals from moving away from the controlled area where BMPs are used.
- For outside surface areas that must be disinfected, use an unsaturated mop to spot clean the area. Do not allow wastewater runoff to enter the drainage system.
- Do not stockpile manure in areas where runoff is allowed to flow into a storm drain or to nearby receiving waters or wetlands.

S403 BMPs for Commercial Composting

Description of Pollutant Sources: Commercial composting facilities, operating outside without cover, require large areas to decompose wastes and other feedstocks. Design these facilities to separate stormwater from leachate (i.e., industrial wastewater) to the greatest extent possible. When stormwater contacts any active composting areas, including waste receiving and processing areas, it becomes leachate. Pollutants in leachate include nutrients, biochemical oxygen demand (BOD), organics, coliform bacteria, acidic pH, color, and suspended solids. Stormwater at composting facilities include runoff from areas not associated with active processing and curing, such as product storage areas, vehicle maintenance areas, and access roads.

NPDES and State Solid Waste Permit Requirements: Composting facilities are regulated under WAC 173-350-220. Solid Waste Regulations require the collection and containment of all leachate produced from activities at commercial composting facilities. Composting facilities that propose to discharge to surface water, municipal sewer system, or groundwater must obtain the appropriate permits. Zero discharge is possible by containing all leachate from the facility (in tanks or ponds) for use early in the composting process or preventing production of leachate (by composting under a roof or in an enclosed building).

Pollutant Control Approach: Consider zero leachate discharge.

Applicable Operational, Structural, and Treatment BMPs:

- See WAC 173-350-220, Composting Facilities
- See *Siting and Operating Composting Facilities in Washington State: Good Management Practices* (Ecology, 2013) for common sense actions that can be implemented at a facility to help run a successful program.
- See Ecology's Organic Materials Management page for at the following web address for the most up-to-date information:

  https://ecology.wa.gov/Waste-Toxics/Reducing-recycling-waste/Organic-materials .
- All composting facilities shall obtain the appropriate state and local permits. Contact your local permitting authority and jurisdictional health department or district for more information.
- Apply for coverage under the Industrial Stormwater General Permit (ISGP) if the facility discharges stormwater to surface water or a municipal stormwater system. If all stormwater from the facility properly infiltrates to groundwater, the ISGP may not be required. There are some cases where an Individual State Waste Discharge permit is required. Check with your local Ecology office and jurisdictional health department or district to discuss your permitting options.
- Screen incoming wastes for dangerous materials and solid wastes. These materials may not be accepted for composting and must be properly disposed of.
- Locate composting areas on impervious surfaces.
- Drain all leachate from composting operations to a sanitary sewer, holding tank, or on-site treatment system. Leachate may not go to the storm drain or groundwater.
- Collect the leachate with a dike or berm, or with intercepting drains placed on the down slope side of the compost area.
- Direct outside runoff away from the composting areas.
- Clean up debris from yard areas as needed to prevent stormwater contamination.

Recommended BMPs:

- Install catch basin inserts to collect excess sediment and debris if necessary. Inspect and maintain catch basin inserts to ensure they are working correctly.
- Locate stored residues in areas designed to collect leachate and limit storage time to prevent degradation and generation of leachate.

S404 BMPs for Commercial Printing Operations

Description of Pollutant Sources: Materials used in the printing process include inorganic and organic acids, resins, solvents, polyester film, developers, alcohol, vinyl lacquer, dyes, acetates, and polymers. Waste products may include waste inks and ink sludge, resins, photographic chemicals, solvents, acid and alkaline solutions, chlorides, chromium, zinc, lead, spent formaldehyde, silver, plasticizers, and used lubricating oils. With indoor printing operations, the only likely points of potential contact with stormwater are the outside temporary storage of waste materials and offloading of chemicals at external unloading bays. Pollutants can include TSS, pH, heavy metals, oil and grease, and COD.

Pollutant Control Approach: Ensure appropriate disposal and NPDES permitting of process wastes. Cover and contain stored raw and waste materials.

Applicable Operational BMPs:

- Discharge process wastewaters to a sanitary sewer, if approved by the local sewer authority, or to an approved process wastewater treatment system.
- Do not discharge process wastes or wastewaters into storm sewers or surface waters.
- Determine whether any of these wastes qualify for regulation as dangerous wastes and dispose of them accordingly.
- Store raw materials or waste materials that could contaminate stormwater in covered and contained areas.
- Train all employees in pollution prevention, spill response, and environmentally acceptable materials handling procedures.
- Store materials in proper, appropriately labeled containers. Identify and label all chemical substances.
- Regularly inspect all stormwater management devices and maintain as necessary.
- Try to use press washes without listed solvents, and with the lowest volatile organic compound (VOC) content possible. Do not evaporate ink cleanup trays to the outside atmosphere.
- Place cleanup sludges into a container with a tight lid and dispose of it as a dangerous waste. Do not dispose of cleanup sludges in the garbage or in containers of soiled towels.

For additional information on pollution prevention, Ecology recommends *Environmental Management and Pollution Prevention: A Guide for Lithographic Printers* (Ecology, 2001).

S413 BMPs for Log Sorting and Handling

Description of Pollutant Sources: Log yards are 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. Typical pollutants include oil and grease, BOD, settleable solids, total suspended solids (including soil), high and low pH, heavy metals, pesticides, wood-based debris, and leachate.

The following are pollutant sources:

- Log storage, rollout, sorting, scaling, and cutting areas
- Log and liquid loading areas
- Log sprinkling
- Debarking, bark bin and conveyor areas
- Bark, ash, sawdust and wood debris piles, and solid wastes
- Metal salvage areas
- Truck, rail, ship, stacker, and loader access areas
- Log trucks, stackers, loaders, forklifts, and other heavy equipment
- Maintenance shops and parking areas
- Cleaning areas for vehicles, parts, and equipment
- Storage and handling areas for hydraulic oils, lubricants, fuels, paints, liquid wastes, and other liquid materials
- Pesticide usage for log preservation and surface protection
- Application of herbicides for weed control
- Contaminated soil resulting from leaks or spills of fluids

Ecology's Baseline General Permit Requirements:

Industries with log yards or areas where logs are sorted or loaded are required to obtain coverage under the Industrial Stormwater General Permit for discharges of stormwater associated with industrial activities. The permit requires preparation and on-site retention of an Industrial Stormwater Pollution Prevention Plan (SWPPP). Required and recommended operational, structural source control, and treatment BMPs are presented in detail in *Industrial Stormwater General Permit Implementation Manual for Log Yards* (Ecology, 2016). Ecology recommends that all log yard facilities obtain a copy of this document.

S414 BMPs for Maintenance and Repair of Vehicles and Equipment

Description of Pollutant Sources: Pollutant sources include parts/vehicle cleaning, spills/leaks of fuel and other liquids, replacement of liquids, outdoor storage of batteries/liquids/parts, and vehicle parking.

Pollutant Control Approach: Control of leaks and spills of fluids using good housekeeping and cover and containment BMPs.

Applicable Operational BMPs:

- Inspect all incoming vehicles, parts, and equipment stored temporarily outside for leaks.
- Use drip pans or containers under parts or vehicles that drip or that are likely to drip liquids, such as during dismantling of liquid containing parts or removal or transfer of liquids. Inspect drip pans regularly to prevent accumulation of stormwater or other liquids, and dispose of any accumulated liquid appropriately.
- Remove batteries and liquids from vehicles and equipment in designated areas designed to prevent stormwater contamination. Store cracked batteries in a covered, non-leaking secondary containment system.
- Remove liquids from vehicles retired for scrap.
- Empty oil and fuel filters before disposal. Provide for proper disposal of used oil and fuel.
- Do not pour/convey washwater, liquid waste, or other pollutants into storm drains or to surface waters. Check with the local sanitary sewer authority for approval to convey water to a sanitary sewer.
- Do not connect maintenance and repair shop floor drains to storm drains or to surface water.
- To allow for snowmelt during the winter, install a drainage trench with a sump for particulate collection. Use the drainage trench for draining the snowmelt only. Do not discharge any vehicular or shop pollutants to the trench drain.

Applicable Structural Source Control BMPs:

- Conduct all maintenance and repair of vehicles and equipment in a building, or other covered impervious containment area that is sloped to prevent run-on of uncontaminated stormwater and runoff of contaminated water.
- Operators may conduct maintenance of refrigeration engines in refrigerated trailers in the parking area. Exercise due caution to avoid the release of engine or refrigeration fluids to storm drains or surface waters.
- Park large mobile equipment, such as log stackers, in a designated contained area.

Applicable Treatment BMPs:

Convey contaminated stormwater runoff from vehicle staging and maintenance areas to a sanitary sewer, if allowed by the local sewer authority, or to an API or CP oil and water separator followed by a Basic Treatment BMP (See Chapter 6 - Runoff Treatment, Flow Control, and LID BMP Library), applicable filter, or other equivalent oil treatment system.

Note this applicable treatment BMP for contaminated stormwater.

Recommended Additional Operational BMPs:

- Store damaged vehicles inside a building or other covered containment, until successfully removing all liquids.
- Clean parts with aqueous detergent based solutions or non-chlorinated solvents such as kerosene or high flash mineral spirits, and/or use wire brushing or sand blasting whenever practicable. Avoid using toxic liquid cleaners such as methylene chloride, 1,1,1-trichloroethane, trichloroethylene or similar chlorinated solvents. Choose cleaning agents that can be recycled.
- Inspect all BMPs regularly, particularly after a significant storm. Identify and correct deficiencies to ensure that the BMPs are functioning as intended.
- Avoid hosing down work areas. Use dry methods for cleaning leaked fluids.
- Recycle greases, used oil, oil filters, antifreeze, cleaning solutions, automotive batteries, hydraulic fluids, transmission fluids, and engine oils. Contact Ecology's Hazardous Waste & Toxics Reduction Program for recommendations on recycling or disposal of waste materials. Contact information can be found at the following web address:

  https://ecology.wa.gov/About-us/Get-to-know-us/Our-Programs/Hazardous-Waste-Toxics-Reduction
- Do not mix dissimilar or incompatible waste liquids stored for recycling.

S418 BMPs for Manufacturing Activities - Outside

Description of Pollutant Sources: Manufacturing pollutant sources include outside process areas, stack emissions, and areas where manufacturing activity has taken place in the past and significant exposed pollutant materials remain.

Pollution Control Approach: Cover and contain outside manufacturing and prevent stormwater run-on and contamination, where feasible.

Applicable Operational BMP:

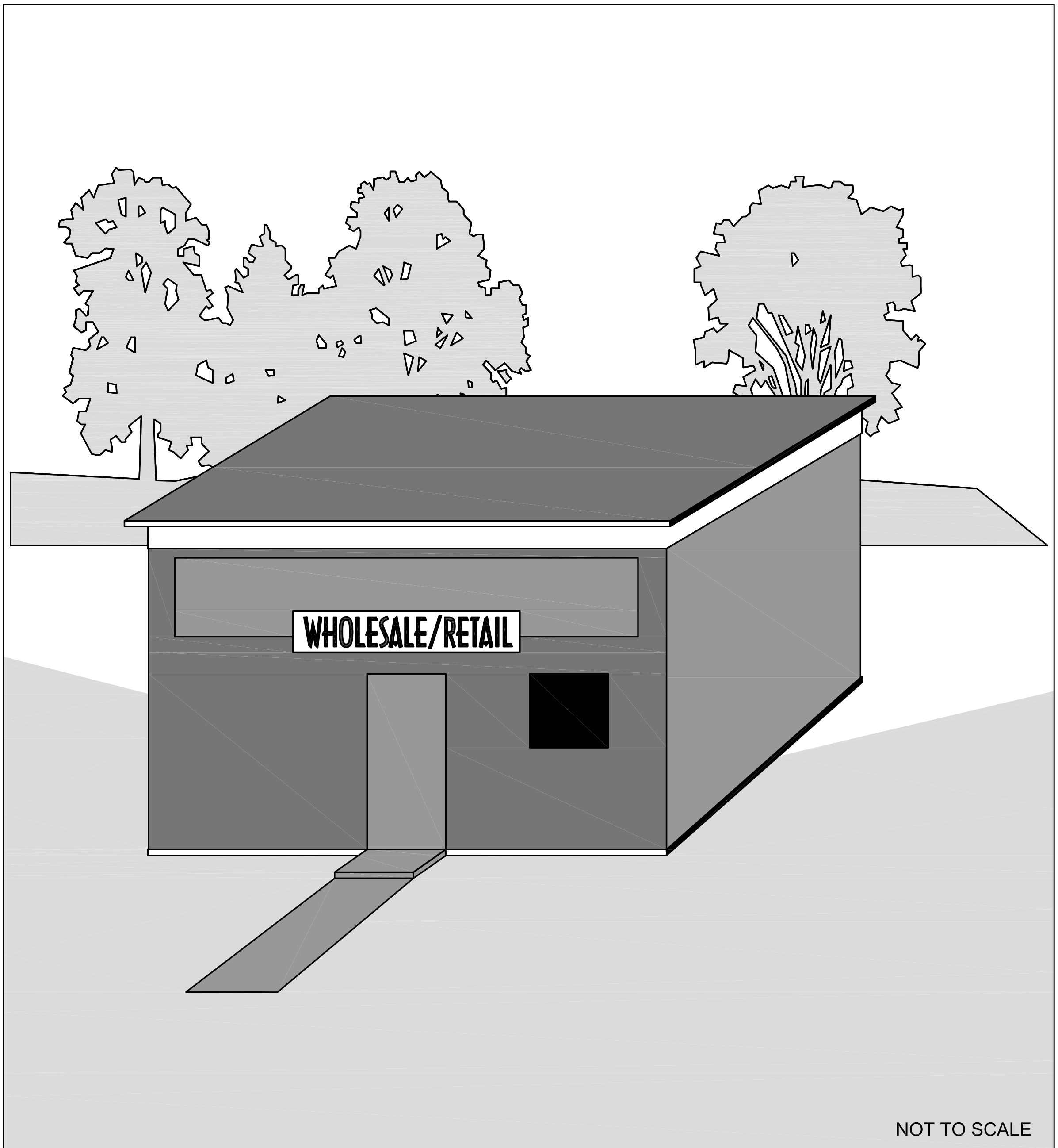
- Sweep paved areas regularly, as needed, to prevent contamination of stormwater.
- Alter the activity by eliminating or minimizing the contamination of stormwater.

Applicable Structural Source Control BMPs:

- Enclose the activity (see Figure 8.14: Enclose the Activity). If possible, enclose the manufacturing activity in a building.
- Cover the activity and connect floor drains to a sanitary sewer, if approved by the local sewer authority. Berm or slope the floor as needed to prevent drainage of pollutants to outside areas. (See Figure 8.15: Cover the Activity).

- Isolate and segregate pollutants as feasible. Convey the segregated pollutants to a sanitary sewer, process treatment, or a dead-end sump depending on available methods and applicable permit requirements.

Figure 8.14: Enclose the Activity

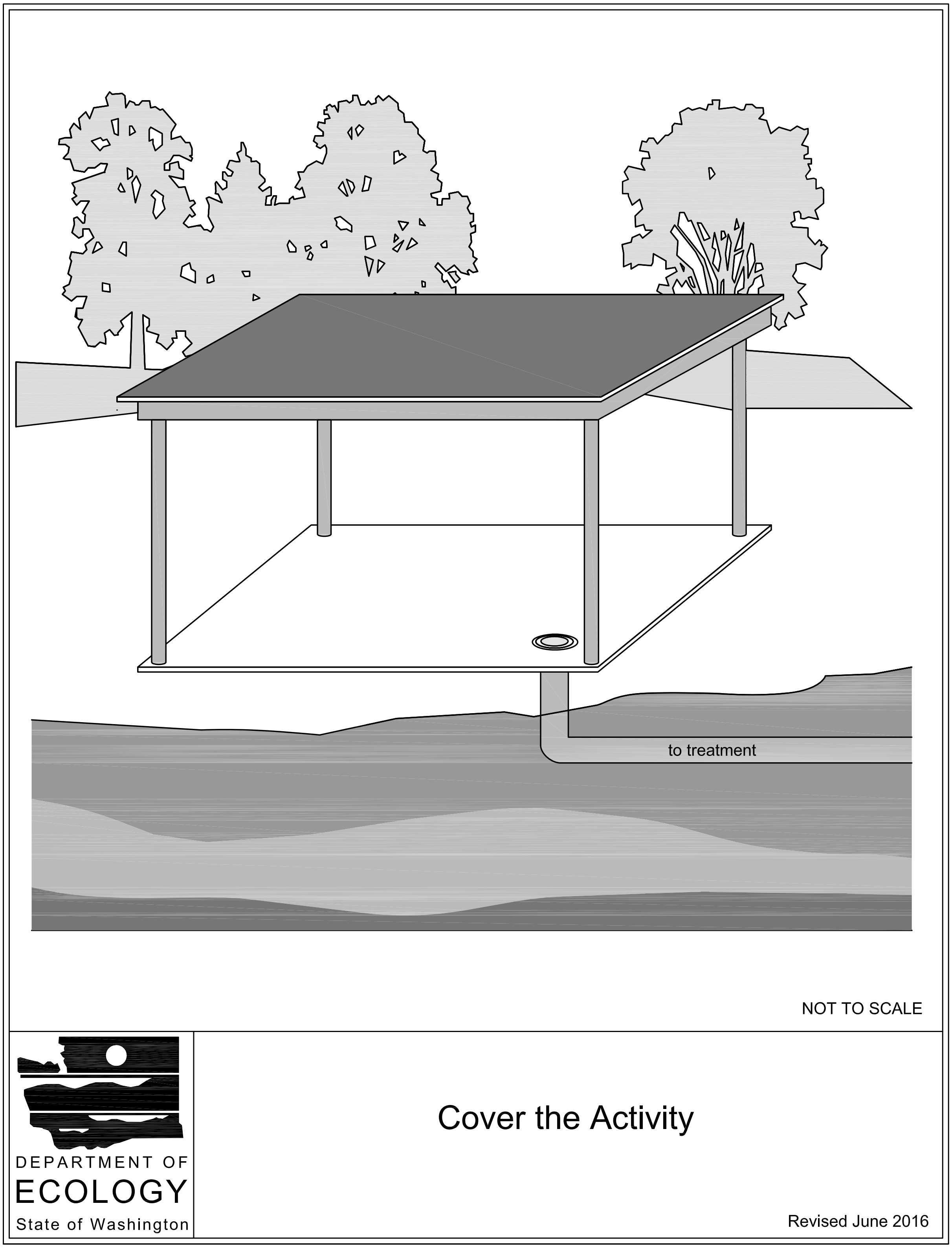


DEPARTMENT OF ECOLOGY
State of Washington

Enclose the Activity

Revised June 2016

Figure 8.15: Cover the Activity



S420 BMPs for Painting / Finishing / Coating of Vehicles / Boats / Buildings / Equipment

Description of Pollutant Sources: Surface preparation and the application of paints, finishes, and/or coatings to vehicles, boats, buildings, and/or equipment outdoors can be sources of pollutants. Potential pollutants include organic compounds, oils and greases, heavy metals, and suspended solids.

Pollutant Control Approach: Cover and contain painting and sanding operations and apply good housekeeping and preventive maintenance practices to prevent the contamination of stormwater with painting over sprays and grit from sanding.

Applicable Operational BMPs:

- Train employees in the careful application of paints, finishes, and coatings to reduce misuse and over spray. Use drop cloths underneath outdoor painting, scraping, and sandblasting work, and properly clean and temporarily store collected debris daily.
- Do not conduct spraying, blasting, or sanding activities over open water or where wind may blow paint into water.
- Wipe up spills with rags and other absorbent materials immediately. Do not hose down the area to a storm sewer, receiving water, or conveyance ditch.
- On dock areas sweep rather than hose down debris. Collect any hose water generated and convey to appropriate treatment and disposal.
- Use a catch basin cover, filter sock, or other effective runoff control device if dust, grit, washwater, or other pollutants may escape the work area and enter a catch basin. The containment device(s) must be in place at the beginning of the workday. Collect contaminated runoff and solids and properly dispose of such wastes before removing the containment device(s) at the end of the workday.
- Use a ground cloth, pail, drum, drip pan, tarpaulin, or other protective device for activities such as outdoor paint mixing and tool cleaning, or where spills can contaminate stormwater.
- Properly dispose of all wastes and prevent all uncontrolled releases to the air, ground, or water.
- Clean paintbrushes and tools covered with water-based paints in sinks connected to sanitary sewers. Do not dump pollutants collected in portable containers into a stormwater drain.
- Clean brushes and tools covered with non-water-based paints, finishes, or other materials in a manner that allows collection of used solvents (e.g. paint thinner, turpentine, xylol) for recycling or proper disposal.
- Store toxic materials under cover (tarp, etc.) during precipitation events and when not in use to prevent contact with stormwater.

Applicable Structural Source Control BMPs:

Enclose and/or contain all work while using a spray gun or conducting sand blasting and in compliance with applicable air pollution control, OSHA, and WISHA requirements. Do not conduct outside spraying, grit blasting, or sanding activities during windy conditions that render containment ineffective.

Recommended Operational BMPs:

- Dispose of water-based paints by drying them out and then placing them in the garbage. Do not dump pollutants collected in portable containers into a sanitary sewer drain or a storm drain.
- Recycle paint, paint thinner, solvents, pressure washwater, and any other recyclable materials.
- Use efficient spray equipment such as electrostatic, air-atomized, high volume/low pressure, or gravity feed spray equipment.
- Purchase recycled paints, paint thinner, solvents, and other products, if feasible.

S422 BMPs for Railroad Yards

Description of Pollutant Sources:

Pollutant sources can include:

- Drips/leaks of vehicle fluids onto the railroad bed
- Human waste disposal
- Litter
- Locomotive/railcar/equipment cleaning areas
- Fueling areas
- Outside material storage areas
- Erosion and loss of soil particles from the railroad bed
- Maintenance and repair activities at railroad terminals
- Switching and maintenance yards
- Herbicides used for vegetation management

Waste materials can include used oil, solvents, degreasers, antifreeze solutions, chromate and other anti-rust compounds, dyes, radiator flush, acids, brake fluids, soiled rags, oil filters, sulfuric acid and battery sludges, and machine chips with residual machining oil and toxic fluids/solids lost during transit. Potential pollutants include oil and grease, TSS, BOD, organics, pesticides, and metals.

Pollutant Control Approach: Apply good housekeeping and preventive maintenance practices to control leaks and spills of liquids in railroad yard areas.

Applicable Operational and Structural Source Control BMPs:

- Implement the applicable BMPs in this chapter depending on the pollution generating activities/sources at a railroad yard facility.
- Do not allow discharge to outside areas from toilets while a train is in transit. Use pumpout facilities to service these units.
- Use drip pans at hose/pipe connections during liquid transfer and other leak-prone areas.
- When undergoing 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.
- During maintenance, do not discard debris or waste liquids along the tracks or in railroad yards.
- 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 out of contact with stormwater. For larger metal scrap, see Applicable Treatment BMPs below.
- Do not dump, drain, or allow the discharge of any water-based coolant from multi-punch presses into storm drains.
- Place track mats under each rail/flange lubricator that is in service where track mats can be safely installed and maintained without danger to rolling stock or personnel.
- Select cost-effective rail/flange lubricant that provides safe and effective rail operation while considering adverse environmental impact. Consider both the chemical composition of the lubricant and the likelihood of transfer off of the rail during rain events.
- Inspect and replace track mats, as necessary. Routinely inspect all track mats for tears or saturation, and replace as necessary.

Figure 8.16: Installed Railroad Track Mats

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Installed Railroad Track Mats

Revised August 2017

- Install spill containment pans/trays or track mats at designated locomotive and railcar maintenance facilities and fixed fueling areas, to reduce environmental impacts from potential spills under locomotives and other track equipment. Direct spill containment pans/trays to an oil / water separator where feasible 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 seepage.
- Install track mats at designated Engine Tie-Up and/or outdoor locomotive parking locations (e.g. service tracks) located in SWPP permitted areas where locomotives are unattended and idle for extended periods of time.
- Do not conduct heavy/major locomotive engine repairs on the rail line. Conduct heavy/major engine repairs at an established railroad maintenance facility.
- Store creosote-treated railroad ties in locations that reduce the potential to impact stormwater runoff.

Recommended Operational and Structural Source Control BMPs:

At each rail/flange lubricator that is in service use rain sensors to adjust the lubrication cycle accordingly to limit the amount of lubricant exposed to stormwater.

Applicable Treatment BMPs:

In areas subjected to leaks/spills of oils or other chemicals, convey stormwater to appropriate treatment such as a sanitary sewer, if approved by the appropriate sewer authority, or, to BMP T5.100: API (Baffle type) Separator, BMP T5.110: Coalescing Plate (CP) Separator, or other treatment, as approved by the local jurisdiction.

Recommended Treatment BMPs:

Store large metal scrap and materials that cannot be stored in covered areas because of their size, volume, and/or weight (for example rail and tie plates) in locations where stormwater runoff is managed, controlled, and directed to a Runoff Treatment BMP that meets the Metals Treatment Performance Goal.

S423 BMPs for Recyclers and Scrap Yards

Description of Pollutant Sources: Includes businesses that reclaim various materials for resale or for scrap, such as vehicles and vehicle/equipment parts, construction materials, metals, beverage containers, and papers.

Potential sources of pollutants include paper, plastic, metal scrap debris, engines, transmissions, radiators, batteries, and other materials that are contaminated or that contain fluids. Other pollutant sources include leachate from metal components, contaminated soil, and the erosion of soil. Activities that can generate pollutants include the transfer, dismantling, and crushing of vehicles and scrap metal; the transfer and removal of fluids; maintenance and cleaning of vehicles, parts, and equipment; and storage of fluids, parts for resale, solid wastes, scrap parts, and materials, equipment and vehicles that contain fluids; generally, in uncovered areas.

Potential pollutants typically found at vehicle recycle and scrap yards include oil and grease, ethylene and propylene glycol, PCBs, total suspended solids, BOD, heavy metals, and acidic pH.

Applicable BMPs:

- 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 BMPs in that guidance document to scrap material recycling facilities depending on the pollutant sources existing at those facilities.
- Check incoming scrap materials, vehicles, and equipment for potential fluid contents and batteries.
- Drain and transfer fluids from vehicles and other equipment only in a designated area with a waste collection system or over drip pans.
- Remove batteries and store on the ground in a leak proof container and under cover.
- Cover and raise any materials that may contaminate stormwater. A tarp and pallet are acceptable.
- Cover and contain stockpiles of any material that has the potential to contaminate stormwater runoff.
- All containers used to store fluids must comply with secondary containment requirements. Storage of flammable and combustible materials must comply with the appropriate Fire Codes.

Required Routine Maintenance:

- Inspect storage areas regularly and promptly clean up any leaks, spills, or contamination.
- Sweep scrap storage areas as needed. Do not hose down anything to a storm drain.
- Keep spill cleanup materials in a location known to all. Ensure that employees are familiar with the site's spill control plan and/or proper spill cleanup procedures.

Recommended BMPs:

- Install catch basin inserts to collect excess sediment and debris if necessary. Inspect and maintain catch basin inserts to ensure they are working correctly.
- Conduct automobile/vehicle metal-shredding inside enclosed buildings with HEPA air filtration systems to prevent the fugitive release of heavy metals and other potentially hazardous materials into the air.

S424 BMPs for Roof / Building Drains at Manufacturing and Commercial Buildings

Description of Pollutant Sources: Stormwater runoff from roofs and sides of manufacturing and commercial buildings can be sources of pollutants caused by leaching of roofing materials, paints, caulking, building vents, and other air emission sources. Research has identified vapors and entrained liquid and solid droplets/particles as potential pollutants in roof/building runoff. Metals, solvents, acidic/alkaline pH, BOD, PCBs, and organics are some of the pollutant constituents identified.

Ecology has performed a study on zinc in industrial stormwater. The study is presented in *Suggested Practices to Reduce Zinc Concentrations in Industrial Stormwater Discharges* (Ecology, 2008). The user should refer to this document for more details on addressing zinc in stormwater.

Ecology has also researched the characterization and abatement of PCBs in building materials before demolition or renovation (Ecology, 2024). The user should refer to that guidance document for more details on preventing PCBs from entering stormwater from buildings that have, or likely have, PCB-containing materials on roofs and building exteriors like siding, joint materials (caulk), paint, and other potential sources.

Pollutant Control Approach: Evaluate the potential sources of stormwater pollutants and apply source control BMPs where feasible.

Applicable Operational Source Control BMPs:

- If leachates and/or emissions from buildings are suspected sources of stormwater pollutants, then sample and analyze the stormwater draining from the building.
- If PCBs in external building materials are suspected, assess the building materials and report findings consistent with the guidance in *How to Find and Address PCBs in Building Materials* (Ecology, 2024).
- Sweep the area routinely to remove any residual pollutants.
- If a roof/building stormwater pollutant source is identified, implement appropriate source control measures such as air pollution control equipment, selection of materials, operational changes, material recycle, process changes, removal/abatement, etc.

Applicable Structural Source Control BMPs:

- Paint/coat the galvanized surfaces as described in *Suggested Practices to Reduce Zinc Concentrations in Industrial Stormwater Discharges* (Ecology, 2008).

Applicable Treatment BMPs:

Treat runoff from roofs to the appropriate level. The facility may use Metals Treatment BMPs as described in 6.1.2 Choosing Your Runoff Treatment BMPs. Some facilities regulated by the Industrial Stormwater General Permit, or local jurisdiction, may have requirements than cannot be achieved with Metals Treatment BMPs. In these cases, additional treatment measures may be required. A treatment method for meeting stringent requirements such as Chitosan-Enhanced Sand Filtration may be appropriate.

S432 BMPs for Wood Treatment Areas

Description of Pollutant Sources: Wood treatment includes both anti-staining and wood preserving using pressure processes or by dipping or spraying. Wood preservatives are registered with the U.S. EPA and include oil-borne and water-borne preservatives. Some examples include creosote, creosote/coal tar, pentachlorophenol, copper naphthenate, arsenic trioxide, malathion, or inorganic arsenicals such as chromated copper arsenate, acid copper chromate, chromate zinc chloride, and fluor-chrome-arsenate-phenol. Anti-staining chemical additives include iodo-prophenyl-butyl carbamate, dimethyl sulfoxide, didecyl dimethyl ammonium chloride, sodium azide, 8 quinolinol; copper (II) chelate, sodium ortho-phenylphenate, 2 (thiocyanomethylthio)-benzothiazole (TCMTB) and methylene bis- (thiocyanate), and zinc naphthenate.

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 (phenomenon where preservative leaks as it returns to normal pressure). Potential pollutants typically include the wood treating chemicals, BOD, suspended solids, oil and grease, benzene, toluene, ethylbenzene, phenol, chlorophenols, nitrophenols, heavy metals, and PAH depending on the chemical additive used.

Pollutant Control Approach: When feasible, cover wood treating drip pads and prevent stormwater contamination from wood treating chemicals. Wood treating facilities may be covered by the Industrial Stormwater General Permit or by an individual permit. Individual permits covering wood treatment facilities include applicable source control BMPs or require the development of BMPs or a SWPPP. Facilities covered under the Industrial Stormwater General Permit must prepare and implement a SWPPP. When developing a SWPPP or BMPs, wood treating facilities should include the applicable operational and structural source control BMPs listed below.

Applicable Operational BMPs:

- Use dedicated equipment for treatment activities to prevent the tracking of treatment chemicals to other areas on the site.
- Minimize non-process traffic on the drip pad. Clean non-dedicated lift trucks on the drip pad.
- Immediately remove, contain, and properly dispose of soils with visible surface contamination (green soil) to prevent the spread of chemicals to groundwater and/or surface water via stormwater runoff.
- If wood is discovered to be actively dripping in the storage yard, relocate the wood to the drip pad until it ceases dripping.

Recommended Operational BMP:

Consider using preservative chemicals that do not adversely affect receiving surface water and groundwater.

Applicable Structural Source Control BMPs:

- Cover and/or enclose, and contain with impervious surfaces, all wood treatment equipment and drip pads. Slope and drain areas around dip tanks, spray booths, retorts, and any other process equipment in a manner that allows return of treatment chemicals to the wood treatment process.
- Freshly treated wood is defined as wood that has not been removed from the drip pad immediately following treatment.
- When feasible, cover drip pads for freshly treated wood that has not ceased dripping to prevent contact of treated wood products with stormwater.
- Segregate clean stormwater from process water. Convey all process water to an approved treatment system.
- Seal any holes or cracks in the asphalt areas that are subject to wood treatment chemical contamination.
- Elevate stored and/or treated wood products to minimize contact with stormwater run-on and runoff.
- Place dipped lumber over the dip tank, or on an inclined ramp for a minimum of 30 minutes to allow excess chemical to drip back to the dip tank.
- Freshly treated lumber from dip tanks or retorts must be placed on a containment area until drippage has ceased prior to placement in outside storage areas.

S433 BMPs for Pools, Spas, Hot Tubs, and Fountains

Description of Pollutant Sources: This section includes BMPs for pools, spas, hot tubs, and fountains used for recreational and/or decorative purposes that may use chemicals and/or be heated. Industrial Stormwater Permittees that use pools, spas, hot tubs, and fountains as part of an industrial process should refer to their Industrial Stormwater Permit.

Discharge from pools, spas, hot tubs, and fountains can degrade ambient water quality. The waters from these sources typically contain bacteria that contaminate the receiving waters. Chemicals lethal to aquatic life such as chlorine, bromine and algaecides can be found in pools, spas, hot tubs, and fountains. These waters may be at an elevated temperature and can have negative effects on receiving waters and to aquatic life. Diatomaceous earth backwash from swimming pool filters can clog gills and suffocate fish.

Routine maintenance activities generate a variety of wastes. Chlorinated water, backwash residues, algaecides, and acid washes are a few examples. Direct disposal of these waters to drainage systems and waters of the State is not permitted without prior treatment and approval.

The quality of any discharge to the ground after proper treatment must comply with Ecology's Groundwater Quality Standards, Chapter 173-200 WAC.

The Washington State Department of Health and local health authorities regulate Water Recreation facilities which include pools, spas, and hot tubs. Owners and operators of those facilities must comply with those regulations, policies and procedures. Following the guidelines here does not exempt or supersede any requirements of the regulatory authorities.

Pollutant Control Approach: Many manufacturers do not recommend draining pools, spas, hot tubs, or fountains; refer to the facility's operation and maintenance manual. If the water feature must be drained, convey discharges (within hoses or pipes) to a sanitary sewer if approved by the local sewer authority or to a storm sewer following the conditions outlined below. Do not discharge to a septic system, since it may cause the system to fail. No discharge to the ground or to surface water should occur, unless permitted by the proper regulatory authority.

Applicable Operational BMPs:

- Clean the pool, spa, hot tub, or fountain regularly. Maintain proper chlorine levels and maintain water filtration and circulation. Doing so will limit the need to drain the facility.
- Manage pH and water hardness to reduce copper pipe corrosion that can stain the facility and pollute receiving waters.
- Before using copper algaecides, try less toxic alternatives. Only use copper algaecides if the other alternatives do not work. Ask a maintenance service or pool chemical supplier for help resolving persistent algae problems without using copper algaecides.
- Develop, implement, and regularly update a facility maintenance plan that follows all discharge requirements.
- Dispose of unwanted chemicals properly. Many of them are hazardous wastes when discarded.
- Discharge waters originating from a pool, spa, hot tub, or fountain to a sanitary sewer, if approved by the local sewer authority, local health authority, or both. Do not discharge waters containing copper-based algaecides to storm sewer systems.
- Do not discharge water directly from a pool, spa, hot tub, fountain, process wastes, or wastewaters into storm drains except if the discharge water is:
    - Dechlorinated/debrominated to 0.1 ppm or less. Some guidance on dechlorination is provided in the Washington State Department of Health's *Water System Design Manual* (DOH, 2009). The *Water System Design Manual* (DOH, 2009) further references *C651-99: AWWA Standard for Disinfecting Water Mains* (AWWA, 1999) and *C652-02: AWWA Standard for Disinfection of Water-Storage Facilities* (AWWA, 2002) for more details. Contact a pool chemical supplier to obtain the neutralizing chemicals needed.
    - Free from sodium chloride.
    - pH-adjusted.

    - Reoxygenated if necessary.
    - Free of any coloration, dirt, suds, or algae.
    - Free of any filter media.
    - Free of acid cleaning wastes.
    - At a temperature that will prevent an increase in temperature in the receiving water. Cool heated water prior to discharge.
    - Released at a rate that can be accommodated by the receiving body (i.e. can infiltrate or be safely conveyed).
- Swimming pool cleaning wastewater and filter backwash shall not be discharged to the storm sewer.
- Bag diatomaceous earth (pool filtering agent) and dispose of it at a landfill.

Applicable Structural Source Control BMPs:

- Ensure that the pool, spa, hot tub, or fountain system is free of leaks and operates within the design parameters.
- Do not provide any permanent links to drainage systems. All connections should be visible and carefully controlled.
- If the dechlorination or cooling process selected requires the water to be stored for a time, it should be contained within the pool or appropriate temporary storage container.

S436 BMPs for Color Events

Description of Pollutant Sources: Color events are charity, religious, or commercial events that involve the use of powdered (typically cornstarch based) and/or liquid dyes. Because they typically occur outside, there is a high likelihood of the color material entering drainage systems and surface water unless measures are taken to prevent these illicit discharges from occurring.

“Biodegradable” and “non–toxic” do NOT mean that a substance can go into storm drains or water bodies. The dye material can harm aquatic organisms by altering water quality and chemistry. State and Federal environmental laws require local jurisdictions to prohibit non-stormwater discharges to storm drains. Dye material and any wash water are prohibited discharges.

Pollutant Control Approach: Plan for the event. Control the application areas for the powder or liquid dyes. Block off storm drain inlets prior to the event. Clean up the areas immediately after the event.

Figure 8.17: Powdered Dyes at Color Events

Color events typically involve the use of powdered dyes such as those pictured.

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State of Washington

Powdered Dyes at Color Events

Revised June 2017

Applicable Operational BMPs:

Pre-Event

- Create a map of your event that includes the following:
  - Event route.
  - Nearby streams, lakes, and ponds.
  - Start and finish areas.
  - Color application stations / areas.
  - Storm drain inlets and open stormwater system features (e.g., ditches, swales, bioretention, detention ponds) at the color application, start and finish areas.
- Create a Pollution Plan that details:
  - Measures taken to ensure that NO dye material, either during or after the event, will enter the drainage system.
  - How all dye material will be removed and disposed of.
  - What will happen in the event of rain (including addressing localized flooding, runoff, and collection of the stormwater).
  - Emergency numbers for the local jurisdiction in case dye material does enter the storm drain or water body.
- Use handheld brooms to complete the initial cleanup of paved surfaces. Follow with use of a vacuum sweeper truck on roads.
- Contract with a commercial street sweeping firm to clean paved surfaces. Have a storm drain cleaning contractor on-call for discharges to storm drains or emergency clean-up if necessary.
- Ensure that the commercial street sweeping firm has a plan in place for the proper disposal of sweepings from the event and associated air filters.
- Ensure that all clean-up will be completed prior to the next forecasted rainfall, or no later than 24-hours after the race event, and that the contractor will have enough equipment and staff on hand for the clean-up.
- Request a copy of the dye product's Safety Data Sheet (SDS) from the manufacturer or supplier. Review the SDS for potential safety and environmental hazards.
- Comply with local jurisdiction event permit requirements that contain stormwater pollution prevention BMPs. If no local event permit is required, provide to the local jurisdiction in charge of stormwater drainage and/or surface water management, in plenty of time (two weeks or more) prior to the event:

  - Copies of the map
  - Pollution prevention plan
  - Commercial cleaning contract
  - Dye SDSs
  - Names and contact information of the event officials for both during and after the event.

Preventing Runoff from Entering Drainage Systems and Water Bodies

- Protect storm drains by using berms, covering the drains, and using catch basin covers.
- Use care when removing berms, covers, and tarps to ensure no dye enters the storm drains.
- Prohibit participants from throwing dye within 100 feet of any stream or other surface waterbody.
- Prohibit participants from throwing dye within 100 feet of any open stormwater feature (e.g,. ditch, swale, bioretention, detention pond).
- Set up color stations at least 100 feet away from any surface water or open stormwater feature.
- The route, start, finish, and color application stations must be at least 100' away from any permeable pavement or the permeable pavement must be completely covered.
- If the event will be held on a small, contained area, cordon off the area and place enough covers on the ground to cover the entire site. If possible, contain the color application to grassy areas where ground covers are unnecessary.

Event Clean-Up

- Dry off tarps and stained wet pavement with towels or absorbent pads.
- Use brooms or street sweepers to clean up paved areas. The fineness of the material may require sweepers with dust control systems.
- Do not use blowers to move dye material.
- Do not use hoses or pressure washers to rinse excess dye off of tarps, sidewalks or paved areas. If it becomes necessary to use water to clean surfaces, all the water must be collected and disposed of to the sanitary sewer system, with approval from the local sewer agency.
- Call the local spill response hotline immediately (24/7) if any colored water enters a storm drain or water body.
- Dispose of the collected sweeping materials, cleaning materials, and air filters appropriately.

- All litter and debris must be picked up and properly disposed of.
- All clean-up must be done within 24-hours of the race event.

S438 BMPs for Construction Demolition

Description of Pollutant Sources: This activity applies to removal of existing buildings and other structures by controlled explosions, wrecking balls, or manual methods, and subsequent clearing of the rubble. The loose debris may contaminate stormwater.

Pollutants of concern include toxic organic compounds (such as PCBs), hazardous wastes, high pH, heavy metals, and suspended solids.

PCBs were added to building materials before 1980 (such as caulk and other sealants, joint materials, paint, siding, roofing, and others), and now with age and weathering are at greater risk of being dislodged during demolition and renovation activities. Particles containing PCBs can be washed into the stormwater, contaminating the conveyance system and downstream water bodies, if not properly managed. PCB-containing building materials were more often used in public buildings such as schools, hospitals, universities, fire houses, police stations, government offices, military sites, as well as privately owned commercial and large multi-unit residential buildings. Recently, guidance has been developed for characterizing and abating PCBs in building materials that will undergo demolition or renovation (Ecology, 2024). The user should refer to this document for more details on preventing PCBs from entering stormwater.

Additional regulations regarding PCBs may apply, including but not limited to the federal Toxic Substances Control Act (TSCA). For more information, refer to the U.S. EPA's guidance for PCBs at the following web address:

https://www.epa.gov/pcbs

Pollutant Control Approach: Do not expose hazardous materials to stormwater. Regularly clean up debris that can contaminate stormwater. Protect the stormwater drainage system from dirty runoff and loose particles. Sweep paved surfaces daily. Educate employees about the need to control site activities. While awaiting active demolition, monitor the integrity of PCB-containing materials and take actions to prevent PCB-containing dust and solids from entering stormwater and stormwater conveyances.

Applicable Operational BMPs:

- Identify, remove, and properly dispose of hazardous substances from the building before beginning construction demolition activities that could expose them to stormwater. Such substances could include PCBs, asbestos, lead paint, mercury switches, and electronic waste.
- Educate employees about the need to control site activities to prevent stormwater pollution, and also train them in spill cleanup procedures.
- Keep debris containers, dumpsters, and debris piles covered.

- Place storm drain covers, or a similarly effective containment device, on all nearby drains to prevent dirty runoff and loose particles from entering the stormwater drainage system.
    - Place the covers (or devices) at the beginning of the workday.
    - Collect and properly dispose of the accumulated materials before removing the covers (or devices) at the end of the workday.
    - Use dikes, berms, or other methods to protect overland discharge paths from runoff if stormwater drains are not present.
- Sweep street gutters, sidewalks, driveways, and other paved surfaces in the immediate area of the demolition at the end of each workday. Collect and properly dispose of loose debris and garbage.
- Lightly spray water (such as from a hydrant or water truck) throughout the site to help control windblown fine materials such as soil, concrete dust, and paint chips. Control the amount of dust control water so that runoff from the site does not occur, yet dust control is achieved. Do not use oils for dust control.
- Follow the guidance document *How to Find and Address PCBs in Building Materials* (Ecology, 2024) for PCB-containing building materials undergoing demolition or renovation.
- Contact the local jurisdiction's stormwater program to inform them when PCB-containing materials are, or are likely to be, present.
- To prevent PCBs in building materials from entering stormwater during the demolition planning/preparation phase (i.e. prior to active demolition), routinely visually survey the areas where PCB-containing building materials are likely to exist to check that they have remained intact. If weathering (e.g. flaking, peeling) becomes noticeably worse as demolition planning continues, consider installing BMPs to prevent runoff containing PCBs from entering the stormwater conveyance system, such as:
    - install catch basin filter inserts
    - dry sweep adjacent hard surfaces
    - prevent washwater or irrigation water from coming into contact with the PCB-containing building materials
    - educate landscaping and maintenance staff about avoiding the use of leaf blowers around the building.

Recommended Operational BMPs:

- 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 onsite.
- Schedule demolition to take place at a dry time of the year to prevent stormwater runoff from the demolition site.

S440 BMPs for Pet Waste

Description of Pollutant Sources: Pets and pet-care can generate pollutants from waste, animal washing, and cage or kennel cleaning. Pet waste that washes into lakes or streams begins to decay, using up oxygen and releasing ammonia. Low oxygen levels and ammonia combined with warm water can kill fish. Pet waste also contains nutrients that encourage weed and algae growth, and contribute to low oxygen 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 or shellfish harvesting closures.

Pollutant Control Approach: Use a plastic bag or pooper scooper to clean up after pets. Properly dispose of pet waste.

Recommended Operational BMPs for Pet Owners

- Regularly pick up and dispose of pet waste deposited on walks and at home.
- Put pet waste in a securely closed bag and deposit it in the trash. Do not place pet waste in yard waste containers because pet waste may carry diseases, and composting may not kill disease-causing organisms.
- Do not compost or use pet waste as fertilizer. Harmful bacteria, worms, and parasites that can transmit disease can live in the soil for years even after the solid portion of the pet waste has dissolved.
- Do not dispose of unused pet pharmaceuticals in a storm drain, in a toilet, or down a sink. Check with your local refuse collector for proper disposal locations of pet medications.
- When cleaning out cages and kennels, dispose of wash water down the toilet or a mop sink. Otherwise, wash directly over lawn areas or make sure the wash water drains to a vegetated area.
- Bathe pets indoors or in a manner that wash water won’t be discharged to storm drains, ditches, or surface waters of the state.

Recommended Operational BMPs for Recreation Areas and Multi-Family Properties

- Post signs at recreation areas and multi-family properties (that allow pets) reminding residents and visitors to pick up after their pets.
- Carefully consider the placement of pet waste stations at recreation sites and near multi-family properties that allow pets. Choose locations convenient for dog walkers to pick up a bag at the start of their walk and locations for them to dispose of it at mid-walk or at the end of their walk.
- Check pet waste stations on a regular basis to keep pet waste bags stocked and disposal stations empty. Consider signage to keep regular trash out of pet waste disposal stations to avoid filling them too quickly. Make sure pet waste disposal stations have a cover to keep out water.

- At multi-family properties with roof-top dog runs, ensure that stormwater from the dog run is not discharged to the stormwater system. Check with the local jurisdiction regarding roof-top dog run connections to sanitary sewer.

Figure 8.18: Example of a Pet Waste Station

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Example of a Pet Waste Station

Revised May 2019

Figure 8.19: Examples of Pet Waste Signs

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Examples of Pet Waste Signs

Revised November 2023

S442 BMPs for Labeling Storm Drain Inlets On Your Property

Description of Pollutant Sources: Waste materials dumped into storm drain inlets can have severe impacts on receiving waters. Posting notices regarding discharge prohibitions at storm drain inlets can prevent waste dumping. Storm drain signs and stencils are highly visible source controls that are typically placed directly adjacent to storm drain inlets.

Pollutant Control Approach: The stencil, affixed sign, or metal grate contains a brief statement that prohibits dumping of improper materials into the urban runoff conveyance system. Storm drain messages have become a popular method of alerting the public about the effects of and the prohibitions against waste disposal.

Applicable Operational BMPs:

- Label storm drain inlets in residential, commercial, industrial areas, and any other areas where contributions or dumping to storm drains is likely.
- Stencil or apply storm drain markers adjacent to storm drain inlets to help prevent the improper disposal of pollutants. Or, use a storm drain grate stamped with warnings against polluting.
- Place the marker in clear sight facing toward anyone approaching the inlet from either side.
- Use a brief statement and/or graphical icons to discourage illegal dumping. Examples include:
    - “No Dumping – Drains to Stream”
    - “Dump No Waste – Drains to Lake”
- Check with your local jurisdiction to find out if they have approved specific signage and/or storm drain message placards for use. Consult the local jurisdiction stormwater staff to determine specific requirements for placard types and methods of application.
- Maintain the legibility of markers and signs. Signage on top of curbs tends to weather and fade. Signage on face of curbs tends to be worn by contact with vehicle tires and sweeper brooms.
- When painting stencils or installing markers, temporarily block the storm drain inlet so that no pollutants are discharged from the labeling activities.

Recommended Operational BMPs:

Use a stencil in addition to a storm drain marker or grate to increase visibility of the message.

Reference for this BMP: (CASQA, 2003)

Figure 8.20: Storm Drain Inlet Labels

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State of Washington

Storm Drain Inlet Labels

Revised October 2017

S443 BMPs for Fertilizer Application

Description of Pollutant Sources: Poor application of fertilizers can cause appreciable stormwater contamination. Fertilizers can leach phosphorus, nitrogen, and coliform bacteria. Fertilizers can contribute to algae blooms, increase nutrient concentrations, and deplete oxygen in receiving waters.

Pollutant Control Approach: Minimize the amount of fertilizer necessary to maintain vegetation. Control the application of fertilizer to prevent the discharge of stormwater pollution.

Applicable Operational BMPs:

- Apply the minimum amount of slow-release fertilizer necessary to achieve successful plant establishment.
- Do not fertilize when the soil is dry or during a drought.
- Never apply fertilizers if it is raining or about to rain.
- Do not apply fertilizers within three days prior to predicted rainfall. The longer the period between fertilizer application and either rainfall or irrigation, the less fertilizer runoff occurs.
- Determine the proper fertilizer application for the types of soil and vegetation involved.
- Follow manufacturers' recommendations and label directions.
- Train employees on the proper use and application of fertilizers.
- Keep fertilizer granules off impervious surfaces. Clean up any spills immediately. Do not hose down to a storm drain, conveyance ditch, or water body.
- If possible, do not fertilize areas within 100 feet of water bodies including wetlands, ponds, and streams.
- Avoid fertilizer applications in stormwater ditches, stormwater facilities, and drainage systems.
- In areas that drain to sensitive water bodies, apply no fertilizer at commercial and industrial facilities, to grass swales, filter strips, or buffer areas unless approved by the local jurisdiction.
- Use slow release fertilizers such as methylene urea, isobutylidene, or resin coated fertilizers when appropriate, generally in the spring. Use of slow release fertilizers is especially important in areas with sandy or gravelly soils.
- Apply fertilizers in amounts appropriate for the target vegetation and at the time of year that minimizes losses to surface and ground waters.
- Time the fertilizer application to periods of maximum plant uptake. Ecology generally recommends application in the fall and spring, although Washington State University turf specialists recommend four fertilizer applications per year.

- Do not use turf fertilizers containing phosphorus unless a soil sample analysis taken within the past 36 months indicates the soil of the established lawn is deficient in phosphorus. For more information about restrictions on turf fertilizers containing phosphorus, see the following website:

  https://agr.wa.gov/departments/pesticides-and-fertilizers/fertilizers/fertilizers-containing-phosphorus

Recommended Operational BMPs:

Test soils to determine the correct fertilizer application rates.

- Evaluation of soil nutrient levels through regular testing ensures the best possible efficiency and economy of fertilization.
- Fertilization needs vary by site depending on plant, soil, and climate conditions.
- Choose organic fertilizers when possible.
- For details on soils testing, contact the local Conservation District, a soils testing professional, or a Washington State University Extension office.

S446 BMPs for Well, Utility, Directional, and Geotechnical Drilling

Description of Pollutant Sources: This activity applies to drilling water wells and utilities, environmental protection and monitoring wells, and geotechnical borings that use machinery in the drilling. It does not apply to the use of devices such as hand augers, or for large structural drilling such as drilled shafts.

Drilling activities can expose soil and contaminated soil. These activities may cause the discharge of stormwater contaminated with sediments and other contaminates. This risk increases when drilling in areas with contaminated soils.

Pollutant Control Approach: Reduce sediment runoff from drilling operations.

Applicable Operational BMPs:

- When drilling in areas of known or suspected soil contamination, test and characterize soil cuttings and accumulated sediment to determine proper management and disposal methods. If applicable, generator knowledge may be used to characterize the soil cuttings and accumulated sediment.
- Obtain permits for drilling activities, and for clearing and grading the access routes and the work site.
- Protect environmentally sensitive areas (streams, wetlands, floodplains, floodways, erosion hazards, and landslide hazards) within the area of influence of the work site.
- Mitigate potential impacts to surrounding areas and/or the drainage system.

- For horizontal directional drilling, take measures to capture and contain drilling fluids and slurry.
- Equip the driller to quickly respond to unusual conditions that may arise.
- Locate and prepare access roadways to minimize the amount of excavation and the potential for erosion.
- Contain accumulated uncontaminated water and sediment on site and pump into a storage tank or direct through a geotextile filtration system (or equivalent system) before discharging to the surrounding ground surface. Contaminants may include, but are not limited to, hydraulic fluids, contaminants in the soil and/or groundwater, polymers, and other drilling fluid additives.
- Keep all sediment-laden water out of storm drains and surface waters. If sediment-laden water does escape from the immediate drilling location, block flow to any nearby waterways or catch basins using fabric, inlet protections, sand bags, erosion fences, or other similar methods. Immediately notify Ecology and the local jurisdiction if sediment-laden water impacts the storm sewer system or surface waters.
- Divert any concentrated flows of water into the site using sandbags or check dams up-slope from the site.
- Dispose of soil cuttings and accumulated sediment appropriately. If cuttings or other soils disturbed in the drilling process are to be temporarily stockpiled on site, they must be covered and surrounded by a berm or filter device. See S429 BMPs for Storage or Transfer (Outside) of Solid Raw Materials, Byproducts, or Finished Products.
- Stabilize exposed soils at the end of the job, using mulch or other erosion control measures. See S425 BMPs for Soil Erosion and Sediment Control at Industrial Sites.
- Contain spent drilling slurry on site and allow it to dewater, or haul to an appropriate, approved disposal site.
- Restore disturbed areas with mulch (see BMP C121: Mulching) and seeding or hydroseeding (see BMP C120: Temporary and Permanent Seeding).

S447 BMPs for Roof Vents

Description of Pollutant Sources: This activity applies to processes that vent emissions to the roof and/or the accumulation of pollutants on roofs. Processes of special concern are stone cutting, metal grinding, spray painting, paint stripping, galvanizing and electroplating. Pollutants from these processes may build up on roofs and may pollute stormwater roof runoff.

Pollutant Control Approach: Evaluate the potential sources of stormwater pollutants and apply source control BMPs where feasible.

Applicable BMPs:

- Identify processes that are vented and may contribute pollutants to the roof. Pollutants of concern include and are not limited to:

  - Metal dust
  - Grease from food preparation
  - Solvents
  - Hydrocarbons
  - Fines
  - Stone dust
- Look for chemical deposition around vents, pipes, and other surfaces.
- Install and maintain appropriate source control measures such as air pollution control equipment (filters, scrubbers, and other treatment). (City of San José Environmental Services, 2004)
  - Check that your scrubber solution is appropriate for the chemistry of the fumes.
  - Install vent covers and drip pans where there are none.
  - Prevent leaks in pipefittings and containment vessels with routine maintenance.
- Consider instituting operational or process changes to reduce pollution.
- If proper installation and maintenance of air pollution control equipment does not prevent pollutant fallout on your roof, additional treatment of the roof runoff may be necessary.
  - Install/provide appropriate devices for roof runoff before it is discharged off site. This may include approved Runoff Treatment BMPs or structural stormwater treatment BMPs.
- Maintain air filters and pollution control equipment on a regular basis to ensure they are working properly. (The smell of odors from outside the building indicates that the pollution control equipment may need maintenance or evaluation.)
- When cleaning accumulated emissions from roof tops, collect the washwater and loose materials using a sump pump, wet vacuum, or similar device. Discharge the collected runoff to the sanitary sewer after approval by the local sewer authority, or have a waste disposal company remove it.

S451 BMPs for Building Repair, Remodeling, Painting, and Construction

Description of Pollutant Sources: This activity refers to:

- The construction of buildings and other structures.
- Remodeling of existing buildings and houses.

- General exterior building repair work.
- Containment or removal of known or suspected exterior hazardous building materials.

Pollutants of concern include toxic hydrocarbons, hazardous wastes, toxic organics (such as PCBs), suspended solids, heavy metals, pH, oils, and greases.

PCBs were added to building materials before 1980 (such as caulk and other sealants, joint materials, paint, siding, roofing, and others), and now with age and weathering are at greater risk of being dislodged during demolition and renovation activities. Particles containing PCBs can be washed into the stormwater, contaminating the conveyance system and downstream water bodies, if not properly managed. Prior to 1980, PCB-containing building materials were more often used in public buildings such as schools, hospitals, universities, fire houses, police stations, government offices, military sites, as well as privately owned commercial and large multi-unit residential buildings. Recently, guidance has been developed for characterizing and abating PCBs in building materials that will undergo demolition or renovation (Ecology, 2024). The user should refer to this document for more details on preventing PCBs from entering stormwater.

Pollutant Control Approach: Educate employees about the need to control site activities. Control leaks, spills, and loose material. Utilize good housekeeping practices. Regularly clean up debris that can contaminate stormwater. Protect the drainage system from dirty runoff and loose particles. Prevent PCB-containing dust and solids from entering stormwater and stormwater conveyances.

Applicable Operational BMPs:

- Identify, remove, and properly dispose of hazardous substances from the building before beginning repairing or remodeling activities that could expose them to stormwater. Such substances could include PCBs, asbestos, lead paint, mercury switches, and electronic waste.
- Follow Ecology's guidance document *How to Find and Address PCBs in Building Materials* (Ecology, 2024) for PCB-containing building materials undergoing demolition or renovation.
- 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. This could include constructing a wind screen of plastic at the edge of the groundcover to keep dust and debris from spreading.
- Contact the local jurisdiction's stormwater program to inform them when PCB-containing materials are, or are likely to be, present. They may be able to prioritize street sweeping and/or storm drain pipe cleaning in the area.
- Educate employees about the need to control site activities to prevent stormwater pollution, and also train them in spill cleanup procedures. Employees may also include maintenance and landscaping staff working around buildings with exterior PCB-containing materials.
- At all times, have available at the work site spill cleanup materials appropriate to the chemicals used on site.

- Clean up the work site at the end of each work day. Put away materials (such as solvents) indoors or cover and secure them, so that unauthorized individuals will not have access to them.
- 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.
- Do not dump any liquid on pavement, on the ground, in the storm drain, or toward the storm drain, regardless of its content, unless it is clean water only.
- Place a drop cloth, where space and access permits, before beginning wood treating activities. Use drip pans in areas where drips are likely to occur if the area cannot be protected with a drop cloth.
- Use ground or drop cloths underneath scraping and sandblasting work. Use ground cloths, buckets, or tubs anywhere that work materials are laid down.
- Clean paint brushes and other tools covered with water-based paints in sinks connected to sanitary sewers or in portable containers that can subsequently be dumped into a sanitary sewer drain.
- Clean brushes and tools covered with non-water-based finishes or other materials in a manner that enables 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.
- Use storm drain covers, or similarly effective devices, to prevent dust, grit, washwater, or other pollutants from escaping the work area. Place the cover or containment device over the storm drain at the beginning of the work day. Collect and properly dispose of accumulated dirty runoff and solids before removing the cover or device at the end of each work day.
- 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)).
- Refer to S431 BMPs for Washing and Steam Cleaning Vehicles / Equipment / Building Structures for best management practices associated with pressure washing buildings.

Recommended Operational BMPs:

- Lightly spray water on the work site to control dust and grit that could blow away. Do not use oils for dust control. Never spray to the point of water runoff from the site.
- Clean tools over a ground cloth or within a containment device such as a tub.
- Consider using filtered vacuuming to collect waste that may be hard to sweep, such as dust on a drop cloth.

- If conducting work in wet weather conditions, consider setting up temporary cover when scraping or pressure-washing lead-based paint.
- Use tools and work methods that generate the least dust and heat. Consider using manual tools, as they generate less fine dust and heat.

S452 BMPs for Goose Waste

Description of Pollutant Sources: Goose waste deposited near water or in water can contribute nutrients and algae growth. Goose feces may contain pathogens and contribute to the spread of diseases. Swimmers itch (schistosome or cercarial dermatitis) is caused by a parasite that can be spread by goose droppings, but does not mature or reproduce in humans.

Pollutant Control Approach: To help decrease geese pollution to water sources, remove waste periodically and use deterrent management practices.

Applicable Operational BMPs:

This BMP is for areas of chronic accumulation of goose waste that impact stormwater systems.

- If possible, pick up goose waste using shovels, brooms, rakes, power sweepers, and trash cans. Properly dispose of goose waste in the garbage.
- Do not blow, sweep, or wash goose waste into waterways or storm sewer systems.
- Regularly clean goose waste from areas of chronic deposition where deterrence measures are impractical.
- Do not feed wild geese or any other wild animals.
- In recreational areas post signs discouraging the feeding of geese and other wild animals.

Optional Operational BMPs:

- Change the habitat from goose friendly to goose resistant. Reduce lawn areas and increase the height of shoreline vegetation (tall grass, shrubs); as geese are reluctant to walk through tall vegetation.
- Create a natural geese barrier. 20 to 100 feet of herbaceous vegetation at least 3 feet in height to discourage geese. A narrow, winding path through the plantings will allow for beach access, while preventing geese from having a direct line of sight through the planted area.
- Make bank slopes steeper than 4:1 to discourage geese by preventing a clear view of the bank top and potential predators. Or, separate the beach from the grass with a few steep steps, which makes the ascent too difficult for most geese.
- Narrow ponds to limit takeoff and landing opportunities.
- Where space is limited use one or two rows of shrub plantings combined with a fence. Fences can be made from woven wire, poultry netting, plastic netting, plastic snow fencing, monofilament line, or electrified wire. Fences should be at least 24 inches tall (3 feet may be

better), firmly constructed, and installed to prevent the geese from walking around the ends. Lower openings should be no larger than 4 inches from the ground to prevent goslings from walking under or through the fence.

- Construct a grid of wire or line above the water's surface to prevent geese from flying into a pond that they have been accustomed to using. The grid should be one to two feet above the water surface, but may be taller if humans need access to the area under the grid. There should be no more than five feet of space between grid lines. To prevent geese from walking under the grid install a perimeter fence. Regularly monitor the grid for holes, trapped wildlife, and sagging.
- Canada geese are protected under federal and state law and a hunting license and open season are required to hunt them. Where lethal control of Canada geese is necessary outside of hunting seasons, it should be carried out only after the above nonlethal control techniques have proven unsuccessful and only under permits issued by the U.S. Fish and Wildlife Service. Currently, the only agency permitted for lethal removal is the U.S. Department of Agriculture's Wildlife Services. Lethal control techniques include legal hunting, shooting out of season by permit, egg destruction by permit, and euthanasia of adults by government officials.
- Scare geese away when they are around. Geese often learn quickly to ignore scare devices that are not a real physical danger. Vary the use, timing, and location of tactics. Take advantage of geese being fearful of new objects. Examples of harassment and scare tactics:
    - **Dog patrols:** When directed by a handler, dogs are the method of choice for large open areas. Results are often immediate. After an aggressive initial use (several times a day for one or two weeks), geese get tired of being harassed and will use adjacent areas instead. A dog can be tethered to a long lead (which may require relocating the dog and tether frequently to cover more area), be allowed to chase and retrieve a decoy thrown over a large flock of geese, or be periodically released to chase the birds (if this is not against leash laws).
    - **Eyespot Balloons:** Large, helium-filled balloons with large eye-like images. Tether balloons on a 20 to 40 foot monofilament line attached to a stake or heavy object. Locate balloons where they will not tangle with trees or utility lines.
    - **Flags and Streamers:** Simple flags from plastic mounted on tall poles or mylar tape to make 6-foot streamers attached to the top of 8 foot long poles. Flags and streamers work best in areas where there is steady wind.
    - **Scarecrows:** Effective in areas where geese view humans as dangerous predators. For maximum effect, the arms and legs should move in the wind, use bright colors, and large eyes. Large, blow-up toy snakes are reported to work as a type of scarecrow.
    - **Noisemakers:** Devices that make a loud bang such as propane cannons, blanks, and whistle bombs can scare geese. Making the noise as soon as geese arrive and persistence are the keys to success when using these devices. Consult noise ordinances and other permitting authorities (such as the local police department)

before using.

    - **Lasers:** Relatively low-power, long-wavelength lasers provide an effective means of dispersing geese under low light conditions. The birds view the light as a physical object or predator coming toward them and generally fly away to escape. Never aim lasers in the direction of people, roads, or aircraft.

- Geese's favorite food is new shoots of grass. Low lying grass also allows easy access to the water for protection from predators. Let grass grow to six inches or taller. Stop fertilizing and watering the lawn to reduce the palatability of the lawn.
- Minimize open sight lines for geese to less than 30 feet.
- Plant shrubs or trees along ponds to limit takeoff and landing opportunities.

Refer to: http://www.humanesociety.org/assets/pdfs/wild_neighbors/canada_goose_guide.pdf and https://wdfw.wa.gov/species-habitats/species/branta-canadensis for additional information.

Appendix 8-A: Urban Land Uses and Pollutant Generating Sources

Use this appendix to identify pollutant-generating sources at various land uses (manufacturing, transportation, communication, wholesale, retail, and service - based on the *North American Industry Classification System* (NAICS) (USCB, 2017)). Public agency activities that do not have a NAICS code are also summarized at the end of this appendix. Applicable operational source control, structural source control, and runoff treatment BMPs for each pollutant source can then be selected by referring to Chapter 8 - Source Control. Other land uses not included in this appendix should also consider implementing applicable BMPs for their pollutant sources. Note that potentially polluting operations may not be limited to those examples identified with NAICS codes.

1. Manufacturing Businesses

Cement

NAICS 3273XX: *Cement and Concrete Product Manufacturing*

Description: These businesses primarily produce Portland cement, the binder used in concrete for paving, buildings, pipe, and other structural products. The three basic steps in cement manufacturing are: 1) proportioning, grinding, and blending raw materials; 2) heating raw materials to produce a hard, stony substance known as clinker; and 3) combining the clinker with other materials and grinding the mixture into a fine powdery form. The raw materials include limestone, silica, alumina, iron, chalk, oyster shell marl, or shale. Waste materials from other industries are often used, such as slag, fly ash, and spent blasting sand. Raw materials are crushed, mixed, and heated in a kiln to produce the correct chemical composition. Kilns typically are coal, gas, or oil fired. The output of the kiln is a clinker that is ground to produce the final product.

The basic process may be wet or dry. In the wet process, water is mixed with the raw ingredients in the initial crushing operation and in some cases is used to wash the material prior to use. Water may also be used in the air pollution control scrubber. The most significant waste material from cement production is the kiln dust. Concrete products may also be produced at ready-mix concrete facilities. Refer to Concrete Products for a description of the BMPs appropriate for these activities.

Potential Pollutant Generating Sources: Stormwater contamination may occur during the crushing, grinding, storage, and handling of kiln dust, limestone, shale, clay, coal, clinker, gypsum, anhydrite, slag, sand, and product and at the vehicle and equipment maintenance, fueling, and cleaning areas. Total suspended solids (TSS), aluminum, iron, and other heavy metals, chemical oxygen demand (COD), pH, potassium, sulfate, and oil and grease are some of the potential pollutants.

Chemical Manufacturing

NAICS 325XXX: *Chemical Manufacturing*

Description: This group is engaged in the manufacture of chemicals, or products based on chemicals such as acids, alkalis, inks, chlorine, industrial gases, pigments, chemicals used in the production of synthetic resins, fibers and plastics, synthetic rubber, soaps and cleaners, pharmaceuticals, cosmetics, paints, varnishes, resins, photographic materials, chemicals, organic chemicals, agricultural chemicals, adhesives, and sealants.

Potential Pollutant Generating Sources: Activities that can contaminate stormwater include bagging, blending, packaging, crushing, milling, shredding, granulation, grinding, storage, distribution, loading/unloading, and processing of materials; equipment storage; application of fertilizers; foundries; lime application; use of machinery; material handling and warehousing; cooling towers; fueling; boilers; hazardous waste treatment, storage and disposal; wastewater treatment; areas of past industrial activity; access roads and tracks; drum washing; and maintenance and repair.

Chemical businesses in the Seattle area surveyed for dangerous wastes were found to produce waste caustic solutions, soaps, heavy metal solutions, inorganic and organic chemicals, solvents, acids, alkalis, paints, varnishes, pharmaceuticals, and inks. The potential pollutants include biochemical oxygen demand (BOD), COD, oil and grease, pH, total phosphorus, ammonia, nitrates, nitrites, total Kjeldahl nitrogen (TKN), TSS, specific organics, and heavy metals.

Concrete Products

NAICS 3273XX: *Cement and Concrete Product Manufacturing*

NAICS 3274XX: *Lime and Gypsum Product Manufacturing*

Description: Businesses that manufacture ready-mix concrete, gypsum products, concrete blocks and bricks, concrete sewer or drainage pipe, septic tanks, and prestressed concrete building components. Concrete is prepared on-site and poured into molds or forms to produce the desired product. The basic ingredients of concrete are sand, gravel, Portland cement, crushed stone, clay, and reinforcing steel for some products. Admixtures including fly ash, calcium chloride, triethanolamine, lignosulfonic acid, sulfonated hydrocarbon, fatty acid glyceride, or vinyl acetate, may be added to obtain desired characteristics such as slower or more rapid curing times.

The first stage in the manufacturing process is proportioning cement, aggregate, admixtures and water, and then transporting the product to a rotary drum, or pan mixer. The mixture is then fed into an automatic block-molding machine that rams, presses, or vibrates the mixture into its final form. The final product is then stacked on iron framework cars where it cures in four hours. After being mixed in a central mixer, concrete is molded in the same manner as concrete block. The concrete cures in the forms for a number of hours. Forms are washed for reuse, and the concrete products are stored until they can be shipped.

Potential Pollutant Generating Sources: Pollutant generating activities/sources include stockpiles of raw materials; washing of waste concrete from trucks, forms, equipment, and the general work area; and water from the curing of concrete products. Besides the basic ingredients for making concrete products, chemicals used in the curing of concrete and the removal of forms may end up in stormwater. These chemicals can include latex sealants, bitumastic coatings, and release agents. Trucks and equipment maintained on-site may generate waste oil and solvents, and other waste materials. Potential pollutants include COD, BOD, TSS, total dissolved solids (TDS), pH, iron, lead, zinc, and oil and grease.

Electrical Products

NAICS 33324x: *Industrial Machinery Manufacturing*

NAICS 33331x: *Commercial and Service Industry Machinery Manufacturing*

NAICS 33341x: *Ventilation, Heating, Air Conditioning, and Commercial Refrigeration Equipment Manufacturing*

NAICS 3339xx: *Other General Purpose Machinery Manufacturing*

NAICS 334xxx: *Computer and Electronic Product Manufacturing*

NAICS 335xxx: *Electrical Equipment, Appliance, And component Manufacturing*

NAICS 336xxx: *Transportation Equipment Manufacturing*

NAICS 339xxx: *Miscellaneous Manufacturing*

Description: A variety of products are produced including electrical transformers and switchgear, motors, generators, relays, and industrial controls; communications equipment for radio and TV stations and systems; electronic components and accessories including semiconductors; printed board circuits; electromedical and electrotherapeutic apparatus; and electrical instrumentation. Manufacturing processes include electroplating, machining, fabricating, etching, sawing, grinding, welding, and parts cleaning. Materials used include metals, ceramics, quartz, silicon, inorganic oxides, acids, alkaline solutions, arsenides, phosphides, cyanides, oils, fuels, solvents, and other chemicals.

Potential Pollutant Generating Sources: Most of the actual manufacturing and processing activity at the types of facilities discussed here normally occur indoors and will not be exposed to stormwater. The types of activities where exposure to stormwater may occur consist primarily of loading and unloading activities, and the storage and handling of raw materials, by-products, final products, or waste products. A wide variety of materials are used at these facilities, including metals, acids used for chemical etching, alkaline solutions, solvents, various oils and fuels, and miscellaneous chemicals. Tanks or drums of these materials may be exposed to stormwater during loading/ and un-loading operations, or through outdoor storage or handling.

Liquid wastes which may be exposed at least temporarily include spent solvents and acids, miscellaneous chemicals, and oily wastes. These wastes may be contaminated with a variety of heavy metals and chlorinated hydrocarbons. Used equipment, scrap metal and wire, soiled rags, and sanding materials may also be exposed to stormwater and constitute a potential source of pollutants. In addition, some facilities may have dumpsters containing nonhazardous wastes or manufacturing debris that may be exposed to stormwater.

Wastewater consists of solutions and rinses from electroplating operations and the wastewaters from cleaning operations. Water may also be used to cool saws and grinding machines. Sludges are produced by the wastewater treatment process. Potential pollutants include BOD, COD, oil & grease, organics, pH, TSS, TKN, nitrate and nitrite nitrogen, copper, lead, silver, and zinc.

Food and Kindred Products

NAICS 115114: *Postharvest Crop Activities (except Cotton Ginning)*

NAICS 311xxx: *Food Manufacturing*

NAICS 312xxx: *Beverage and Tobacco Product Manufacturing*

Description: Businesses in this category include facilities manufacturing or processing foods, beverages, and related products for human consumption, and prepared feeds for animals and fowls. Facilities engaged in manufacturing cigarettes, cigars, and other tobacco products are also included. Food processing typically occurs inside buildings. Exceptions are meat packing plants where live animals may be kept outside, and fruit and vegetable plants where the raw material may be temporarily stored outside. Meat production facilities include stockyards, slaughtering, cutting and deboning, meat processing, rendering, and materials recovery. Dairy production facilities include receiving stations, clarification, separation, and pasteurization followed by culturing, churning, pressing, curing, blending, condensing, sweetening, drying, milling, and packaging. Canned frozen and preserved fruits and vegetables are typically produced by washing, cutting, blanching, and cooking followed by drying, dehydrating, and freezing.

Grain mill products are processed during washing, milling, debranning, heat treatment, screening, shaping, and vitamin and mineral supplementing. Bakery products processing includes dough mixing and shaping, cooling, and decorating. Operations at an edible oil manufacturer include refining, bleaching, hydrogenation, fractionation, emulsification, deodorization, filtration, and blending. Beverage production includes brewing, distilling, fermentation, blending, and packaging. Wine processors often crush grapes outside the process building and/or store equipment outside when not in use. Some wine producers use juice from grapes crushed elsewhere. Some vegetable and fruit processing plants use caustic solutions.

Potential Pollutant Generating Sources: The nature of the business, and the required sanitary conditions, require that raw and processed materials be protected from stormwater. As such, the contamination of stormwater from these activities is primarily from the loading and unloading of products and raw materials; spillage and leaks from tanks and containers stored outdoors; waste management practices; pest control; and improper connections to the storm sewer. The following are the pollutants typically expected from this industry segment: BOD, fecal coliform bacteria, oil & grease, pH, TKN, TSS, copper, manganese, and pesticides.

Glass Products

NAICS 32721x: *Glass and Glass Product Manufacturing*

Description: The produced glass form may be flat or window glass, safety glass, container glass, tubing, glass wool, or fibers. The raw materials are sand mixed with a variety of oxides such as aluminum, antimony, arsenic, copper, cobalt oxide, barium, and lead. The raw materials are mixed and heated in a furnace. Processes that vary with the intended product shape the resulting molten material. The cooled glass may be edged, ground, polished, annealed and/or heat-treated to produce the final product. Air emissions from the manufacturing buildings are scrubbed to remove particulates.

Potential Pollutant Generating Sources: Raw materials are generally stored in silos, except for crushed recycled glass and materials washed off recycled glass. Contamination of stormwater and/or groundwater can be caused by raw materials lost during unloading operations, errant flue dust, equipment/vehicle maintenance, and engine fluids from mobile lifting equipment that is stored outside. The maintenance of the manufacturing equipment will produce waste lubricants and cleaning solvents. The flue dust is likely to contain heavy metals such as arsenic, cadmium, chromium, mercury, and lead. Potential pollutants include suspended solids, oil & grease, high/low pH, and heavy metals such as arsenic, cadmium, chromium, mercury, and lead.

Industrial Machinery & Equipment, Trucks & Trailers, Aircraft, Aerospace, and Railroad

NAICS 333xxx: *Machinery Manufacturing*

NAICS 336xxx: *Transportation Equipment Manufacturing*

Description: This category includes the manufacture of a variety of equipment including engines and turbines, farm and garden equipment, construction and mining machinery, metal working machinery, pumps, computers and office equipment, automatic vending machines, refrigeration and heating equipment, and equipment for the manufacturing industries. This group also includes many small machine shops, and the manufacturing of trucks, trailers and parts, airplanes and parts, missiles, spacecraft, and railroad equipment and instruments.

Manufacturing processes include various forms of metal working and finishing, such as electro-plating, anodizing, chemical conversion coating, etching, chemical milling, cleaning, machining, grinding, polishing, sand blasting, laminating, hot dip coating, descaling, degreasing, paint stripping, painting, and the production of plastic and fiberglass parts. Raw materials include ferrous and non-ferrous metals, such as aluminum, copper, iron, steel, and their alloys, paints, solvents, acids, alkalis, fuels, lubricating and cutting oils, and plastics.

Potential Pollutant Generating Sources: Potential pollutant sources include spills and leaks from fueling, maintenance shops, loading/unloading of materials, and outside storage of gasoline, diesel, cleaning fluids, equipment, solvents, paints, wastes, detergents, acids, other chemicals, oils, metals, and scrap materials. Air emissions from stacks and ventilation systems are potential areas for exposure of materials to rainwater.

Metal Products

NAICS 331xxx: *Primary Metal Manufacturing*

NAICS 332xxx: *Fabricated Metal Product Manufacturing*

NAICS 337124: *Metal Household Furniture Manufacturing*

NAICS 337214: *Office Furniture (except Wood) Manufacturing*

NAICS 339xxx: *Miscellaneous Manufacturing*

Description: This group includes mills that produce basic metals and primary products, as well as foundries, electroplaters, and fabricators of final metal products. Basic metal production includes aluminum, copper, and steel. Mills that transform metal billets, either ferrous or nonferrous such as aluminum, to primary metal products are included. Primary metal forms include sheets, flat bar, building components such as columns, beams and concrete reinforcing bar, and large pipe.

Steel mills in the Pacific Northwest use recycled metal and electric furnaces. The molten steel is cast into billets or ingots that may be reformed on site or taken to rolling mills that produce primary products. As iron and steel billets may sit outside before reforming, surface treatment to remove scale may occur prior to reforming. Foundries pour or inject molten metal into a mold to produce a shape that cannot be readily formed by other processes. The metal is first melted in a furnace. The mold is made of sand or metal die blocks that are locked together to make a complete cavity. The molten metal is ladled in and the mold is cooled. The rough product is finished by quenching, cleaning, and chemical treatment. Quenching involves immersion in a plain water bath or water with an additive.

Businesses that fabricate metal products from metal stock provide a wide range of products. The raw stock is manipulated in a variety of ways including machining of various types, grinding, heating, shearing, deformation, cutting and welding, soldering, sand blasting, brazing, and laminating. Fabricators may first clean the metal by sand blasting, descaling, or solvent degreasing. Final finishing may involve electroplating, painting, or direct plating by fusing or vacuum metalizing. Raw materials, in particular recycled metal, are stored outside prior to use, as are billets before reforming. The descaling process may use salt baths, sodium hydroxide, or acid (pickling).

Primary products often receive a surface coating treatment. Prior to the coating the product surface may be prepared by acid pickling to remove scale, or by alkaline cleaning to remove oils and greases. The two major classes of metallic coating operations are hot and cold coating. Aluminum, tin, and zinc coatings are applied in molten metal baths. Chromium and tin are usually applied electrolytically from plating solutions.

Potential Pollutant Generating Sources: Potential pollutant generating sources include outside storage of chemicals, metal feedstock, byproducts (fluxes), finished products, fuels, lubricants, waste oil, sludge, waste solvents, dangerous wastes, piles of coal, coke, dusts, fly ash, baghouse waste, slag, dross, sludges, sand refractory rubble, and machining waste; unloading of chemical feedstock and loading of waste liquids such as spent pickle liquor by truck or rail; material handling equipment such as cranes, conveyors, trucks, and forklifts; particulate emissions from scrubbers, baghouses or electrostatic precipitators; fugitive emissions; maintenance shops; erosion of soil from plant yards; and floor, sink, and process wastewater drains.

Paper, Pulp, and Paperboard Mills

NAICS 3221xx: *Pulp, Paper, and Paperboard Mills*

Description: Large industrial complexes in which pulp and/or paper, and/or paperboard are produced. Products also include newsprint, bleached paper, glassine, tissue paper, vegetable parchment, and industrial papers. Raw materials include wood logs, chips, waste paper, jute, hemp, rags, cotton linters, bagasse, and esparto. The chips for pulping may be produced on-site from logs, and/or imported.

The following manufacturing processes are typically used: raw material preparation, pulping, bleaching, and papermaking. All of these operations use a wide variety of chemicals including caustic soda, sodium and ammonium sulfites, chlorine, titanium oxide, starches, solvents, adhesives, biocides, hydraulic oils, lubricants, dyes, and many chemical additives.

Potential Pollutant Generating Sources: The large process equipment used for pulping is not enclosed. Thus, precipitation falling over these areas may become contaminated. Maintenance of the process equipment produces waste products similar to that produced from vehicle and mobile equipment maintenance. Logs may be stored, debarked, and chipped on site. Large quantities of chips are stored outside. Although this can be a source of pollution, the volume of stormwater flow is relatively small because the chip pile retains the majority of the precipitation. Mobile equipment such as forklifts, log stackers, and chip dozers are sources of leaks/spills of hydraulic fluids. Vehicles and equipment are fueled and maintained on-site.

Paper Products

NAICS 3222xx: *Converted Paper Product Manufacturing*

Description: Included are businesses that take paper stock and produce basic paper products such as cardboard boxes and other containers, and stationery products such as envelopes and bond paper. Wood chips, pulp, and paper can be used as feedstock.

Potential Pollutant Generating Sources: Potential pollutant generating sources include outside loading and unloading of solid and/or liquid materials; outside storage and handling of dangerous wastes, liquid, and/or solid materials; maintenance and fueling activities for forklifts and other vehicles and equipment; and outside processing activities related to paper production.

Petroleum Products

NAICS 3241xx: *Petroleum and Coal Products Manufacturing*

Description: The petroleum refining industry manufactures gasoline, kerosene, distillate and residual oils, lubricants, and related products from crude petroleum, and asphalt paving and roofing materials. Although petroleum is the primary raw material, petroleum refineries also use other materials such as natural gas, benzene, toluene, chemical catalysts, caustic soda, and sulfuric acid. Wastes may include filter clays, spent catalysts, sludges, and oily water.

Asphalt paving products consist of sand, gravel, and petroleum-based asphalt that serves as the binder. Raw materials include stockpiles of sand and gravel and asphalt emulsions stored in aboveground tanks.

Potential Pollutant Generating Sources: Potential pollutant generating sources include outside processing such as distillation, fractionation, catalytic cracking, solvent extraction, coking, desulfuring, reforming, and desalting; petrochemical and fuel storage and handling; outside liquid chemical piping and tankage; mobile liquid handling equipment such, as tank trucks, forklifts, etc.; maintenance and parking of trucks and other equipment; waste piles, and handling and storage of asphalt emulsions, cleaning chemicals, and solvents; and waste treatment and conveyance systems.

The following are potential pollutants at oil refineries: oil & grease, BOD, COD, total organic carbon (TOC), phenolic compounds, polycyclic aromatic hydrocarbons (PAHs), ammonia nitrogen, TKN, sulfides, TSS, low and high pH, and chromium (total and hexavalent).

Printing

NAICS 323xxx: *Printing and Related Support Activities*

Description: This industrial category includes the production of newspapers, periodicals, commercial printing materials, and businesses that do their own printing and those that perform services for the printing industry, for example bookbinding. Processes include typesetting, engraving, photoengraving, and electrotyping.

Potential Pollutant Generating Sources: Various materials used in modifying the paper stock include inorganic and organic acids, resins, solvents, polyester film, developers, alcohol, vinyl lacquer, dyes, acetates, and polymers. Waste products may include waste inks, ink sludge, resins, photographic chemicals, solvents, acid and alkaline solutions, chlorides, chromium, lead, silver, zinc, spent formaldehyde, plasticizers, and used lubricating oils. As the printing operations occur indoors, the only likely points of potential contact with stormwater are the outside temporary storage of waste materials, offloading of chemicals at external unloading bays, and vehicle/equipment repair and maintenance. Pollutants of concern include COD, heavy metals, oil & grease, pH, and TSS.

Rubber and Plastic Products

NAICS 3252xx: *Resin, Synthetic Rubber, and Artificial and Synthetic Fibers and Filaments Manufacturing*

NAICS 326xxx: *Plastics and Rubber Products Manufacturing*

Description: Products in this category include rubber tires, hoses, belts, gaskets, seals, plastic sheet, film, tubes, pipes, bottles, cups, ice chests, packaging materials, and plumbing fixtures. The rubber and plastics industries use a variety of processes ranging from polymerization to extrusion using natural or synthetic raw materials. These industries use natural or synthetic rubber, plastics components, pigments, adhesives, resins, acids, caustic soda, zinc, paints, fillers, and curing agents.

Potential Pollutant Generating Sources: Pollutant generating sources/activities include storage of liquids, other raw materials or by-products, scrap materials, oils, solvents, inks and paints; unloading of liquid materials from trucks or rail cars; washing of equipment; waste oil and solvents produced by cleaning manufacturing equipment; used equipment that could drip oil and residual process materials; and maintenance shops.

Potential pollutants are BOD, COD, nitrate and nitrite nitrogen, TKN, total phosphorus, TSS, pH, trichloroethane, methylene chloride, toluene, zinc, and oil & grease.

Ship and Boat Building and Repair Yards

NAICS 3366xx: *Ship and Boat Building*

Description: Businesses that build or repair ships and boats. Typical activities include hull scraping, sandblasting, finishing, metal fabrication, electrical repairs, engine overhaul, welding, fiberglass repairs, hydroblasting, and steam cleaning.

Potential Pollutant Generating Sources: Outside boatyard activities that can be sources of stormwater pollution include pressure washing, surface preparation, paint removal, sanding, painting, engine/vessel maintenance and repairs, and material handling and storage.

Secondary sources of stormwater contaminants are cooling water, pump testing, gray water, sanitary waste, washing down the work area, and engine bilge water. Engine room bilge water and oily wastes are typically collected and disposed of through a licensed contracted disposal company. Two primary sources of copper are leaching of copper from anti-fouling paint and wastes from hull maintenance. Wastes generated by boatyard activities include spent abrasive grits, spent solvent, spent oils, fuel, ethylene glycol, washwater, paint overspray, various cleaners/detergents and anti-corrosive compounds, paint chips, scrap metal, welding rods, wood, plastic, resins, glass fibers, dust, and miscellaneous trash such as paper and glass.

Ecology, local shipyards, and METRO have sampled pressure-wash wastewater. The effluent quality has been variable and frequently exceeded water quality criteria for copper, lead, tin, and zinc. From monitoring results received to date, metal concentrations typically range from 5 to 10 mg/L, but have gone as high as 190 mg/L copper with an average 55 mg/L copper.

Wood

NAICS 321xxx (except 321114): *Wood Product Manufacturing (except Wood Preservation)*

Description: This group includes sawmills, and all businesses that make wood products using cut wood, with the exception of wood treatment businesses. Wood treatment as well as log storage and sorting yards are covered in other sections of this appendix. Included in this group are planing mills, millworks, and businesses that make wooden containers and prefab building components, mobile homes, and glued-wood products such as laminated beams, office and home furniture, partitions, and cabinets. All businesses employ cutting equipment whose by-products are chips and sawdust. Finishing is conducted in many operations.

Potential Pollutant Generating Sources: Businesses may have operations that use paints, solvents, wax emulsions, melamine formaldehyde, and other thermosetting resins, and produce waste paints, paint thinners, turpentine, shellac, varnishes and other waste liquids. Outside storage, trucking, and handling of these materials can also be pollutant sources.

Potential pollutants are BOD, COD, nitrate and nitrite nitrogen, TKN, total phosphorus, TSS, arsenic, copper, total phenols, oil & grease, and pH.

Wood Treatment

NAICS 321114: *Wood Preservation*

Description: This group includes both anti-staining and wood preserving. Some wood trimming may occur. After treatment, the lumber is typically stored outside. Forklifts are used to move both the raw and finished product. Wood treatment consists of a pressure process using the chemicals described below. Anti-staining treatment is conducted using dip tanks or by spraying. Wood preservatives may include creosote, creosote/coal tar, pentachlorophenol, copper naphthenate or inorganic arsenicals such as chromated copper arsenate dissolved in water. The use of pentachlorophenol is declining in the Puget Sound region.

Potential Pollutant Generating Sources: Potential pollutant generating sources/activities include the retort area, handling of the treated wood, outside storage of treated materials and products, equipment/vehicle storage and maintenance, and the unloading, handling, and use of the preservative chemicals. Based on (USEPA, 1995) the following stormwater contaminants have been reported: BOD, COD, TSS, and the specific pesticide(s) used for the wood preservation.

Other Manufacturing Businesses

NAICS 313xxx: *Textile Mills*

NAICS 314xxx: *Textile Product Mills*

NAICS 315xxx: *Apparel Manufacturing*

NAICS 316xxx: *Leather and Allied Product Manufacturing*

NAICS 3253xx: *Pesticide, Fertilizer, and Other Agricultural Chemical Manufacturing*

NAICS 327xxx: *Nonmetallic Mineral Product Manufacturing*

Description: Includes manufacturing of textiles and apparel, agricultural fertilizers, leather products, clay products such as bricks, pottery, bathroom fixtures; and nonmetallic mineral products.

Potential Pollutant Generating Sources: Pollutant generating sources at facilities in these categories include fueling, loading & unloading, material storage and handling (especially fertilizers), and vehicle and equipment cleaning and maintenance. Potential pollutants include BOD, COD, oil & grease, TSS, heavy metals and fertilizer components including nitrates, nitrites, ammonia nitrogen, TKN, and phosphorus compounds.

2. Transportation and Communication

Airfields and Aircraft Maintenance

NAICS 481xxx: *Air Transportation*

NAICS 4881xx: *Support Activities for Air Transportation*

Description: Industrial activities include vehicle and equipment fueling, maintenance and cleaning, and aircraft/runway deicing.

Potential Pollutant Generating Sources: Fueling is accomplished by tank trucks at the aircraft and is a source of spills. Dripping of fuel and engine fluids from the aircraft and at vehicle and equipment maintenance/cleaning areas, and application of deicing materials to the aircraft and the runways are potential sources of stormwater contamination. Aircraft maintenance and cleaning produces a wide variety of waste products, similar to those found with any vehicle or equipment maintenance, including: used oil and cleaning solvents, paints, oil filters, soiled rags, and soapy wastewater. Deicing chemicals used on aircraft and/or runways include ethylene and propylene glycol, and urea. Other chemicals currently considered for ice control are sodium and potassium acetates, isopropyl alcohol, and sodium fluoride. Pollutant constituents include BOD, COD, oil & grease, pH, TSS, TKN, and specific deicing components such as glycol and urea.

Fleet Vehicle Yards

NAICS 484xxx: *Truck Transportation*

NAICS 485xxx: *Transit and Ground Passenger Transportation*

NAICS 4871xx: *Scenic and Sightseeing Transportation, Land*

NAICS 4884xx: *Support Activities for Road Transportation*

NAICS 492xxx: *Couriers and Messengers*

NAICS 5321xx: *Automotive Equipment Rental and Leasing*

NAICS 621910: *Ambulance Services*

Description: Includes all businesses that own, operate, and maintain or repair large vehicle fleets, including cars, buses, trucks and taxis, as well as the renting or leasing of cars, trucks, and trailers.

Potential Pollutant Generating Sources: Potential pollutant generating sources include spills/leaks of fuels, used oils, oil filters, antifreeze, solvents, brake fluid, and batteries, sulfuric acid, battery acid sludge, and leaching from empty contaminated containers and soiled rags; leaking underground storage tanks that can cause groundwater and/or soil contamination; dirt, oils, and greases from outside steam cleaning and vehicle washing; dripping of liquids from parked vehicles; solid and liquid wastes that are not properly stored outside; and loading and unloading areas.

Potential pollutants from this section may include BOD, heavy metals, oil & grease, TSS, organics, and pH.

Railroads

NAICS 482xxx: *Rail Transportation*

NAICS 4882xx: *Support Activities for Rail Transportation*

Description: Railroad activities are spread over a large geographic area: along railroad lines, in switching yards, and in maintenance yards. Railroad activity occurs on both property owned or leased by the railroad and at the loading or unloading facilities of its customers. Using BMPs at commercial or public loading and unloading areas is the responsibility of the particular property owner.

Potential Pollutant Generating Sources: The following are potential sources of pollutants: dripping of vehicle fluids onto the road bed, leaching of wood preservatives from the railroad ties, human waste disposal, litter, locomotive sanding areas, locomotive/railcar/equipment cleaning areas, fueling areas, outside material storage areas, the erosion and loss of soil particles from the bed, and herbicides used for vegetation management.

Maintenance activities include maintenance shops for vehicles and equipment, track maintenance, and ditch cleaning. In addition to the railroad stock, the maintenance shops service highway vehicles and other types of equipment. Waste materials can include waste oil, solvents, degreasers, antifreeze, radiator flush, acid solutions, brake fluids, soiled rags, oil filters, sulfuric acid and battery sludge, and machine chips with residual machining oil and any toxic fluids or solids lost during transit. The following are potential pollutants at rail yards: BOD, heavy metals, oil & grease, TSS, organics, and pesticides.

Warehouses and Mini-Warehouses

NAICS 493xxx: *Warehousing and Storage*

Description: Businesses that store goods in buildings and other structures.

Potential Pollutant Generating Sources: The following are potential pollutant sources from warehousing operations: Loading and unloading areas, outside storage of materials and equipment, and fueling and maintenance areas. Potential pollutants include oil & grease and TSS.

Other Transportation and Communication

NAICS 2211xx: *Electric Power Generation, Transmission, and Distribution*

NAICS 515xxx: *Broadcasting (except Internet)*

NAICS 517xxx: *Telecommunications*

NAICS 518xxx: *Data Processing, Hosting, and Related Services*

NAICS 519xxx: *Other Information Services*

NAICS 5615xx: *Travel Arrangement and Reservation Services*

Description: This group includes travel agencies, communication services such as TV and radio stations, cable companies, and electric and gas services. It does not include railroads, airplane transport services, airlines, pipeline companies, and airfields.

Potential Pollutant Generating Sources: Gas and electric services are likely to own vehicles that are washed, fueled and maintained on site. Communication service companies can generate used oils and dangerous wastes. The following are the potential pollutants: BOD, heavy metals, oil & grease, and TSS.

3. Retail and Wholesale Businesses

Gas Stations

NAICS 447xxx: *Gasoline Stations*

Refer to S409 BMPs for Fueling At Dedicated Stations to select applicable BMPs.

Recyclers and Scrap Yards

NAICS 423140: *Motor Vehicle Parts (Used) Merchant Wholesalers*

NAICS 423930: *Recyclable Material Merchant Wholesalers*

Refer to S423 BMPs for Recyclers and Scrap Yards.

Commercial Composting

NAICS 325314: *Fertilizer (Mixing Only) Manufacturing*

Description: This typically applies to businesses that have numerous compost piles that require large open areas to break down the wastes. Composting can contribute nutrients, organics, fecal coliform bacteria, low pH, color, and suspended solids to stormwater runoff.

Potential Pollutant Generating Sources: The compost must be contained, but may be a cause for concern during loading and unloading. Compost can have high levels of nutrients, organics, coliform bacteria, low pH, color concerns and suspended solids. Composting requires heavy equipment such as trucks and loaders. The equipment can generate oil & grease.

Restaurants/Fast Food

NAICS 711110: *Theater Companies and Dinner Theaters*

NAICS 722xxx: *Food Services and Drinking Places*

Description: Businesses that provide food service to the general public, including drive through facilities.

Potential Pollutant Generating Sources: Potential pollutant sources include high-use customer parking lots, outdoor used grease storage, and garbage dumpsters. The cleaning of roofs and other outside areas of restaurant and cooking vent filters in the parking lot can cause cooking grease to be discharged to the storm drains. The discharge of washwater or grease to storm drains or surface water is not allowed.

Retail/General Merchandise

NAICS 442xxx: *Furniture and Home Furnishings Stores*

NAICS 443xxx: *Electronics and Appliance Stores*

NAICS 444xxx: *Building Material and Garden Equipment And Supplies Dealers*

NAICS 445xxx: *Food and Beverage Stores*

NAICS 446xxx: *Health and Personal Care Stores*

NAICS 447xxx: *Gasoline Stations*

NAICS 448xxx: *Clothing and Clothing Accessories Stores*

NAICS 451xxx: *Sporting Goods, Hobby, Musical Instrument, and Book Stores*

NAICS 452xxx: *General Merchandise Stores*

NAICS 453xxx: *Miscellaneous Store Retailers*

NAICS 454xxx: *Nonstore Retailers*

Description: This group includes general merchandising stores such as department stores, shopping malls, variety stores, 24-hour convenience stores, and general retail stores that focus on a few product types such as clothing and shoes. It also includes furniture and appliance stores.

Potential Pollutant Generating Sources: Of particular concern are the high-use parking lots of shopping malls and 24-hour convenience stores. Furniture and appliance stores may provide repair services in which dangerous wastes may be produced.

Retail/Wholesale Vehicle and Equipment Dealers

NAICS 423110: *Automobile and Other Motor Vehicle Merchant Wholesalers*

NAICS 4238xx: *Machinery, Equipment, and Supplies Merchant Wholesalers*

NAICS 441xxx: *Motor Vehicle and Parts Dealers*

NAICS 453930: *Manufactured (Mobile) Home Dealers*

NAICS 5321xx: *Automotive Equipment Rental and Leasing*

NAICS 5324xx: *Commercial & Industrial Machinery & Equipment Rental & Leasing*

Description: This group includes all retail and wholesale businesses that sell, rent, or lease cars, trucks, boats, trailers, mobile homes, motorcycles, and recreational vehicles. It includes both new and used vehicle dealers. It also includes sellers of heavy equipment for construction, farming, and industry. These businesses generally have large parking lots. Most retail dealers that sell new vehicles and large equipment also provide repair and maintenance services.

Potential Pollutant Generating Sources: Oil and other materials that have dripped from parked vehicles can contaminate stormwater at high-use parking areas. Vehicles are washed regularly, generating vehicle grime and detergent pollutants. The stormwater or washwater runoff will contain oils and various organics, metals, and phosphorus. Repair and maintenance services generate a variety of waste liquids and solids including used oils and engine fluids, solvents, waste paint, soiled rags, and dirty used engine parts. Many of these materials are dangerous wastes.

Retail/Wholesale Nurseries and Building Materials

NAICS 4233xx: *Lumber and Other Construction Materials Merchant Wholesalers*

NAICS 4237xx: *Hardware and Plumbing and Heating Equipment and Supplies Merchant Wholesalers*

NAICS 4238xx: *Machinery, Equipment, and Supplies Merchant Wholesalers*

NAICS 424930: *Flower, Nursery Stock, & Florists' Supplies Merchant Wholesalers*

NAICS 444xxx: *Building Equipment and Garden Equipment and Supplies Dealers*

Description: These businesses are in a separate group because they are likely to store much of their merchandise outside of the main building. They include nurseries, and businesses that sell building and construction materials and equipment, paint, and hardware.

Potential Pollutant Generating Sources: Some businesses may have small fueling capabilities for forklifts and may also maintain and repair their vehicles and equipment. Some businesses may have unpaved areas, with the potential to contaminate stormwater by leaching of nutrients, pesticides, and herbicides. Businesses in this group surveyed in the Puget Sound area for dangerous wastes were found to produce waste solvents, paints, and used oil. Stormwater runoff from exposed storage areas can contain suspended solids, and oil & grease from vehicles, forklifts, and high-use customer parking lots, and other pollutants. Runoff from nurseries may contain nutrients, pesticides, and/or herbicides.

Retail/Wholesale Chemicals and Petroleum

NAICS 4246xx: *Chemical and Allied Products Merchant Wholesalers*

NAICS 4247xx: *Petroleum and Petroleum Products Merchant Wholesalers*

NAICS 447xxx: *Gasoline Stations*

NAICS 454310: *Fuel Dealers*

Description: These businesses sell plastic materials, chemicals and related products. This group also includes the bulk storage and selling of petroleum products such as diesel oil, automotive fuels, etc.

Potential Pollutant Generating Sources: The general areas of concern are the spillage of chemicals or petroleum during loading and unloading, and the washing and maintenance of tanker trucks and other vehicles. Also, the fire code requires that vegetation be controlled within a tank farm to avoid a fire hazard. Herbicides are typically used. The concentration of oil in untreated stormwater has been known to exceed the water quality effluent guideline for oil and grease. Runoff is also likely to contain significant concentrations of benzene, chloroform, phenol, lead, and zinc.

Retail/Wholesale Foods and Beverages

NAICS 4244xx: *Grocery and Related Product Merchant Wholesalers*

NAICS 4248xx: *Beer, Wine, & Distilled Alcoholic Beverage Merchant Wholesalers*

NAICS 445xxx: *Food and Beverage Stores*

NAICS 447110: *Gasoline Stations with Convenience Stores*

NAICS 4523xx: *General Merchandise Stores, including Warehouse Clubs and Supercenters*

NAICS 4542xx: *Vending Machine Operators*

NAICS 454390: *Other Direct Selling Establishments*

Description: Included are businesses that provide retail food including general groceries, fish and seafood, meats and meat products, dairy products, poultry, soft drinks, and alcoholic beverages.

Potential Pollutant Generating Sources: Vehicles may be fueled, washed and maintained at the business. Spillage of food and beverages may occur. Waste food and broken contaminated glass may be temporarily stored in containers located outside. High-use customer parking lots may be sources of oil and other contaminants.

Other Retail/Wholesale Businesses

NAICS 423xxx: *Merchant Wholesalers, Durable Goods*

NAICS 424xxx: *Merchant Wholesalers, Nondurable Goods*

NAICS 425xxx: *Wholesale Electronic Markets and Agents and Brokers*

NAICS 441xxx: *Motor Vehicle and Parts Dealers*

NAICS 442xxx: *Furniture and Home Furnishing Stores*

NAICS 443xxx: *Electronic and Appliance Stores*

NAICS 444xxx: *Building Material and Garden Equipment and Supplies Dealers*

NAICS 446xxx: *Health and Personal Care Stores*

NAICS 448xxx: *Clothing and Clothing Accessories Stores*

NAICS 451xxx: *Sporting Goods, Hobby, Musical Instrument, and Book Stores*

NAICS 452xxx: *General Merchandise Stores*

NAICS 453xxx: *Miscellaneous Store Retailers*

Description: Businesses in this group include sellers of vehicle parts, tires, farm supplies, hand and garden tools, furniture and home furnishings, photographic and office equipment, electrical goods, sporting goods and toys, paper products, drugs, and apparel.

Potential Pollutant Generating Sources: Pollutant sources include loading/unloading areas, high-use parking lots, and delivery vehicles that may be fueled, washed, and maintained on premises.

4. Service Businesses

Animal Care Services

NAICS 1152xx: *Support Activities for Animal Production*

NAICS 45391x: *Pet and Pet Supplies Stores*

NAICS 54194x: *Veterinary Services*

NAICS 711212: *Racetracks*

NAICS 71329x: *Other Gambling Industries*

NAICS 81291x: *Pet care (except Veterinary) Services*

Description: This group includes racetracks, kennels, fenced pens, veterinary clinics, and businesses that provide boarding services for animals including horses, dogs, and cats.

Potential Pollutant Generating Sources: The primary sources of pollution include animal manure, washwaters, waste products from animal treatment, runoff from pastures where larger livestock are allowed to roam, and vehicle maintenance and repair shops. Pastures may border streams and direct access to the stream may occur. Both surface water and groundwater may be contaminated. Potential stormwater contaminants include BOD, fecal coliform bacteria, nutrients, oil & grease, and TSS.

Commercial Car and Truck Washes

NAICS 48849x: *Other Support Activities for Road Transportation*

NAICS 488999: *All Other support Activities for Transportation*

NAICS 811192: *Car Washes*

Description: Facilities include automatic systems found at individual businesses or at gas stations and 24-hour convenience stores, as well as self-service. There are three main types: tunnels, rollovers, and hand-held wands. The tunnel wash, the largest, is housed in a long building through which the vehicle is pulled. At a rollover wash, the vehicle remains stationary while the equipment passes over. Wands are used at self-serve car washes. Some car washing businesses also sell gasoline.

Potential Pollutant Generating Sources: Wash wastewater may contain detergents and waxes. Wastewater should be discharged to sanitary sewers. In self-service operations a drain is located inside each car bay. Although these businesses discharge the wastewater to the sanitary sewer, some washwater can find its way to the storm drain, particularly with the rollover and wand systems. Rollover systems often do not have air-drying. Consequently, as it leaves the enclosure the car sheds water to the pavement. With the self-service system, washwater with detergents can spray outside the building and drain to the storm sewer. Users of self-serve operations may also clean engines and change oil, dumping the used oil into the storm drain. Potential pollutants include BOD, detergents, oil & grease, soaps, and TSS.

Equipment Repair

NAICS 532xxx: *Rental and Leasing Services*

NAICS 8112xx: *Electronic and Precision Equipment Repair and Maintenance*

NAICS 8113xx: *Commercial and Industrial Machinery and Equipment (except Automotive and Electronic) Repair and Maintenance*

NAICS 8114xx: *Personal and Household Goods Repair and Maintenance*

Description: This group includes several businesses that specialize in repairing different equipment including communications equipment, radios, TVs, household appliances, and refrigeration systems. Also included are businesses that rent or lease heavy construction equipment, because miscellaneous repair and maintenance may occur on site.

Potential Pollutant Generating Sources: Potential pollutant sources include storage and handling of fuels, waste oils and solvents, and loading/unloading areas. Potential pollutants include oil & grease, low/high pH, and TSS.

Laundries and Other Cleaning Services

NAICS 5612xx: *Facilities Support Services*

NAICS 56174x: *Carpet and Upholstery Cleaning Services*

NAICS 8123xx: *Drycleaning and Laundry Services*

Description: This category includes all types of cleaning services such as laundries, linen suppliers, diaper services, coin-operated laundries, dry cleaners, and carpet and upholstery services. Wet washing may involve the use of acids, bleaches, and/or multiple organic solvents. Dry cleaners use an organic-based solvent, although small amounts of water and detergent are sometimes used. Solvents may be recovered and filtered for further use. Carpets and upholstery may be cleaned with dry materials, hot water extraction process, or in-plant processes using solvents followed by a detergent wash.

Potential Pollutant Generating Sources: Wash liquids are discharged to sanitary sewers. Stormwater pollutant sources include: loading and unloading of liquid materials, particularly at large commercial operations, disposal of spent solvents and solvent cans, high-use customer parking lots, and outside storage and handling of solvents and waste materials. Potential stormwater contaminants include chlorinated and other solvents, oil & grease, soaps and detergents, low/high pH, and TSS.

Marinas and Boat Clubs

NAICS 713930: *Marinas*

Description: Marinas and yacht clubs provide moorage for recreational boats. Marinas may also provide fueling and maintenance services. Other activities include cleaning and painting of boat surfaces, minor boat repair, and pumping of bilges and sanitary holding tanks. Not all marinas have a system to receive pumped bilge water.

Potential Pollutant Generating Sources: Both solid and liquid wastes are produced as well as stormwater runoff from high-use customer parking lots. Waste materials include sewage and bilge water. Maintenance by the tenants will produce used oils, oil filters, solvents, waste paints and varnishes, used batteries, and empty contaminated containers and soiled rags. Potential stormwater contaminants include heavy metals, oil & grease, low/high pH, and TSS.

Golf and Country Clubs

NAICS 713910: *Golf Courses and Country Clubs*

Description: Public and private golf courses and parks are included.

Potential Pollutant Generating Sources: Maintenance of grassed areas and landscaped vegetation has historically required the use of fertilizers and pesticides. Golf courses contain small lakes that are sometimes treated with algaecides and/or mosquito larvicides. The fertilizer and pesticide application process can lead to inadvertent contamination of nearby surface waters by overuse, misapplication, or the occurrence of storms shortly after application. Heavy watering of surface greens in golf courses may cause pesticides or fertilizers to migrate to surface and shallow groundwater resources. The use of pesticides and fertilizers generates waste containers. Equipment must be cleaned and maintained.

Miscellaneous Services

NAICS 54192x: *Photographic Services*

NAICS 5617xx: *Services to Buildings and Dwellings*

NAICS 562xxx: *Waste Management and Remediation Services*

NAICS 712xxx: *Museums, Historical Sites, And Similar Institutions*

NAICS 713xxx: *Amusement, Gambling, and Recreation Industries*

NAICS 8122xx: *Death Care Services*

NAICS 8129xx: *Other Personal Services*

Description: This group includes photographic studios, commercial photography, funeral services, amusement parks, furniture and upholstery repair, pest control services, and other professional offices. Pollutants from these activities can include pesticides, waste solvents, heavy metals, pH, suspended solids, soaps and detergents, and oil & grease.

Potential Pollutant Generating Sources: Leaks and spills of materials from the following businesses can be sources of stormwater pollutants:

1. Building maintenance produces wash and rinse solutions, oils, and solvents.
2. Pest control produces rinse water with residual pesticides from washing application equipment and empty containers.
3. Outdoor advertising produces photographic chemicals, inks, waste paints, and organic paint sludges containing metals.
4. Funeral services produce formalin, formaldehyde, and ammonia.
5. Upholstery and furniture repair businesses produce oil, stripping compounds, wood preservatives and solvents.

Professional Services

NAICS 52xxxx: *Finance and Insurance*

NAICS 54xxxx: *Professional, Scientific, and Technical Services*

NAICS 55xxxx: *Management of Companies and Enterprises*

NAICS 561xxx: *Administrative and Support Services*

NAICS 61xxxx: *Education Services*

NAICS 62xxxx: *Health Care and Social Assistance*

NAICS 71xxxx: *Arts, Entertainment, And Recreation*

NAICS 72xxxx: *Accommodation and Food Services*

NAICS 8121xx: *Personal Care Services*

NAICS 8129xx: *Other Personal Services*

NAICS 813xxx: *Religious, Grantmaking, Civic, Professional, & Similar Organization*

Description: The remaining service businesses include theaters, hotels/motels, finance, banking, hospitals, medical/dental laboratories, medical services, nursing homes, schools/universities, and legal, financial and engineering services. Stormwater from parking lots will contain undesirable concentrations of oil & grease, suspended particulates, and metals such as lead, cadmium and zinc. Dangerous wastes might be generated at hospitals, nursing homes and other medical services.

Potential Pollutant Generating Sources: The primary concern is runoff from high use parking areas, spills from vehicle or equipment fueling or repair at maintenance shops, loading/unloading areas, and storage and handling of dangerous wastes.

Vehicle Maintenance and Repair

NAICS 8111xx: *Automotive Repair and Maintenance*

NAICS 8113xx: *Commercial and Industrial Machinery and Equipment (except Automotive and Electronic) Repair and Maintenance*

Description: This category includes businesses that paint, repair and maintain automobiles, motorcycles, trucks, and buses; and battery, radiator, muffler, lubrication, tune-up, and tire shops, excluding those businesses listed elsewhere in this manual.

Potential Pollutant Generating Sources: Pollutant sources include storage and handling of vehicles, solvents, cleaning chemicals, waste materials, vehicle liquids, batteries, and washing and steam cleaning of vehicles, parts, and equipment. Potential pollutants include waste oil, solvents, degreasers, antifreeze, radiator flush, acid solutions with cadmium, chromium, copper, lead, and zinc, brake fluid, soiled rags, oil filters, sulfuric acid and battery sludge, and machine chips in residual machining oil.

Multifamily Residences

NAICS 53111x: *Lessors of Residential Buildings and Dwellings*

NAICS 531311: *Residential Property Managers*

NAICS 7213xx: *Rooming and Boarding Houses, Dormitories, and Workers' Camps*

Description: Multifamily residential buildings such as apartments and condominiums. The activities of concern are vehicle parking, vehicle washing, oil changing, minor repairs, and temporary storage of garbage.

Potential Pollutant Generating Sources: Stormwater contamination can occur at vehicle parking lots and from washing of vehicles. Runoff from parking lots may contain undesirable concentrations of oil & grease, TSS, and metals such as cadmium, lead, and zinc.

Construction Businesses

NAICS 23xxxx: *Construction*

NAICS 5617xx: *Services to Buildings and Dwellings*

NAICS 562xxx: *Waste Management and Remediation Services*

Description: This category includes builders of homes, commercial and industrial buildings, and heavy equipment, as well as plumbing, painting, paper hanging, carpentry, electrical, roofing and sheet metal, wrecking and demolition, stonework, drywall, and masonry contractors. It does not include construction sites.

Potential Pollutant Generating Sources: Potential pollutant sources include leaks/spills of used oils, solvents, paints, batteries, acids, strong acid/alkaline wastes, paint/varnish removers, tars, soaps, coatings, asbestos, lubricants, anti-freeze compounds, litter, and fuels at the headquarters, operation, staging, and maintenance/repair locations of the businesses.

Demolition contractors may store reclaimed material before resale. Roofing contractors generate residual tars and sealing compounds, spent solvents, kerosene, and soap cleaners, as well as nonhazardous waste roofing materials. Sheet metal contractors produce small quantities of acids and solvent cleaners such as kerosene, metal shavings, adhesive residues, enamel coatings, and asbestos residues that have been removed from buildings. Asphalt paving contractors are likely to store application equipment such as dump trucks, pavers, tack coat tankers and pavement rollers at their businesses. Stormwater passing through this equipment may be contaminated by the petroleum residuals. Potential pollutants include BOD, COD, heavy metals, oil & grease, organic compounds, pH, TSS, etc.

5. Public Agency Activities

Introduction

Local, state, and federal governments conduct many of the pollutant generating activities conducted at business facilities. Local jurisdictions include cities and counties, as well as single-purpose entities such as fire, sewer, and water districts.

Public Facilities and Streets

Description: Included in this group are public buildings. Also included are maintenance (deicing), and repair of streets and roads.

Potential Pollutant Generating Sources: Wastes generated include deicing and anti-icing compounds, solvents, paint, acid and alkaline wastes, paint and varnish removers, and debris. Large amounts of scrap materials are also produced throughout the course of construction and street repair. Potential pollutants include suspended solids, oil & grease, and low/high pH.

Maintenance of Open Public Space Areas

Description: The maintenance of large open spaces that are covered by expanses of grass and landscaped vegetation. Examples are zoos and public cemeteries. Golf courses and parks are covered in NAICS 713910.

Potential Pollutant Generating Sources: Maintenance of grassed areas and landscaped vegetation has historically required the use of fertilizers and pesticides. Golf courses contain small lakes that are sometimes treated with algaecides and/or mosquito larvicides. The application of pesticides can lead to inadvertent contamination of nearby surface waters by overuse, misapplication, or the occurrence of storms shortly after application. Heavy watering of surface greens in golf courses may cause pesticides or fertilizers to migrate to surface and shallow groundwater resources. The application of pesticides and fertilizers generates waste containers. Equipment must be cleaned and maintained. Maintenance shops where the equipment is maintained must comply with the BMPs specified under S414 BMPs for Maintenance and Repair of Vehicles and Equipment.

Maintenance of Public Stormwater Facilities

Description: Facilities include roadside catch basins on arterials and within residential areas, conveyance pipes, detention facilities such as ponds and vaults, oil and water separators, biofiltration swales, filter strips, settling basins, infiltration systems, and all other types of stormwater treatment systems.

Potential Pollutant Generating Sources: Research has shown that roadside catch basins can remove from 5 to 15 percent of the pollutants present in stormwater. However, to be effective they must be cleaned. Research has indicated that once catch basins are about 60 percent full of sediment, they cease removing sediments. Generally in urban areas, catch basins become 60 percent full within 6 to 12 months.

Water and solids produced during the cleaning of Runoff Treatment BMPs, including oil and water separators, can adversely affect both surface and groundwater quality if disposed of improperly.

Ecology has documented water quality violations and fish kills due to improper disposal of decant water (water that is removed) and catch basin sediments from maintenance activities. Disposal of decant water and solids shall be conducted in accordance with local, state, and federal requirements.

Historically, decant water from trucks has been placed back in the storm drain. Solids have been disposed of in permitted landfills and in unpermitted vacant land including wetlands. Research has shown that these residuals contain pollutants at concentrations that exceed water quality criteria. For example, limited sampling by King County and the Washington State Department of Transportation of sediments removed from catch basins in residential and commercial areas has found the concentrations of petroleum hydrocarbons to frequently exceed 200 mg/gram. Above this concentration, regulations require disposal at a lined landfill.

Water and Sewer Districts and Departments

Description: The maintenance of water and sewer systems can produce residual materials that, if not properly handled, can cause short-term environmental impacts in adjacent surface and/or groundwaters. With the exception of a few simple processes, both water and sewage treatment produce residual sludge that must be disposed of properly. However, this activity is controlled by other Ecology regulatory programs and is not discussed in this manual. Larger water and sewer districts or departments may service their own vehicles.

Potential Pollutant Generating Sources: Maintenance operations of concern include the cleaning of sanitary sewers, water lines, and water reservoirs, general activities around treatment plants, disposal of sludge, and the temporary shutdown of pump stations for either normal maintenance or emergencies. During the maintenance of water transmission lines and reservoirs, water district/departments must dispose of wastewater, both when the line or reservoir is initially emptied, as well as when it is cleaned and then sanitized. Sanitation requires chlorine concentrations of 25 to 100 ppm, considerably above the normal concentration used to chlorinate drinking water. These waters are discharged to sanitary sewers where available.

However, transmission lines from remote water supply sources often pass through both rural and urban-fringe areas where sanitary sewers are not available. In these areas, chlorinated water may need to be discharged to a nearby stream or storm drain, particularly since the emptying of a pipe section occurs at low points that frequently exist at stream crossings. Although prior to disposal the water is dechlorinated using sodium thiosulfate or a comparable chemical, malfunctioning of the dechlorination system can kill fish and other aquatic life. The drainage from reservoirs located in areas without sewers is conveyed to storm drains. The cleaning of sewer lines and manholes generates sediments. These sediments contain both inorganic and organic materials, are odorous, and may be contaminated with microorganisms and heavy metals. Activities around sewage treatment plants can be a source of non-point pollution. Besides the normal runoff of stormwater from paved surfaces, grit removed from the headworks of the plant is stored temporarily in dumpsters that may be exposed to the elements. Maintenance and repair shops may produce waste paints, used oil, cleaning solvents, and soiled rags.

Port Districts

Description: The port districts considered here include the following business activities: recreational boat marinas and launch ramps, airfields, container trans-shipment, bulk material import/export including farm products, lumber, logs, alumina, and cement; and break-bulk (piece) material such as machinery, equipment, and scrap metals. Port districts frequently have tenants whose activities are not marine-dependent.

Potential Pollutant Generating Sources: Marine terminals require extensive use of mobile equipment that may drip liquids. Waste materials associated with containers/vehicle/equipment washing/steam cleaning, maintenance and repair may be generated at a marine terminal. Debris can accumulate in loading/unloading or open storage areas, providing a source of stormwater contamination. Wooden debris from the crating of piece cargo crushed by passing mobile loading equipment leaches soluble pollutants when in contact with pooled stormwater. Log sorting yards produce large quantities of bark that can be a source of suspended solids and leached pollutants. Potential pollutants include oil & grease, heavy metals, organics, and TSS.

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Appendix 8-B: Management of Street Waste Solids and Liquids

Introduction

This appendix addresses street waste as defined in chapter 173-350 WAC, Solid waste handling standards. WAC 173-350 is the governing rule for management of typical street waste solids. Ecology adopted revisions to this rule that became effective September 1, 2018, in part to provide clarity on managing soils impacted by release of contaminants, such as street waste. Ecology has solid waste guidance to help ensure handlers of street waste manage it in accordance with WAC 173-350. End users and other authorities may have their own requirements for street waste reuse and handling.

- Per WAC 173-350:
  - **"Street waste"** means solids or dewatered materials collected from stormwater catch basins and similar stormwater treatment and conveyance structures, and materials collected during street and parking lot sweeping.

"Street waste," as defined here, does not include solids and liquids from street washing using detergents, cleaning of electrical vaults, vehicle wash sediment traps, restaurant grease traps, industrial process waste, sanitary sewage, mixed process, or combined sewage/stormwater wastes. Wastes from oil/water separators at sites that load fuel are not included as street waste. Street waste also does not include flood debris, landslide debris, and chip seal gravel.

Regulations for Street Waste Management

Street waste is solid waste. While street waste from routine road maintenance is likely not dangerous waste, it is presumed to be solid waste under WAC 173-350. This Rule classifies Street Waste as a likely “contaminated soil," which is included in the definition of “solid waste.” Since stormwater conveyance structures are places where contaminants from streets can accumulate at concentrations that could be harmful for indiscriminant placement, material from such structures is presumed to be “contaminated soil.”

- Per WAC 173-350:
  - **"Contaminated soil"** means soil containing one or more contaminants from a release and when moved from one location to another for placement on or into the ground:
    a. Contains contaminants at concentrations that exceed a cleanup level under chapter 173-340 WAC, Model Toxics Control Act—Cleanup, that would be established for existing land use at the location where soil is placed; or
    b. Contains contaminants that affect pH, and pH of the soil is below 4.5 or above 9.5 or is not within natural background pH limits that exist at the location where soil is placed.

    Unless excluded in WAC 173-350-020, contaminated soil is solid waste and must be managed at a solid waste handling facility in conformance with this chapter or chapter 173-351 WAC, Criteria for municipal solid waste landfills. Characterization of material may be required based on solid waste facility acceptance standards. Examples of potentially contaminated soil may include, but are not limited to, street waste, petroleum contaminated soil, engineered soil, and soil likely to have contaminants from a release associated with industrial or historical activities.

Based on test results, street waste could contain contaminants at concentrations that would require either disposal at a permitted solid waste disposal facility, or treatment at a permitted solid waste handling facility for use.

Owners/operators storing or treating street waste prior to disposal or use are typically subject to permitting under the section in WAC 173-350 dealing with “piles used for storage and treatment,” since most storage and treatment takes place in outdoor piles. Indoor or other storage or treatment is subject to permitting under the section dealing with “transfer stations and drop boxes.” To obtain a permit, an owner/operator will need to meet design standards, operating requirements, including characterization procedures and concentration limits if propose to use materials, and record keeping and reporting.

Typically, the County Health Department produces permits for disposal of solid waste and not Ecology. While Ecology has defined Street Wastes in WAC 173-350, Ecology’s authority does not extend to actual disposal of the waste material.

Note: Decant facilities are not subject to solid waste permitting if they will not have intermediate storage or treatment of decanted solids between the decant part of a facility operating in conformance with water quality rules and placement into transfer vehicles going to permitted solid waste facilities. Water quality rules are more fully described later in this Appendix.

Street waste solids may contain contaminants at levels too high to allow unrestricted use. Street waste will need to meet the definition in WAC 173-350 for “clean soil” in order for its management or use outside of permitted solid waste handling facilities. “Clean soil” is tied to meeting contaminant concentrations so as not to create a cleanup site where placement of materials would occur.

- Per WAC 173-350:
    - **"Clean soil"** means soil that does not contain contaminants from a release. It also includes soil that contains one or more contaminants from a release and when moved from one location to another for placement on or into the ground:
        a. Does not contain contaminants at concentrations that exceed a cleanup level under chapter 173-340 WAC, Model Toxics Control Act—Cleanup, that would be established for existing land use at the location where soil is placed; or
        b. Contains contaminants that affect pH, but pH of the soil is between 4.5 and 9.5 or within natural background pH limits that exist at the location where soil is placed.

        Examples of potentially clean soil may include, but are not limited to, soil from undeveloped lands unlikely to have impacts from release of contaminants associated with area-wide or local industrial or historical activities. This includes similar soils over which development may have occurred but land use is unlikely to have led to a release, such as use for residential housing, or over which development provided protection from impacts from a release, such as coverage by pavement. Soil with substances from natural background conditions, as natural background is defined in WAC 173-350-100, is clean soil under this section.

Street waste that will go directly to a permitted landfill or transfer station is not subject to the standards of WAC 173-350, though operators will need to adhere to receiving facility acceptance criteria. For street waste that will not go directly to a permitted landfill or transfer station, an operator needs to consult with their jurisdictional health department to see what solid waste regulations apply to street waste management. In Washington, chapter 70.95 RCW, Solid waste management – Reduction and recycling, gives jurisdictional health departments primary authority over solid waste handling and permitting.

As stated earlier, guidance will be available soon with more specificity on how to manage "contaminated soil" under the recently revised WAC 173-350.

Street Waste Solids

Soils generated from maintenance of the MS4 may be reclaimed, recycled, or reused when allowed by local codes and ordinances. Street Wastes are defined in Chapter 173-350 WAC . Soils that are identified as contaminated, pursuant to Chapter 173-350 WAC, shall be disposed of at a qualified solid waste disposal facility.

Typically, the County Health Department produces permits for disposal of solid waste and not Ecology. Ecology's authority does not extend to actual disposal of street waste material.

The text in this box originates from one or more of the following Permits:
Appendix 1 of the Phase I / Phase II Municipal Stormwater Permits
Construction Stormwater General Permit

Contaminants in Street Waste Solids

Street waste does not typically classify as dangerous waste. The owner of the stormwater facility and/or collector of street waste is considered the waste generator and responsible for deciding whether the waste designates as dangerous waste. However, sampling has historically shown that material from routine maintenance of roads and stormwater facilities does not classify as dangerous waste.

It is possible that street waste from spill sites has high enough concentration of contaminants to classify it as dangerous waste. Street waste suspected to be dangerous waste should not be collected with other street waste to avoid creating a larger volume of dangerous waste. Street waste with obvious contamination (unusual color, staining, corrosion, unusual odors, fumes, and oily sheen) should be left in place or segregated until tested. Identifying a separate storage bay at decant facilities for suspected contaminated waste is a good measure to ensure that you can deal with potentially contaminated waste.

Base testing activities on probable contaminants. If collecting potentially dangerous waste because of emergency conditions, or if the waste becomes suspect after it is collected, an owner/operator should manage and store it separately until a determination as to proper disposal is made. Dangerous waste must be handled following chapter 173-303 WAC, Dangerous waste regulations.

Test results from sampling street waste show that it contains contaminants including total petroleum hydrocarbons (TPH), carcinogenic polycyclic aromatic hydrocarbons (c-PAHs), and several metals. These contaminants can be at concentrations high enough to be harmful to human health and the environment unless managed appropriately. The following tables provide a summary of some past test results.

Table 8.1: Typical TPH Levels in Street Sweeping and Catch Basin Solids

Reference	Street Sweeping (mg/kg)	Catch Basin Solid (mg/kg)
Snohomish County (1) (Landau, 1995)	390 - 4300	
King County (1) (Herrera, 1995)		123 - 11049 (Median 1036)
Snohomish County & Selected Cities (1) (W&H Pacific, 1994)	163 - 1500 (Median 760)	163 -1562 (Median 760)
City of Portland (2) (Bretsch, 2000)		MDL - 1830 (Median 208)
City of Seattle - Diesel Range (2) (Seattle Public Utilities and Herrera, 2009)	330 - 520	780 - 1700
City of Seattle - Motor Oil (2) (Seattle Public Utilities and Herrera, 2009)	2000 - 2800	3500 - 7000
Oregon (1) (Collins, 1998)	1600 - 2380	
Oregon (3) (Collins, 1998)	98 - 125	
(1) Method WTPH 418.1; does not incorporate new methods to reduce background interference due to vegetative material. (2) Method NWTPH-Dx (3) Method WTPH - HCID		

Table 8.2: Typical c-PAH Values in Street Waste Solids and Related Materials

Sample Source	City of Everett					WSDOT	
Analyte	Street Sweepings	Soil	3-Way Topsoil	Vactor Solids	Leaf & Sand	Sweepings - Fresh	Sweepings - Weathered
Benzo (a)anthracene	0.1U	0.076U	0.074U	0.21	0.45	0.56	0.40
Chrysene	0.14	0.09	0.074U	0.32	0.53	0.35	0.35
Benzo(b)fluor-anthene	0.11	0.076U	0.074U	0.27	0.52	0.43	0.51
Benzo(k)fluor-anthene	0.13	0.076U	0.074U	0.25	0.38	0.39	0.40
Benzo (a)pyrene	0.13	0.076U	0.074U	0.26	0.5	0.41	0.33U
Indeno(1,2,3-cd)pyrene	0.1U	0.076U	0.074U	0.19	0.39	NR	NR
Dibenzo(a,h)an-thracene	0.1U	0.076U	0.074U	0.081	0.12	0.39	0.33U
Revised MTCA Benzo (a)pyrene [ND=PQL]	0.215	0.134	0.134	0.388	0.727	0.708	0.597
Benzo (a)pyrene [ND = 1/2 PQL]	0.185	0.069	0.067	0.388	0.727	0.708	0.366
Benzo (a)pyrene [See * below]	0.185	0.069	0	0.388	0.727	0.708	0.366
Benzo (a)pyrene [ND = 0]	0.155	0.001	0	0.388	0.727	0.708	0.135

* If the analyte was not detected for any PAH, then ND=0; If analyte was detected in at least 1 PAH, then ND=1/2PQL; If the average concentration (using ND=1/2 PQL) is greater than the maximum detected value, then ND=Maximum value.

Table 8.3: Typical Metals Concentrations in Catch Basin Sediments

PARAMETER	Ecology 1993	Thurston 1993	King County 1995	King county 1995	City of Seattle 2003 through 2011
Metals: Total (mg/kg)	(Min - Max)	(Min - Max)	(Min - Max)	Mean	Min - Max (Mean)
As	< 3 - 24	.39 - 5.4	4 -56	0.250	<5 - 50 (9.3)
Cd	0.5 - 2.0	< 0.22 - 4.9	0.2 - 5.0	0.5	
Cr	19 - 241	5.9 - 71	13 - 100	25.8	
Cu	18 - 560	25 - 110	12 - 730	29	9.1 - 3,280 (166)
Pb	24 - 194	42 - 640	4 - 850	80	3 - 3,690 (154)
Ni	33 - 86	23 - 51	14 - 41	23	
Zn	90 - 558	97 - 580	50 - 2000	130	44 - 4170 (479)
Hg	0.04 - 0.16	0.24 - 0.193			<0.03 - 3.8 (0.16)

Table 8.4: Pollutants in Catch Basin Solids - Comparison to Dangerous Waste Criteria

PARAMETER	Range of Values in Catch Basin Waste	Range of Values in Catch Basin Waste	Dangerous Waste Criteria
METALS	Total Metals (mg/kg)	TCLP Metals (mg/kg)	TCLP values (mg/l)
As	<3 - 56	< 0.02 - 0.5	5.0
Cd	< 0.22 - 5	0.0002 - 0.03	1.0
Cr	5.9 - 241	0.0025 - 0.1	5.0
Cu	12 - 730	0.002 - 0.88	none
Pb	4 - 850	0.015 - 3.8	5.0
Ni	23 - 86	< 0.01 - 0.36	none
Zn	50 - 2,000	0.04 - 6.7	none
Hg	0.02 - 0.19	0.0001 - 0.0002	0.2
Data from (Thurston County, 1993), (Herrera, 1995) and (Serdar, 1993).			

Street Waste Liquids

<u>**General Procedures**</u>

Street waste collection should emphasize retention of solids in preference to liquids. Street waste solids are the principal objective in street waste collection and are substantially easier to store and treat than liquids.

Street waste liquids require treatment before their discharge. Street waste liquids, which include, but are not limited to, eductor and street sweeping truck decant and drainage from piles and containers, usually contain high amounts of suspended and total solids and adsorbed metals. Treatment requirements depend on the discharge location.

Discharges to sanitary sewer and storm sewer systems must be approved by the entity responsible for operation and maintenance of the system. Ecology will not generally require waste discharge permits for discharge of stormwater decant to sanitary sewers or to stormwater treatment BMPs constructed and maintained in accordance with this manual.

The following order of preference, for disposal of liquid from collection of street waste and water removed from stormwater treatment BMPs, is ***required***.

1. **Discharge of street waste decant liquids to a municipal sanitary sewer connected to a Publicly Owned Treatment Works (POTW) is the *preferred disposal option*.** Discharge to a municipal sanitary sewer requires the approval of the sewer authority. Approvals for discharge to a POTW will likely contain pretreatment, quantity, and location conditions to protect the POTW.

2. **Discharge of street waste decant liquids may be allowed into a Basic or Metals Runoff Treatment BMP, if option 1 is not available.** Street waste liquid may be discharged back into the storm sewer system under the following conditions only when ***all*** of the following apply:

   - The preferred disposal option of discharge to sanitary sewer is not reasonably available;
   - The liquid comes from street waste only. Do not send liquids decanted from sanitary wastes to stormwater BMPs;
   - The discharge is to a Basic or Metals Runoff Treatment BMP. If pretreatment does not remove visible sheen from oils, the Runoff Treatment BMP must be able to prevent the discharge of oils causing a visible sheen;
   - The discharge from the eductor or sweeper truck is as near to the inlet of the Runoff Treatment BMP as is practical, to minimize contamination or recontamination of the collection system;

- The storm sewer system owner/operator has granted approval and has determined that the Runoff Treatment BMP will accommodate the increased loading. Pretreatment conditions to protect the Runoff Treatment BMP may be issued as part of the approval process; and
- Ecology must approve in advance flocculants for the pretreatment of street waste liquids. The liquids must be non-toxic under the circumstances of use. If the owner/operator adds flocculants to street waste liquids, they must follow the requirements of BMP C250: Construction Stormwater Chemical Treatment and BMP C251: Construction Stormwater Filtration.

The reasonable availability of sanitary sewer discharge will be determined by the local jurisdiction, by evaluating such factors as distance, time of travel, load restrictions, and capacity of the Runoff Treatment BMP.

3. **Operators may temporarily place portable tanks (e.g. Baker Tanks) near where sweeping is taking place to temporarily hold water and solids from the sweeper.** Transfer this water/solid mixture to the decant facility at a later time.

4. **Operators may discharge liquids removed from the street while sweeping during rain events, if the designated decant facility is a distance away (i.e. travel time would significantly impact the amount of sweeping).** When sweeping during rain events, the sweeper will fill with water quickly.

   Discharge to Wastewater Collection System: Operators may discharge water from eductor or sweeper trucks to the wastewater collection system through manholes located in the street that is swept with approval from the Sewer Authority. The method used to move water from the sweeper to the wastewater collection system should be developed by the Sewer Authority.

   Discharge to Stormwater Collection System: Operators may discharge clear decanted water to the stormwater collection system for the roadway being swept when all of the conditions listed below apply. Operators cannot deposit decanted water into a collection system different from the system for the roadway being swept. Conditions to discharge:

   - The catch basin receiving the decanted water already receives runoff from the swept street.
   - The water entering the sweeper storage tank is runoff from the street and not water placed on the street by a water truck or the sweeper during the sweeping operation.
   - The sweeper stays in place for a minimum of 15 minutes at the discharge location to allow solids to settle prior to decanting the water from the storage tank.
   - The operator places an appropriately sized catch basin filter in the catch basin or a filter sock attached to the end of the outlet hose allowing for a slow release of

water. Remove the catch basin filter or filter sock following its use.

- The operator stops discharging liquids to the catch basin when there is a concentration of solids leaving the tank.

- The storm sewer system owner/operator must approve the discharge.

5. **Operators may return water removed from stormwater ponds, vaults, and oversized catch basins to the storm sewer system.** Stormwater ponds, vaults, and oversized catch basins contain substantial amounts of liquid, which hampers the collection of solids and poses problems if the removed waste must be hauled away from the site. Water removed from these facilities may be discharged back into the pond, vault, or oversized catch basin provided:

   - Clear water removed from a stormwater treatment structure may be discharged directly to a down gradient cell of a treatment pond or into the storm sewer system.

   - Turbid water may be discharged back into the structure it was removed from if:

     - The removed water has been stored in a clean container (eductor truck, Baker tank, or other appropriate container or facility used specifically for handling stormwater or clean water); ***and***

     - There will be no discharge from the stormwater pond, vault, or oversized catch basin for at least 24 hours.

   - The discharge must be approved by the storm sewer system owner/operator.

The text in this box originates from one or more of the following Permits:
Appendix 1 of the Phase I / Phase II Municipal Stormwater Permits
Construction Stormwater General Permit

Contaminants in Street Waste Liquids

Table 8.5: Typical Street Waste Decant Values Compared to Surface Water Quality Criteria

PARAMETER	State Surface Water Quality Criteria		Range of Values Reported	
METALS	Freshwater Acute (ug/l - dissolved metals)	Freshwater Chronic (ug/l - dissolved metals)	Total Metals (ug/l)	Dissolved Metals (ug/l)
Arsenic	360	190	100 - 43,000	60 - 100
Cadmium*	2.73	0.84	64 - 2,400	2 - 5
Chromium (total)			13 - 90,000	3 - 6
Chromium (III)*	435	141		

Table 8.5: Typical Street Waste Decant Values Compared to Surface Water Quality Criteria (continued)

PARAMETER	State Surface Water Quality Criteria		Range of Values Reported	
METALS	Freshwater Acute (ug/l - dissolved metals)	Freshwater Chronic (ug/l - dissolved metals)	Total Metals (ug/l)	Dissolved Metals (ug/l)
Chromium (VI)	0.5	10		
Copper*	13.04	8.92	81 - 200,000	3 - 66
Lead*	47.3	1.85	255 - 230,000	1 - 50
Nickel*	1114	124	40 - 330	20 - 80
Zinc*	90.1	82.3	401 - 440,000	1,900 - 61,000
Mercury	2.10	0.012	0.5 - 21.9	
*Hardness dependent; hardness assumed to be 75 mg/L.				

Table 8.6: Typical Values for Conventional Pollutants in Street Waste Decant

PARAMETER	Ecology 1993	(Min - Max)	King County 1995	(Min - Max)
Values as mg/l; except where stated	Mean		Mean	
pH	6.94	6.18 - 7.98	8	6.18 - 11.25
Conductivity (umhos/cm)	364	184 - 1,110	480	129 - 10,100
Hardness (mg/l CaCO3)	234	73 - 762		
Fecal Coliform (MPN/100 ml)	3,000			
BOD	151	28 - 1,250		
COD	900	120 - 26,900		
Oil & Grease	11	7.0 - 40	471	15 - 6,242
TOC	136	49 - 7,880	3,670	203 - 30,185
Total Solids	1,930	586 - 70,400		
Total Dissolved Solids	212	95 - 550		
Total Suspended Solids	2,960	265 -		

Table 8.6: Typical Values for Conventional Pollutants in Street Waste Decant (continued)

PARAMETER	Ecology 1993	(Min - Max)	King County 1995	(Min - Max)
Values as mg/l; except where stated	Mean		Mean	
		111,000		
Settleable Solids (ml/l/hr)	27	2 - 234	57	1 - 740
Turbidity (ntu)	1,000	55 - 52,000	4,673	43 - 78,000

Table 8.7: Street Waste Decant Values Following Settling

PARAMETER; Total Metals in mg/l	Portland - Inverness Site Min - Max	King County - Renton Min - Max	METRO Pretreatment Discharge Limits
Arsenic	0.0027 - 0.015	< MDL - 0.12	4
Cadmium	0.0009 - 0.0150	< MDL - 0.11	0.6
Chromium	0.0046 - 0.0980	0.017 - 0.189	5
Copper	0.015 - 0.8600	0.0501 - 0.408	8
Lead	0.050 - 6.60	0.152 - 2.83	4
Nickel	0.0052 - 0.10	0.056 - 0.187	5
Silver	0.0003 - 0.010	< MDL	3
Zinc	0.130 - 1.90	0.152 - 3.10	10
Settleable Solids; ml/L	No Data	0.02 - 2.0	7
Nonpolar FOG	5.7 - 25	5 - 22	100
Ph (std)	6.1 - 7.2	6.74 - 8.26	5.0 - 12.0
TSS	2.8 - 1310		
Recorded Total Monthly Flow; Gallons	Data not available	31,850 - 111,050	
Recorded Max. Daily Flow; Gallons	Data not available	4,500 - 18,600	25,000 GPD
Calculated Average Daily Flow; GPD	Data not available	1,517 - 5,428	
1) Data from King County's Renton Facility (data from 1998 - 1999) and the City of Portland's Inverness Site (data from 1999 - 2001); detention times not provided.			

Collection Site Assessment

Ecology suggests a collection site assessment to identify spills or locations that potentially contain dangerous wastes.

The collection site assessment will aid in determining if waste is a dangerous waste and in deciding what to test for if dangerous waste is suspected. The collection site assessment will also help determine if the waste meets the requirements of the receiving facility.

There are three steps to a collection site assessment:

1. A **historical review** of the site for spills, previous contamination and nearby cleanup sites or dangerous waste facilities.

   The historical review will be easier if done on an area wide basis prior to scheduling any waste collection. The historical review should be more thorough for operators who have never collected waste at the site before. At a minimum, the historical review should include operator knowledge of the area's collection history or records from previous waste collections.

   Private operators should ask the owner of the site for records of previous contamination and the timing of the most recent cleaning. Ecology’s Hazardous Substance Information Office maintains a Toxic Release Inventory and a Facility/Site Database, tracking more than 15,000 sites.

   Ecology's online Facility/Site Database is available at www.ecy.wa.gov/fs/.

   The database allows anyone with web-access to search for facility information by address, facility name, town, zip code, and SIC code, etc. It lists why Ecology is tracking each one (NPDES, TSCA, RCRA, Clean Air Act, etc.), as well as who to call within Ecology to find out more about the given facility. EPA’s toxic release website is http://i-aspub.epa.gov/triexplorer/tri_release.chemical

2. A **visual inspection** for potential contaminant sources such as a past fire, leaking tanks and electrical transformers, and surface stains.

   Look at the area for contaminant sources prior to collection of the waste. If the inspection finds a potential contaminant source, delay the waste collection until the potential contaminant is assessed.

   A second portion of the visual inspection is a good housekeeping assessment of the area. Locations with poor housekeeping commonly cut corners in less obvious places. Inspect these sites in greater detail for illegal dumping and other contamination spreading practices.

3. **Sweeping route, catch basin, waste, and container inspection** before and during collection.

   The inspection of the waste and catch basin or vault is the last and perhaps most critical step in the collection site assessment.

For example, if the stormwater facility has an unusual color in or around it, then it is possible someone dumped something near it or into it. Some colors to be particularly wary of are yellow/green from antifreeze dumping and black and rainbow sheen from oil and/or grease dumping. In addition, if the inspector observes any staining or corrosion, then a solvent may have been dumped.

Fumes are also good indicators of potential contamination. Avoid deliberate smelling of catch basins for worker safety, but suspicious odors may be encountered from catch basins thought to be safe. Some suspicious odors are rotten eggs (hydrogen sulfide is present), gasoline or diesel fumes, or solvent odors. If unusual odors are noted, contact a dangerous waste inspector before cleaning the basin.

Finally, operator experience is the best guide to avoid collection of contaminated waste.

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Glossary

The following definitions of terms and abbreviations are provided for use with this manual. A definition provided in this glossary may be superseded by an alternative definition adopted by local ordinance, unless it matches the definition provided by a Washington Administrative Code (WAC) or the Revised Code of Washington (RCW).

- A -- B -- C -- D -- E -- F -- G -- H -- I -- J -- K -- L -- M -- N -- O -- P -- Q -- R -- S -- T -- U -- V -- W -- X -- Y -- Z -

- A -

AADT

Annual Average Daily Traffic

AASHTO classification

The official classification of soil materials and soil aggregate mixtures for highway construction, used by the American Association of State Highway and Transportation Officials.

AASHTO H-20

The load representing a truck used in design of highways and bridges. The basic design truck is a single unit weighing 40 kips. A kip (often called a kilopound) represents 1,000 pound-force. The subsequent HS-20 designation represents higher loads typical of tractor-semi-trailer combinations.

Absorption

The penetration of a substance into or through another, such as the dissolving of a soluble gas in a liquid.

ADA

Americans with Disabilities Act

Adaptive management

The modification of management practices to address changing conditions and new knowledge. Adaptive management is an approach that incorporates monitoring and research to allow projects and activities, including projects designed to produce environmental benefits, to go forward in the face of some uncertainty regarding consequences. The key provision of adaptive management is the responsibility to change adaptively in response to new understanding or information after an action is initiated.

Adjacent steep slope

A slope with a gradient of 15 percent or steeper within five hundred feet of the site.

Adjustment

A variation in the application of a Core Element to a particular project. Adjustments provide substantially equivalent environmental protection.

Administrator

The local government official(s) authorized to make decisions in regard to Adjustments and Exceptions/Variances.

Adsorption

The adhesion of a substance to the surface of a solid or liquid; often used to extract pollutants by causing them to be attached to such adsorbents as activated carbon or silica gel. Hydrophobic, or water-repulsing adsorbents, are used to extract oil from waterways when oil spills occur. Heavy metals such as zinc and lead often adsorb to sediment particles.

ADT

Average Daily Traffic

Aeration

The process of supplying or impregnating a substance with air. In waste treatment, the process used to foster biological and chemical purification. In soils, the process by which air in the soil is replenished by air from the atmosphere. In a well-aerated soil, the soil air is similar in composition to the atmosphere above the soil. Poorly aerated soils usually contain a much higher percentage of carbon dioxide and a correspondingly lower percentage of oxygen.

Aerobic

Living or active only in the presence of free (dissolved or molecular) oxygen.

Aerobic bacteria

Bacteria that require the presence of free oxygen for their metabolic processes.

Aggressive plant species

Opportunistic species of inferior biological value that tend to out compete more desirable forms and become dominant; applied to native species in this manual.

AKART

All Known, Available, and Reasonable methods of prevention, control, and Treatment.

Algae

Primitive plants, many microscopic, containing chlorophyll and forming the base of the food chain in aquatic environments. Some species may create a nuisance when environmental conditions are suitable for prolific growth.

Algal bloom

Proliferation of living algae on the surface of lakes, streams or ponds; often stimulated by phosphate over-enrichment. Algal blooms reduce the oxygen available to other aquatic organisms.

AMC

Antecedent Moisture Condition

American Public Works Association (APWA)

The Washington State Chapter of the American Public Works Association.

Anadromous

Fish that grow to maturity in the ocean and return to rivers for spawning.

Anaerobic

Living or active in the absence of oxygen.

Anaerobic bacteria

Bacteria that do not require the presence of free or dissolved oxygen for metabolism.

Animal feeding operation

A lot or facility (other than an aquatic animal production facility) where the following conditions are met:

i. Animals (other than aquatic animals) have been, are, or will be stabled or confined and fed or maintained for a total of 45 days or more in any 12-month period, and

ii. Crops, vegetation, forage growth, or post-harvest residues are not sustained in the normal growing season over any portion of the lot or facility.

Annual flood

The highest peak discharge, on average, that can be expected in any given year.

ANSI

American National Standards Institute

Antecedent moisture condition (AMC)

The degree of wetness of a watershed or within the soil at the beginning of a storm.

Anti-seep collar

A device constructed around a pipe or other conduit and placed through a dam, levee, or dike for the purpose of reducing seepage losses and piping failures.

Anti-vortex device

A facility placed at the entrance to a pipe conduit structure such as a drop inlet spillway or hood inlet spillway to prevent air from entering the structure when the pipe is flowing full.

API

American Petroleum Institute

Applicable BMPs

Those source control BMPs that are expected to be required by local jurisdictions at new development and redevelopment sites. Applicable BMPs will also be required if they are incorporated into NPDES Permits, or if they are included by local jurisdictions in a stormwater program for existing facilities.

Applicant

The person who has applied for a development permit or approval.

Appurtenances

Machinery, appliances, or auxiliary structures attached to a main structure, but not considered an integral part thereof, for the purpose of enabling it to function.

Aquifer

A geologic stratum containing groundwater that can be withdrawn and used for human purposes.

Arid

Excessively dry; having insufficient rainfall to support agriculture without irrigation.

Arterial

A road or street primarily for through traffic. The term generally includes roads or streets considered collectors. It does not include local access roads which are generally limited to providing access to abutting property. See also RCW 35.78.010, RCW 36.86.070, and RCW 47.05.021.

As-built drawings

Engineering plans which have been revised to reflect all changes to the plans which occurred during construction.

As-graded

The extent of surface conditions on completion of grading.

ATB

Asphalt Treated Base

Average daily traffic (ADT)

The expected number of vehicles using a roadway is represented by the projected ADT volume considered in designing the roadway. ADT counts must be estimated using the *Trip Generation Manual* published by the Institute of Transportation Engineers or a traffic study prepared by a licensed engineer in the state of Washington or a transportation specialist with expertise in traffic volume estimation. ADT counts shall be made for the design life of the project. For project sites with seasonal or varied use, the highest period of expected traffic impacts should be evaluated.

AWWA

American Water Works Association

- B -

Background

A description of pollutant levels arising from natural sources, and not because of man's immediate activities.

Backwater

Water upstream from an obstruction which is deeper than it would normally be without the obstruction.

Baffle

A device to check, deflect, or regulate flow.

Bankfull discharge

A flow condition where streamflow completely fills the stream channel up to the top of the bank. In undisturbed watersheds, the discharge conditions occur on average every 1.5 to 2 years and control the shape and form of natural channels.

Base flood

A flood having a 1 percent chance of being equaled or exceeded in any given year. Also referred to as the 100-year flood.

Base flood elevation

The water surface elevation of the base flood. It shall be referenced to the National Geodetic Vertical Datum of 1983 (NGVD).

Baseline sample

A sample collected during dry-weather flow (i.e., it does not consist of runoff from a specific precipitation event).

Basic treatment

Treatment of stormwater using a Runoff Treatment BMP chosen and sized to meet the basic treatment performance goal.

Basic treatment performance goal

The intent of a Runoff Treatment BMP to achieve 80% removal of total suspended solids for influent concentrations that are 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 BMP is intended to achieve an effluent goal of 20 mg/l total suspended solids.

Basin plan

A plan that assesses, evaluates, and proposes solutions to existing and potential future impacts to the beneficial uses of, and the physical, chemical, and biological properties of waters of the state within a basin. Basins typically range in size from 1 to 50 square miles. A plan should include but not be limited to recommendations for:

- Stormwater requirements for new development and redevelopment;
- Capital improvement projects;
- Land Use management through identification and protection of critical areas, comprehensive land use and transportation plans, zoning regulations, site development standards, and conservation areas;
- Source control activities including public education and involvement, and business programs;
- Other targeted stormwater programs and activities, such as maintenance, inspections and enforcement;
- Monitoring; and
- An implementation schedule and funding strategy.

A plan that is “adopted and implemented” must have the following characteristics:

- It must be adopted by legislative or regulatory action of jurisdictions with responsibilities under the plan;
- Ordinances, regulations, programs, and procedures recommended by the plan should be in effect or on schedule to be in effect; and,
- An implementation schedule and funding strategy that are in progress.

Bearing capacity

The maximum load that a material can support before failing.

Bedload

Sediment particles that are transported as a result of shear stress created by flowing water, that move along, and that are in frequent contact with the streambed.

Bedrock

The more or less solid rock in place, either on or beneath the surface of the earth. It may be soft, medium, or hard, and have a smooth or irregular surface.

Bench

A relatively level step excavated into earth material on which fill is to be placed.

Beneficial uses

Uses of waters of the State, which include but are not limited to: use for domestic, stock watering, industrial, commercial, agricultural, irrigation, mining, fish and wildlife maintenance and enhancement, recreation, generation of electric power and preservation of environmental and aesthetic values, and all other uses compatible with the enjoyment of the public waters of the State.

Berm

A constructed barrier of compacted earth, rock, or gravel. In a stormwater facility, a berm may serve as a vertical divider typically built up from the bottom.

Best available science

The technical provisions in this manual represent common provisions for the protection of waters of the state from adverse impacts of urban stormwater. Implementation of these provisions is necessary to minimize project-specific and cumulative impacts on waters of the state. This manual reflects the best available science and practices related to protection of water quality. The manual will incorporate new information as it becomes available and allow alternative practices that provide equal or greater protection for waters of the state.

Best management practices (BMPs)

The schedules of activities, prohibitions of practices, maintenance procedures, and structural and/or managerial practices, that when used singly or in combination, prevent or reduce the release of pollutants and other adverse impacts to waters of Washington State.

BFM

Bonded Fiber Matrix

Binding site plan

A drawing to a scale specified by local ordinance which:

a. identifies and shows the areas and locations of all streets, roads, improvements, utilities, open spaces, and any other matters specified by local regulations;

b. contains inscriptions or attachments setting forth such appropriate limitations and conditions for the use of the land as are established by the local jurisdiction having authority to approve the site plan; and

c. contains provisions making any development be in conformity with the site plan (RCW 58.17.020).

Biochemical oxygen demand (BOD)

An indirect measure of the concentration of biologically degradable materials present in organic wastes. The amount of free oxygen used by aerobic organisms when allowed to attack the organic material in an aerobically maintained environment at a specified temperature (20°C) for a specific time period (5 days), and thus stated as BOD5. It is expressed in milligrams of oxygen used per liter of liquid waste volume (mg/L) or in milligrams of oxygen per kilogram of waste solution (mg/kg = ppm = parts per million). Also called biological oxygen demand.

Biodegradable

Capable of being readily broken down by biological means, especially by microbial action. Microbial action includes the combined effect of bacteria, fungus, flagellates, amoebae, ciliates, and nematodes. Degradation can be rapid or may take many years depending upon such factors as available oxygen and moisture.

Bioengineering

The combination of biological, mechanical, and ecological concepts (and methods) to control erosion and stabilize soil through the use of vegetation or in combination with construction materials.

Biofilter

A designed treatment facility using a combined soil and vegetation system for filtration, infiltration, adsorption, and biological uptake of pollutants in stormwater when runoff flows over and through. Vegetation growing in these facilities acts as both a physical filter which causes gravity settling of particulates by regulating velocity of flow, and also as a biological sink when direct uptake of dissolved pollutants occurs.

Biofiltration

The process of reducing pollutant concentrations in water by filtering the polluted water through biological materials. Pollutant removal mechanisms include sedimentation, filtration, soil sorption, and/or biological uptake. This type of BMP can provide Runoff Treatment and conveyance, but not Flow Control.

Biological control

A method of controlling pest organisms by means of introduced or naturally occurring predatory organisms, sterilization, the use of inhibiting hormones, or other means, rather than by mechanical or chemical means.

Biological magnification

The increasing concentration of a substance along succeeding steps in a food chain. Also called biomagnification.

Bioretention BMPs

Engineered stormwater facilities that provide Runoff Treatment by passing the stormwater through a specified soil profile (Bioretention Soil Mix, or BSM), and typically either retain or detain the treated stormwater for Flow Control. Bioretention facilities include a variety of plant material including trees, shrubs, grasses, and/or other herbaceous plants adapted to the local climate and soil moisture conditions. Bioretention is typically implemented as an LID practice, and as such is typically sited to receive stormwater runoff from a small contributing area.

Biosolids

Municipal sewage sludge that is a primarily organic, semisolid product resulting from the wastewater treatment process, can be beneficially recycled, and meets all applicable requirements under Chapter 173-308 WAC. Biosolids include a material derived from biosolids and septic tank sludge, also known as septage, that can be beneficially recycled and meets all applicable requirements under Chapter 173-308 WAC. For the purposes of Chapter 173-308 WAC, semisolid products include biosolids or products derived from biosolids ranging in character from mostly liquid to fully dried solids.

Biotic integrity

The condition where the biologic or living community of an aquatic or terrestrial system is unimpaired and the complement of species diversity and richness expected for that system is present.

BMP

Best Management Practice

BOD

Biochemical Oxygen Demand

Bole

The trunk of a tree.

Bollard

A post (may or may not be removable) used to prevent vehicular access.

Bond

A surety bond, cash deposit or escrow account, assignment of savings, irrevocable letter of credit or other means acceptable to or required by the manager to guarantee that work is completed in compliance with the project's drainage plan and in compliance with all local government requirements.

Borrow area

A source of earth fill material used in the construction of embankments or other earth fill structures.

BSBL

Building Setback Line

BSM

Bioretention Soil Mix

BST

Bituminous Surface Treatment

Buffer

The area adjacent to a critical or sensitive area for which location and limits are described by federal, state, or local jurisdictions and intent is ensuring protection of the critical area by separating incompatible use from the critical or sensitive area.

Building setback line (BSBL)

A line measured parallel to a property, easement, drainage facility, or buffer boundary, that delineates the area (defined by the distance of separation) where buildings or other obstructions are prohibited (including decks, patios, outbuildings, or overhangs beyond 18 inches). Wooden or chain link fences and landscaping are allowable within a building setback line. In this manual the minimum building setback line shall be 5 feet.

- C -

California bearing ratio

A test using a plunger of a specific area to penetrate a soil sample to determine the load-bearing strength of a road subgrade.

Capital Improvement Project or Program (CIP)

A project prioritized and scheduled as a part of an overall construction program or, the actual construction program.

Catch basin

A chamber or well, usually built at the curb line of a street, for the admission of surface water to a sewer or subdrain, having at its base a sediment sump designed to retain grit and detritus below the point of overflow.

Catchline

The point where a severe slope intercepts a different, more gentle slope.

Catchment

Surface drainage area.

Cation exchange capacity (CEC)

The amount of exchangeable cations that a soil can adsorb. Units are milliequivalents per 100 grams of soil, typically abbreviated as meq. Soil found to have a CEC of 5 meq at pH 7.0 will have a CEC < 5 meq when pH < 7.0.

CAVFS

Compost-Amended Vegetated Filter Strip

CEC

Cation Exchange Capacity

Certified Erosion and Sediment Control Lead (CESCL)

An individual who has current certification through an approved erosion and sediment control training program that meets the minimum training standards established by Ecology (see BMP C160: Certified Erosion and Sediment Control Lead). A CESCL is knowledgeable in the principles and practices of erosion and sediment control. The CESCL must have the skills to assess site conditions and construction activities that could impact the quality of stormwater and, the effectiveness of erosion and sediment control measures used to control the quality of stormwater discharges. Certification is obtained through an Ecology approved erosion and sediment control course. Course listings are provided online at Ecology's website.

CESCL

Certified Erosion and Sediment Control Lead

CESCP

Contractor's Erosion and Sediment Control Plan

CFR

Code of Federal Regulations

Channel

A feature that conveys surface water and is open to the air.

Channel, constructed

Channels or ditches constructed (or reconstructed natural channels) to convey surface water.

Channel, natural

A stream, creek, or swale that conveys surface water and/or groundwater and has existed long enough to establish a stable route and/or biological community.

Channel stabilization

Erosion prevention and stabilization of velocity distribution in a channel using vegetation, jetties, drops, revetments, and/or other measures.

Channel storage

Water temporarily stored in channels while enroute to an outlet.

Channelization

Alteration of a stream channel by widening, deepening, straightening, cleaning, or paving certain areas to change flow characteristics.

Check dam

Small dam constructed in a gully or other small watercourse to decrease the streamflow velocity, minimize channel scour, and promote deposition of sediment.

Chemical oxygen demand (COD)

A measure of the amount of oxygen required to oxidize organic and oxidizable inorganic compounds in water. The COD test, like the BOD test, is used to determine the degree of pollution in water.

CIP

Capital Improvement Project

Civil engineer

A professional engineer licensed in the State of Washington in Civil Engineering.

Civil engineering

The application of the knowledge of the forces of nature, principles of mechanics and the properties of materials to the evaluation, design and construction of civil works for the beneficial uses of mankind.

Clay lens

A naturally occurring, localized area of clay which acts as an impermeable layer to runoff infilt-ration.

Clearing

The destruction and removal of vegetation by manual, mechanical, or chemical methods.

Closed depression

An area which is low-lying and either has no, or such a limited, surface water outlet that during storm events the area acts as a retention basin.

CN

Curve Number

COD

Chemical Oxygen Demand

Cohesion

The capacity of a soil to resist shearing stress, exclusive of functional resistance.

Coliform bacteria

Microorganisms common in the intestinal tracts of man and other warm-blooded animals; all the aerobic and facultative anaerobic, gram-negative, non-spore-forming, rod-shaped bacteria that ferment lactose with gas formation within 48 hours at 35°C. Used as an indicator of bacterial pollution.

Commercial agriculture

Those activities conducted on lands defined in RCW 84.34.020(2), and activities involved in the production of crops or livestock for commercial trade. An activity ceases to be considered commercial agriculture when the area on which it is conducted is proposed for conversion to a nonagricultural use or has lain idle for more than five years, unless the idle land is registered in a federal or state soils conservation program, or unless the activity is maintenance of irrigation ditches, laterals, canals, or drainage ditches related to an existing and ongoing agricultural activity.

Common plan of development or sale

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 include:

1. phased projects and projects with multiple filings or 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.

If the project is part of a common plan of development or sale, the disturbed area of the entire plan must be used in determining permit requirements.

Compaction

The densification, settlement, or packing of soil in such a way that permeability of the soil is reduced. Compaction effectively shifts the performance of a hydrologic soil group to a lower permeability hydrologic soil group. For example, a group B hydrologic soil can be compacted and effectively converted to a group C hydrologic soil in the way it performs in terms of runoff. Compaction may also refer to the densification of a fill by mechanical means.

Compost

Organic material that has undergone biological degradation and transformation under controlled conditions designed to promote aerobic decomposition at a solid waste facility in compliance with the requirements of Chapter 173-350 WAC, or biosolids composted in compliance with Chapter 173-308 WAC. Composting is a form of organic material recycling. Natural decay of organic solid waste under uncontrolled conditions does not result in composted material. (Note: Various BMPs have restrictions on the percentage of biosolids in compost, or do not allow biosolids in compost.)

Comprehensive planning

Planning that takes into account all aspects of water, air, and land resources and their uses and limits.

Concurrency

The timely provision of public facilities and services at the time when development occurs or within a specified period. The Growth Management Act requires that public facilities be provided concurrently with new development.

Conservation district

A public organization created under state enabling law as a special-purpose district to develop and carry out a program of soil, water, and related resource conservation, use, and development within its boundaries, usually a subdivision of state government with a local governing body and always with limited authority. Often called a soil conservation district or a soil and water conservation district.

Constructed wetland

Wetlands intentionally created on sites that are not wetlands for the primary purpose of wastewater or stormwater treatment and managed as such. Constructed wetlands are normally considered part of the stormwater collection and treatment system.

Construction Stormwater Pollution Prevention Plan (SWPPP)

A document that describes the potential for pollution problems on a construction project and explains and illustrates the measures to be taken on the construction site to control those problems.

Contour

An imaginary line on the surface of the earth connecting points of the same elevation.

Converted vegetation (areas)

The surfaces on a project site where native vegetation, pasture, scrub/shrub, or unmaintained non-native vegetation (e.g., Himalayan blackberry, scotch broom) are converted to lawn or landscaped areas, or where native vegetation is converted to pasture.

Conveyance

A mechanism for transporting water from one point to another, including pipes, ditches, and channels.

Conveyance system

The drainage facilities, both natural and constructed, that collect, contain, and provide for the flow of surface and stormwater from the highest points on the land down to a receiving water. The natural elements of the conveyance system include swales and small drainage courses, streams, rivers, lakes, and wetlands. The constructed elements of the conveyance system include gutters, ditches, pipes, channels, and most retention/detention facilities.

Cover crop

A close-growing crop grown primarily for the purpose of protecting and improving soil between periods of permanent vegetation.

CP

Coalescing Plate

CPESC

Certified Professional in Erosion and Sediment Control

Created wetland

Means those wetlands intentionally created from nonwetland sites to produce or replace natural wetland habitat (e.g., compensatory mitigation projects).

Critical areas

At a minimum, areas that include wetlands, areas with a critical recharging effect on aquifers used for potable water, fish and wildlife habitat conservation areas, frequently flooded areas, geologically hazardous areas (including unstable slopes), and associated areas and ecosystems.

Critical drainage area

An area with such severe flooding, drainage and/or erosion/sedimentation conditions that the area has been formally adopted as a Critical Drainage Area by rule under the procedures specified in an ordinance.

Critical reach

The point in a receiving stream below a discharge point at which the lowest dissolved oxygen level is reached and stream recovery begins.

Crown projection

The perimeter of a tree’s crown (outermost extent of the branches and foliage) projected vertically to the ground.

CSBC

Crushed Surfacing Base Course

CSO

Combined Sewer Overflow

CSWGP

Construction Stormwater General Permit

CTAPE

Chemical Technology Assessment Protocol–Ecology

CTRC

Chemical Technical Review Committee

CULD

Conditional Use Level Designation

Culvert

Pipe or concrete box structure that drains open channels, swales, or ditches under a roadway or embankment. Typically with no catch basins or manholes along its length.

Custom design storm

A synthetic rainfall event used to design Runoff Treatment BMPs in a particular jurisdiction. The design storm must be based on a statistical analysis of local historical precipitation data and reviewed and approved by the local jurisdiction.

Cut

Portion of land surface or area from which earth has been removed or will be removed by excavating; the depth below original ground surface to excavated surface.

Cut-and-fill

Process of earth moving by excavating part of an area and using the excavated material for adjacent embankments or fill areas.

Cut slope

A slope formed by excavating overlying material to connect the original ground surface with a lower ground surface created by the excavation. A cut slope is distinguished from a bermed slope, which is constructed by importing soil to create the slope.

- D -

Dangerous waste

According to RCW 70.105.010, any discarded, useless, unwanted, or abandoned substances, including, but not limited to, certain pesticides, or any residues or containers of such substances that are disposed of in such quantity or concentration as to pose a substantial, present, or potential hazard to human health, wildlife, or the environment. These wastes may have short-lived, toxic properties that may cause death, injury, or illness or have mutagenic, teratogenic, or carcinogenic properties; or be corrosive, explosive, flammable; or may generate pressure through decomposition or other means. See also Hazardous waste.

Dead storage

The volume available in a depression in the ground below any conveyance system, or surface drainage pathway, or outlet invert elevation that could allow the discharge of surface and stormwater runoff.

Dedication of land

Refers to setting aside a portion of a property for a specific use or function.

Degradation

(Biological or chemical) The breakdown of complex organic or other chemical compounds into simpler substances, usually less harmful than the original compound, as with the degradation of a persistent pesticide. (Geological) Wearing down by erosion. (Water) The lowering of the water quality of a watercourse by an increase in the pollutant loading.

Degraded (disturbed) wetland (community)

A wetland (community) in which the vegetation, soils, and/or hydrology have been adversely altered, resulting in lost or reduced functions and values; generally, implies topographic isolation; hydrologic alterations such as hydroperiod alteration (increased or decreased quantity of water), diking, channelization, and/or outlet modification; soils alterations such as presence of fill, soil removal, and/or compaction; accumulation of toxicants in the biotic or abiotic components of the wetland; and/or low plant species richness with dominance by invasive weedy species.

Denitrification

The microbial process of reducing nitrates to gaseous forms of nitrogen, nitrous oxide (N_2O), or dinitrogen (N_2). This process occurs in anaerobic conditions (low oxygen), and requires an energy source such as organic matter for microbial growth.

Depression storage

The amount of precipitation that is trapped in depressions on the surface of the ground.

Design deviation

Project-specific modification of one or more design criteria based on site-specific conditions approved by the local jurisdiction.

Designer

The professional civil engineer licensed in the State of Washington who prepares the analysis, design, and engineering plans for an applicant's permit or approval submittal.

Design storm

A prescribed hyetograph or precipitation distribution and the total precipitation amount (for a specific duration recurrence frequency) used to estimate runoff for a hypothetical storm of interest or concern for the purposes of analyzing existing drainage, designing new drainage facilities, or assessing other impacts of a proposed project on the flow of surface water. Examples include the SCS Type IA and Type II storms, modified Type IA storms, regional storms, long-duration storms, short-duration storms, and custom design storms.

Design storm frequency

The anticipated period in years that will elapse, based on the average probability of storms in the design region, before a storm of a given intensity and/or total volume will recur. Thus a 10-year storm can be expected to occur on the average once every 10 years; the same storm has a 10% chance of occurring each year. Facilities designed to handle flows that occur under such storm conditions would be expected to be surcharged by any storms of greater amount or intensity.

Detention

The release of stormwater runoff from the site at a slower rate than it is collected by the stormwater BMP, the difference being held in temporary storage.

Detention BMP

An aboveground or belowground facility, such as a pond or tank, that temporarily stores stormwater runoff and subsequently releases it at a slower rate than it is collected by the drainage system. There is little or no infiltration of stored stormwater.

Detention time

The theoretical time required to displace the contents of the live storage within a Runoff Treatment or Flow Control BMP at a given rate of discharge (volume divided by rate of discharge).

Determination of Nonsignificance (DNS)

The written decision by the responsible official of the lead agency that a proposal is not likely to have a significant adverse environmental impact, and therefore an EIS is not required.

Development

New development, Redevelopment, or both. See definitions for each.

Discharge

Runoff leaving a new development or redevelopment via overland flow, built conveyance systems, or infiltration facilities. A hydraulic rate of flow, specifically fluid flow; a volume of fluid passing a point per unit of time, commonly expressed as cubic feet per second, cubic meters per second, gallons per minute, gallons per day, or million gallons per day.

Dispersion

Release of surface and stormwater runoff such that the flow spreads over a wide area and is located so as not to allow flow to concentrate anywhere upstream of a drainage channel with erodible underlying granular soils.

Ditch

A long narrow excavation dug in the earth for drainage with its top width less than 10 feet at design flow.

Divide, Drainage

The boundary between one drainage basin and another.

DNR

Washington State Department of Natural Resources

DNS

Determination of Nonsignificance

DOH

Washington State Department of Health

Drain

A buried pipe or other conduit (closed drain). A ditch (open drain) for carrying off surplus surface water or groundwater.

(To) Drain

To provide channels, such as open ditches or closed drains, so that excess water can be removed by surface flow or by internal flow. To lose water (from the soil) by percolation.

Drainage

Refers to the collection, conveyance, containment, and/or discharge of surface and stormwater runoff.

Drainage basin

A geographic and hydrologic subunit of a watershed.

Drainage channel

A drainage pathway with a well-defined bed and banks indicating frequent conveyance of surface and stormwater runoff.

Drainage course

A pathway for watershed drainage characterized by wet soil vegetation; often intermittent in flow.

Drainage easement

A legal encumbrance that is placed against a property's title to reserve specified privileges for the users and beneficiaries of the drainage facilities contained within the boundaries of the easement.

Drainage pathway

The route that surface and stormwater runoff follows downslope as it leaves any part of the site.

Drainage review

An evaluation of a proposed project's compliance with drainage requirements.

Drainage, Soil

As a natural condition of the soil, soil drainage refers to the frequency and duration of periods when the soil is free of saturation; for example, in well-drained soils the water is removed readily but not rapidly; in poorly drained soils the root zone is waterlogged for long periods unless artificially drained, and the roots of ordinary crop plants cannot get enough oxygen; in excessively drained soils the water is removed so completely that most crop plants suffer from lack of water. Strictly speaking, excessively drained soils are a result of excessive runoff due to steep slopes or low available water-holding capacity due to small amounts of silt and clay in the soil material. The following classes are used to express soil drainage:

- Well drained - Excess water drains away rapidly and no mottling occurs within 36 inches of the surface.
- Moderately well drained - Water is removed from the soil somewhat slowly, resulting in small but significant periods of wetness. Mottling occurs between 18 and 36 inches.
- Somewhat poorly drained - Water is removed from the soil slowly enough to keep it wet for significant periods but not all of the time. Mottling occurs between 8 and 18 inches.
- Poorly drained - Water is removed so slowly that the soil is wet for a large part of the time. Mottling occurs between 0 and 8 inches.
- Very poorly drained - Water is removed so slowly that the water table remains at or near the surface for the greater part of the time. There may also be periods of surface ponding. The soil has a black to gray surface layer with mottles up to the surface.

Drainage system

The system of gutters, pipes, streams, or ditches used to carry surface water and stormwater from surrounding lands to streams or lakes. Includes constructed and natural features that function together as a system to collect, convey, channel, hold, inhibit, retain, detain, infiltrate, divert, treat, or filter stormwater.

Drawdown

Lowering of the water surface (in open-channel flow), water table, or piezometric surface (in groundwater flow) resulting from a withdrawal of water.

Drop-inlet spillway

Overall structure in which the water drops through a vertical riser connected to a discharge conduit.

Drop spillway

Overall structure in which the water drops over a vertical wall onto an apron at a lower elevation.

Drop structure

A structure for dropping water to a lower level and dissipating its surplus energy; a fall. A drop may be vertical or inclined.

Dry weather flow

The combination of groundwater seepage and allowed non-stormwater flows found in storm sewers during dry weather. Also that flow in streams during the dry season.

Drywell

A well completed above the water table so that its bottom and sides are typically dry except when receiving fluids. Drywells are designed to disperse water below the land surface and are commonly used for stormwater management in eastern Washington. See also UIC.

- E -

Earth material

Any rock, natural soil or fill and/or any combination thereof. Earth material shall not be considered topsoil used for landscape purposes. Topsoil used for landscaped purposes shall comply with ASTM D5268 specifications. Engineered soil/landscape systems are also defined independently.

Easement

The legal right to use a parcel of land for a particular purpose. It does not include fee ownership, but may restrict the owner's use of the land.

Ecology

Washington State Department of Ecology

Effective impervious surface

Those impervious surfaces that are connected via sheet flow or discrete conveyance to a drainage system. Impervious surfaces are considered ineffective if:

1. the runoff is fully dispersed in accordance with BMP F6.42: Full Dispersion;
2. residential roof runoff is infiltrated in accordance with BMP T5.10A: Downspout Full Infiltration; or
3. all runoff from the impervious surface is infiltrated (i.e. calculations show that the 100-yr, 3-hr storm OR the 100-yr, 72-hr storm, whichever is larger, is fully infiltrated).

EIA

Effective Impervious Area

EIS

Environmental Impact Statement

Embankment

A structure of earth, gravel, or similar material raised to form a pond bank or foundation for a road.

Emergency spillway

A vegetated earth channel used to safely convey flood discharges in excess of the capacity of the principal spillway.

Emergent plants

Aquatic plants that are rooted in the sediment but whose leaves are at or above the water surface. These wetland plants often have high habitat value for wildlife and waterfowl, and can aid in pollutant uptake.

Emerging technology

Treatment technologies that have not been evaluated with approved protocols, but for which preliminary data indicate that they may provide a necessary function(s) in a stormwater treatment system. Emerging technologies need additional evaluation to define design criteria to achieve, or to contribute to achieving, state performance goals, and to define the limits of their use.

Energy dissipator

Any means by which the total energy of flowing water is reduced. In stormwater design, they are usually mechanisms that reduce velocity prior to, or at, the point of discharge from an outfall in order to prevent erosion. They include rock splash pads, drop manholes, concrete stilling basins or baffles, and check dams.

Energy gradient

The slope of the specific energy line (i.e., the sum of the potential and velocity heads).

Engineered soil/ landscape system

This is a self-sustaining soil and plant system that simultaneously supports plant growth, soil microbes, water infiltration, nutrient and pollutant adsorption, sediment and pollutant biofiltration, water interflow, and pollution decomposition. The system shall be protected from compaction and erosion. The system shall be planted and/or mulched as part of the installation.

The engineered soil/plant system shall have the following characteristics:

a. Be protected from compaction and erosion.

b. Have a plant system to support a sustained soil quality.

c. Possess permeability characteristics of not less than 6.0, 2.0, and 0.6 inches/hour for hydrologic soil groups A, B, and C, respectively (per ASTM D3385). D is less than 0.6 inches/hour.

d. Possess minimum percent organic matter of 12, 14, 16, and 18 percent (dry-weight basis) for hydrologic soil groups A, B, C, and D, respectively (per ASTM D2974).

Engineering geology

The application of geologic knowledge and principles in the investigation and evaluation of naturally occurring rock and soil for use in the design of civil works.

Engineering plan

A plan prepared and stamped by a professional civil engineer.

Enhancement

To raise value, desirability, or attractiveness of an environment associated with surface water.

Environmental Impact Statement (EIS)

A document that discusses the likely significant adverse impacts of a proposal, ways to lessen the impacts, and alternatives to the proposal. They are required by the national and state environmental policy acts when projects are determined to have significant environmental impact.

EPA

U.S. Environmental Protection Agency

Erodible granular soils

Soil materials that are easily eroded and transported by running water, typically fine or medium grained sand with minor gravel, silt, or clay content. Such soils are commonly described as Everett or Indianola series soil types in the SCS classification. Also included are any soils showing examples of existing severe stream channel incision as indicated by unvegetated streambanks standing over two feet high above the base of the channel.

Erodible or leachable materials

Wastes, chemicals, or other substances that measurably alter the physical or chemical characteristics of runoff when exposed to rainfall. Examples include erodible soils that are stockpiled, uncovered process wastes, manure, fertilizers, oily substances, ashes, kiln dust, and garbage dumpster leakage.

Erosion

The wearing away of the land surface by running water, wind, ice, or other geological agents, including such processes as gravitational creep. Also, detachment and movement of soil or rock fragments by water, wind, ice, or gravity. The following terms are used to describe different types of water erosion:

- Accelerated erosion - Erosion much more rapid than normal or geologic erosion, primarily as a result of the influence of the activities of man or, in some cases, of the animals or natural catastrophes that expose bare surfaces (e.g., fires).
- Geological erosion - The normal or natural erosion caused by geological processes acting over long geologic periods and resulting in the wearing-away of mountains, the building up of floodplains, coastal plains, etc. Synonymous with natural erosion.
- Gully erosion - The erosion process whereby water accumulates in narrow channels and, over short periods, removes the soil from this narrow area to considerable depths, ranging from 1 to 2 feet to as much as 75 to 100 feet.
- Natural erosion - Wearing away of the earth's surface by water, ice, or other natural agents under natural environmental conditions of climate, vegetation, etc., undisturbed by man. Synonymous with geological erosion.
- Normal erosion - The gradual erosion of land used by man which does not greatly exceed natural erosion.
- Rill erosion - An erosion process in which numerous small channels only several inches deep are formed; occurs mainly on recently disturbed and exposed soils. See Rill.
- Sheet erosion - The removal of a fairly uniform layer of soil from the land surface by runoff.
- Splash erosion - The spattering of small soil particles caused by the impact of raindrops on wet soils. The loosened and spattered particles may or may not be subsequently removed by surface runoff.

Erosion and sediment control facility

A type of stormwater BMP, typically used during construction, designed to hold water for a period of time to allow sediment contained in the stormwater runoff directed to the facility to settle out, filter, or change chemically so as to improve the quality of the runoff.

Erosion and sediment control (ESC)

Any temporary or permanent measures taken to reduce erosion, control siltation and sedimentation, and ensure that sediment-laden water does not leave the site.

Erosion classes (soil survey)

A grouping of erosion conditions based on the degree of erosion or on characteristic patterns. Applied to accelerated erosion, not to normal, natural, or geological erosion. Four erosion classes are recognized for water erosion and three for wind erosion.

ESA

Endangered Species Act (federal)

ESAL

Equivalent Single-Axle Load

ESC

Erosion and Sediment Control

Escarpment

A steep face or a ridge of high land.

Estuarine wetland

Generally, an eelgrass bed; salt marsh; or rocky, sandflat, or mudflat intertidal area where fresh and salt water mix. (Specifically, a tidal wetland with salinity greater than 0.5 parts per thousand, usually semi-enclosed by land but with partially obstructed or sporadic access to the open ocean).

Estuary

An area where fresh water meets salt water, or where the tide meets the river current (e.g., bays, mouths of rivers, salt marshes, and lagoons). Estuaries serve as nurseries and spawning and feeding grounds for large groups of marine life and provide shelter and food for birds and wildlife.

Eutrophication

The process where nutrient over-enrichment of water leads to excessive growth of aquatic plants, especially algae.

Evapotranspiration

The collective term for the processes of water returning to the atmosphere by interception and evaporation from plant surfaces and transpiration through plant leaves.

Excavation

The mechanical removal of earth material.

Exception

Relief from the application of a Core Element to a project.

Exfiltration

The downward movement of runoff through the bottom of an infiltration BMP into the soil layer or the downward movement of water through soil.

Existing condition

The impervious surfaces, drainage systems, land cover, native vegetation, 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. If sites have impervious areas and drainage systems that were built without approved permits, the existing condition is defined as those that existed prior to the first issue date of the Municipal Stormwater Permit to the local jurisdiction. Existing conditions may be verified using aerial photography or other records.

- F -

FCWA

Federal Clean Water Act

FEMA

Federal Emergency Management Agency

Fertilizer

Any material or mixture used to supply one or more of the essential plant nutrient elements.

FHWA

Federal Highway Administration

FIFRA

Federal Insecticide, Fungicide, and Rodenticide Act

Fill

A deposit of earth material placed by artificial means.

Filter fabric

A woven or nonwoven, water-permeable material generally made of synthetic products such as polypropylene and used in stormwater management and erosion and sediment control applications to trap sediment or prevent the clogging of aggregates by fine soil particles.

Filter fabric fence

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. Also commonly referred to in the Washington Department of Transportation standard specifications as “construction geotextile for temporary silt fences.”

Filter strip

A grassy area with gentle slopes that treats stormwater runoff from adjacent paved areas before it concentrates into a discrete channel.

FIRM

Flood Insurance Rate Map

First order stream

An unbranched tributary, which is a continuous perennial stream reach, meaning that the water table is always above the bottom of the stream channel during a year of normal precipitation and the perennial reach continues downstream to a confluence with another perennial stream.

Fish-bearing stream

Determined by the local jurisdiction based on readily available data. According to WAC 222-16-030: Type S, F, and Np waters are fish habitat streams. Until these fish habitat water type maps are available, an interim water typing system applies (see WAC 222-16-031): Type 1, 2, 3, and 4 waters are fish habitat streams.

Flocculation

The process by which suspended colloidal or very fine particles are assembled into larger masses or floccules that eventually settle out of suspension. This process occurs naturally but can also result from the use of chemicals such as alum.

Flood

An overflow or inundation that comes from a river or any other source, including (but not limited to) streams, tides, wave action, storm drains, or excess rainfall. Any relatively high stream flow overtopping the natural or artificial banks in any reach of a stream.

Flood-proofing

Adaptations that ensure a structure is substantially impermeable to the passage of water below the flood protection elevation that resists hydrostatic and hydrodynamic loads and effects of buoyancy.

Flood control

Methods or facilities for reducing flood flows and the extent of flooding.

Flood control project

A structural system installed to protect land and improvements from floods by the construction of dikes, river embankments, channels, or dams.

Flood frequency

The frequency with which the flood of interest may be expected to occur at a site in any average interval of years. Frequency analysis defines the "n-year flood" as being the flood that will, over a long period of time, be equaled or exceeded on the average once every "n" years.

Flood fringe

That portion of the floodplain outside of the floodway which is covered by floodwaters during the base flood; it is generally associated with slower moving or standing water rather than rapidly flowing water.

Flood hazard areas

Those areas subject to inundation by the base flood. Includes, but is not limited to streams, lakes, wetlands, and closed depressions.

Flood Insurance Rate Map (FIRM)

The official map on which the Federal Emergency Management Agency has delineated many areas of flood hazard, floodway, and the risk premium zones.

Flood Insurance Study

The official report provided by the Federal Emergency Management Agency that includes flood profiles and the FIRM.

Flood peak

The highest value of the stage or discharge attained by a flood; thus, peak stage or peak discharge.

Flood protection elevation

The base flood elevation or higher as defined by the local government.

Flood protection facility

Any levee, berm, wall, enclosure, raise bank, revetment, constructed bank stabilization, or armoring, that is commonly recognized by the community as providing significant protection to a property from inundation by flood waters.

Flood routing

An analytical technique used to compute the effects of system storage dynamics on the shape and movement of flow represented by a hydrograph.

Flood stage

The stage at which overflow of the natural banks of a stream begins.

Floodplain

The total area subject to inundation by a flood including the flood fringe and floodway.

Floodway

The channel of the river or stream and those portions of the adjoining floodplains that are reasonably required to carry and discharge the base flood flow. The portions of the adjoining floodplains which are considered to be "reasonably required" is defined by flood hazard regulations.

Flow Control based performance standard

A performance standard that is based on the volume and/or velocity of flow, which must be met by using Flow Control BMPs. Examples of Flow Control based performance standards are:

- The Flow Control Performance Standard in 2.4.6 CE6: Flow Control
- Hydroperiod protection requirements in 2.4.8 CE8: Wetlands Protection

Flow control BMP

A stormwater facility designed to mitigate the impacts of increased surface and stormwater runoff flow rates generated by development. Flow control BMPs are designed either to hold water for a considerable length of time and then release it by evaporation, plant transpiration, and/or infiltration into the ground, or to hold runoff for a short period of time, releasing it to the conveyance system at a controlled rate.

Flow duration

The aggregate time that peak flows are at or above a particular flow rate of interest. For example, the amount of time that peak flows are at or above 50% of the 2-year peak flow rate for a period of record.

Flow frequency

The inverse of the probability that the flow will be equaled or exceeded in any given year (the exceedance probability). For example, if the exceedance probability is 0.01 or 1 in 100, that flow is referred to as the 100-year flow.

Flow path

The route that stormwater runoff follows between two points of interest.

Forebay

An easily maintained, extra storage area provided near an inlet of a BMP to trap incoming sediments before they accumulate in a pond or wetland BMP.

Forest practice

Any activity conducted on or directly pertaining to forest land and relating to growing, harvesting, or processing timber, including but not limited to:

a. Road and trail construction.

b. Harvesting, final and intermediate.

c. Precommercial thinning.

d. Reforestation.

e. Fertilization.

f. Prevention and suppression of diseases and insects.

g. Salvage of trees.

h. Brush control.

Forested communities (wetlands)

In general terms, communities (wetlands) characterized by woody vegetation that is greater than or equal to 6 meters in height; in this manual the term applies to such communities (wetlands) that represent a significant amount of tree cover consisting of species that offer wildlife habitat and other values and advance the performance of wetland functions overall.

Freeboard

The vertical distance between the highest designed water surface elevation and the elevation of the crest of the facility. For example, in pond design, freeboard is the vertical distance between the emergency overflow water surface and the top of the pond embankment.

Freeway

A multilane, arterial highway with full access control.

Frequently flooded areas

The 100-year floodplain designations of the Federal Emergency Management Agency and the National Flood Insurance Program or as defined by the local government.

Frost-heave

The upward movement of soil surface due to the expansion of water stored between particles in the first few feet of the soil profile as it freezes. May cause surface fracturing of asphalt or concrete.

Fully controlled limited access highway

A highway where the right of owners or occupants of abutting land or other persons to access, light, air, or view in connection with the highway is controlled to give preference to through traffic by providing access connections with selected public roads only, and by prohibiting crossings or direct private driveway connections at grade (see WAC 468-58-010).

- G -

Gabion

A rectangular or cylindrical wire mesh cage (a chicken wire basket) filled with rock and used as a protecting agent, revetment, etc., against erosion. Soft gabions, often used in streambank stabilization, are made of geotextiles filled with soil, in between which cuttings are placed.

Gauge

A device for registering precipitation, water level, discharge, velocity, pressure, temperature, etc. Also, a measure of the thickness of metal; e.g., diameter of wire or wall thickness of steel pipe.

Gaging station

A selected section of a stream channel equipped with a gage, recorder, or other facilities for determining stream discharge.

Geologically hazardous areas

Areas that because of their susceptibility to erosion, sliding, earthquake, or other geological events, are not suited to the siting of commercial, residential, or industrial development consistent with public health or safety concerns.

Geologist

A person who has earned a degree in geology from an accredited college or university or who has equivalent educational training and has at least five years of experience as a practicing geologist or four years of experience and at least two years post-graduate study, research or teaching. The practical experience shall include at least three years work in applied geology and landslide evaluation, in close association with qualified practicing geologists or geotechnical professional/civil engineers.

Geometrics

The mathematical relationships between points, lines, angles, and surfaces used to measure and identify areas of land.

Geotechnical professional civil engineer

A practicing, geotechnical/civil engineer licensed as a professional Civil Engineer with the State of Washington who has at least four years of professional employment as a geotechnical engineer in responsible charge, including experience with landslide evaluation.

Grade

The slope of a road, channel, or natural ground. The finished surface of a canal bed, roadbed, top of embankment, or bottom of excavation; any surface prepared for the support of construction such as paving or the laying of a conduit.

(To) Grade

To finish the surface of a canal bed, roadbed, top of embankment or bottom of excavation.

Gradient terrace

An earth embankment or a ridge-and-channel constructed with suitable spacing and an acceptable grade to reduce erosion damage by intercepting surface runoff and conducting it to a stable outlet at a stable nonerosive velocity.

Grassed waterway

A natural or constructed waterway, usually broad and shallow, covered with erosion-resistant grasses, used to conduct surface water from an area at a reduced flow rate. See also biofilter.

Groundwater

Water in a saturated zone or stratum beneath the land surface or beneath a surface water body (WAC 173-200-020).

Groundwater protection area

A geographic area that is by or close by a surrounding community and nontransient noncommunity water system, that uses groundwater as a source of drinking water (40 C.F.R. 144.87) and other sensitive groundwater areas critical to protecting underground sources of drinking water from contamination; such as sole source aquifers, highly productive aquifers supplying private wells, critical aquifer recharge areas and/or other state and local areas determined by state and local governments.

Groundwater recharge

Inflow to a groundwater reservoir or aquifer.

Groundwater table

The free surface of the groundwater, that surface subject to atmospheric pressure under the ground, generally rising and falling with the season, the rate of withdrawal, the rate of restoration, and other conditions. It is seldom static.

GULD

General Use Level Designation

Gully

A channel caused by the concentrated flow of surface and stormwater runoff over unprotected erodible land.

- H -

Habitat

The specific area or environment in which a particular type of plant or animal lives. An organism's habitat must provide all of the basic requirements for life and should be protected from harmful biological, chemical, and physical alterations.

Hard surface

An impervious surface, a permeable pavement, or a vegetated roof.

Hardpan

A cemented or compacted and often clay-like layer of soil that is impenetrable by roots. Also known as glacial till.

Harmful pollutant

A substance that has adverse effects to an organism including immediate death, chronic poisoning, impaired reproduction, cancer, or other effects.

Hazardous substance

Any liquid, solid, gas, or sludge, including any material, substance, product, commodity, or waste, regardless of quantity, that exhibits any of the physical, chemical, or biological properties described in WAC 173-303-090 or WAC 173-303-100. See also Dangerous waste.

Hazardous waste

According to RCW 70.105.010, all dangerous and extremely hazardous waste, including substances composed of both radioactive and hazardous components. See also Dangerous waste.

Head (hydraulics)

The height of water above any plane of reference. The energy, either kinetic or potential, possessed by each unit weight of a liquid, expressed as the vertical height through which a unit weight would have to fall to release the average energy possessed. Used in various compound terms such as pressure head, velocity head, and head loss.

Head loss

Energy loss due to friction, eddies, changes in velocity, or changes in direction of flow.

Heavy metals

Metals of high specific gravity that are present in municipal and industrial wastes and pose long-term environmental hazards. Heavy metals include antimony, arsenic, beryllium, cadmium, chromium, cobalt, copper, lead, mercury, nickel, selenium, thallium, and zinc.

High-ADT roadways and parking areas

Any road with average daily traffic (ADT) > 30,000 vehicles; and parking areas with either more than 100 trip ends per 1,000 square feet of gross building area or > 300 total trip ends are high-use traffic areas. Examples include commercial buildings with a frequent turnover of customers and other visitors.

High-use site

A site that typically generates high concentrations of oil due to high traffic turnover or the frequent transfer of oil and/or other petroleum products. High-use sites include:

- 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, or 300 total trips ends per day;
- 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;
- 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.);
- 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.

Highway

A main public road connecting towns and cities.

Hog fuel

Wood-based mulch.

HPA

Hydraulic Project Approval

HRM

Highway Runoff Manual

HSPF

Hydrological Simulation Program-Fortran. A continuous simulation hydrologic model that transforms an uninterrupted rainfall record into a concurrent series of runoff or flow data by means of a set of mathematical algorithms that represent the rainfall-runoff process at some conceptual level.

Humus

Organic matter in or on a soil, composed of partly or fully decomposed bits of plant tissue or from animal manure.

Hydraulic conductivity

The quality of saturated soil that enables water or air to move through it. Also known as permeability coefficient.

Hydraulic gradient

Slope of the potential head relative to a fixed datum.

Hydrodynamics

Means the dynamic energy, force, or motion of fluids as affected by the physical forces acting upon those fluids.

Hydrograph

A graph of runoff rate, inflow rate, discharge rate, or another characteristic of a body of water during a specific period.

Hydrologic cycle

The circuit of water movement from the atmosphere to the earth and return to the atmosphere through various stages or processes as precipitation, interception, runoff, infiltration, percolation, storage, evaporation, and transpiration.

Hydrologic Soil Groups

A soil characteristic classification system defined by the Natural Resources Conservation Service in which a soil may be categorized into one of four soil groups (A, B, C, or D) based upon infiltration rate and other properties.

Type A: Low runoff potential. Soils having high infiltration rates, even when thoroughly wetted, and consisting chiefly of deep, well drained to excessively drained sands or gravels. These soils have a high rate of water transmission.

Type 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.

Type 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.

Type 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, till, or clay layer at or near the surface, soils with a compacted subgrade at or near the surface, and shallow soils or nearly impervious material. These soils have a very slow rate of water transmission.

(Novotny and Olem, 1994)

Hydrology

The science of the behavior of water in the atmosphere, on the surface of the earth, and underground.

Hydroperiod

A seasonal occurrence of flooding and/or soil saturation; it encompasses depth, frequency, duration, and seasonal pattern of inundation.

Hyetograph

A graph or table of percentages of total precipitation for a series of time steps representing the total time in which precipitation occurs.

- I -

ICPI

Interlocking Concrete Pavement Institute

IECA

International Erosion Control Association

IFC

International Fire Code

Illicit discharge

All non-stormwater discharges to stormwater drainage systems that cause or contribute to a violation of state water quality, sediment quality, or groundwater quality standards, including but not limited to sanitary sewer connections, industrial process water, interior floor drains, car washing, and greywater systems.

Impact basin

A device used to dissipate the energy of flowing water. Generally constructed of concrete in the form of a partially depressed or partially submerged vessel, it may utilize baffles to dissipate velocities.

Impaired waters

Water bodies that do not fully support their beneficial uses.

Impervious

A surface which cannot be easily penetrated. For instance, rain does not readily penetrate paved surfaces.

Impervious surface

A surface area which either prevents or retards the entry of water into the soil mantle as under natural conditions prior to development. A surface area which causes water to run off the surface in greater quantities or at an increased rate of flow from the flow present under natural conditions prior to development. Common impervious surfaces include, but are not limited to, roof tops, walkways, patios, driveways, parking lots or storage areas, concrete or asphalt paving, gravel roads, packed earthen materials, and oiled, macadam or other surfaces which similarly impede the natural infiltration of stormwater.

- For purposes of determining whether the thresholds for application of Core Elements are exceeded, open, uncovered retention or detention BMPs shall not be considered as impervious surfaces. Open, uncovered retention or detention BMPs shall be considered impervious surfaces for the purposes of runoff modeling.
- When an underdrain (not intended to infiltrate) is used below an artificial turf surface, that surface shall be considered (and modeled) as impervious surface.

Impoundment

A natural or constructed containment for surface water.

Improvements

The term “improvements” may refer to existing improvements or improvement projects.

- Existing improvements include streets (with or without curbs or gutters), sidewalks, crosswalks, parking lots, water mains, sanitary and storm sewers, drainage facilities, street trees and other appropriate items.
- Improvement projects replace paved or other impervious areas with a better surface, and/or in a way that enhances the traffic-carrying capacity of a road or parking area and/or improves safety.

Industrial activities

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.

Ineffective impervious surface

Impervious surfaces on residential development sites where the runoff is not concentrated and is dispersed by means of sheet flow off the pavement, and then through at least 100 feet of native vegetation before flowing into a drainage system. An example is a tennis court in the middle of a park.

Infiltration

The downward movement of water from the land surface to the subsoil.

Infiltration BMP

A drainage facility designed to use the hydrologic process of surface and stormwater runoff soaking into the ground, commonly referred to as a percolation, to dispose of surface and stormwater runoff.

Infiltration rate

The rate, usually expressed in inches/hour, at which water moves downward (percolates) through the soil profile. Short-term infiltration rates may be inferred from soil analysis or derived from field measurements. Long-term infiltration rates are affected by variability in soils and subsurface conditions at the site, the effectiveness of pretreatment or influent control, and the degree of long-term maintenance of the infiltration BMP.

Ingress/egress

The points of access to and from a property.

Inlet

A form of connection between surface of the ground and a stormwater conveyance system for the admission of surface and stormwater runoff.

Insecticide

A substance, usually chemical, that is used to kill insects.

Interception (Hydraulics)

The process by which precipitation is caught and held by foliage, twigs, and branches of trees, shrubs, and other vegetation. Often used for "interception loss" or the amount of water evaporated from the precipitation intercepted.

Interflow

That portion of rainfall 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 for example, in a roadside ditch, wetland, spring or seep. Interflow is a function of the soil system depth, permeability, and water-holding capacity.

Intermittent stream or intermittent channel

A stream or portion of a stream that flows only in direct response to precipitation. Intermittent streams receive little or no water from springs and no long-continued supply from melting snow or other sources and are dry for a large part of the year, ordinarily more than three months.

Invasive weedy plant species

Opportunistic species of inferior biological value that tend to out compete more desirable forms and become dominant; applied to non native species in this manual.

Invert

The lowest point on the inside of a sewer, drainage pipe, or other conduit.

Invert elevation

The vertical elevation of a pipe or orifice in a pond that defines the water level.

IPM

Integrated Pest Management

Irrigation ditch

The portion of a designed and constructed conveyance system that serves the purpose of transporting irrigation water from its supply source to its place of use. This may include natural watercourses or channels incorporated in the system design but does not include the area adjacent to the watercourse or channel.

ISA

International Society of Arboriculture

Isopluvial map

A map with lines representing the constant depth of total precipitation for a given return frequency.

ISGP

Industrial Stormwater General Permit

- J -

- K -

- L -

Lag time

The interval between the center of mass of the storm precipitation and the peak flow of the resultant runoff.

Lake

An area permanently inundated by water in excess of two meters deep and greater than 20 acres in size as measured at the ordinary high water marks.

Land disturbing activity

Any activity that results in a change in the existing soil cover (both vegetative and nonvegetative) and/or the existing soil topography. Land disturbing activities include, but are not limited to clearing, grading, filling, and excavation. Compaction that is associated with stabilization of structures and road construction shall also be considered a land disturbing activity. Vegetation maintenance practices, including landscape maintenance and gardening, are not considered land-disturbing activity. Stormwater facility maintenance is not considered land disturbing activity if conducted according to established standards and procedures.

Landslide

Episodic downslope movement of a mass of soil or rock that includes but is not limited to rockfalls, slumps, mudflows, and earthflows. For the purpose of these rules, snow avalanches are considered to be a special case of landsliding.

Landslide hazard areas

Those areas subject to a severe risk of landslide.

Leachable materials

Substances that, when exposed to rainfall, measurably alter the physical or chemical characteristics of the rainfall runoff. Examples include erodible soils, uncovered process wastes, manure, fertilizers, oil substances, ashes, kiln dust, and garbage dumpster leakage.

Leachate

Liquid that has percolated through soil and contains substances in solution or suspension.

Leaching

Removal of the more soluble materials from the soil by percolating waters.

Legume

A member of the legume or pulse family, Leguminosae, one of the most important and widely distributed plant families. The fruit is a "legume" or pod. Includes many valuable food and forage species, such as peas, beans, clovers, alfalfas, sweet clovers, and vetches. Practically all legumes are nitrogen-fixing plants.

Level-pool routing

The basic technique of storage routing used for sizing and analyzing detention storage and determining water levels for ponding water bodies. The level-pool routing technique is based on the continuity equation: Inflow – Outflow = Change in storage.

Level spreader

A temporary ESC device used to spread out stormwater runoff uniformly over the ground surface as sheet flow (i.e., not through channels). The purpose of level spreaders is to prevent concentrated, erosive flows from occurring, and to enhance infiltration.

LID

Low Impact Development

Liquefaction

The temporary transformation of a soil mass of soil or sediment into a fluid mass. Liquefaction occurs when the cohesion of particles in the soil or sediment is lost.

Local government

Any county, city, town, or special purpose district having its own incorporated government for local affairs.

Local jurisdiction

Any county, city, town, or special-purpose district having its own incorporated government for local affairs.

Long-duration design storm

One of the four design storms consisting of two rainfall events separated by a dry period that were developed for climate regions identified in eastern Washington. The storms were based on a statistical analysis of historical precipitation in eastern Washington and have been adapted for use in this manual as single-hump design storms consisting of only one continuous rainfall event. See Modified SCS Type IA design storm and Regional design storm. Also see further discussion in Appendix 4-A: Background Information on Design Storms and Selected Modeling Methods

Los Angeles (L.A.) abrasion

The standard L.A. abrasion test subjects a coarse aggregate sample (retained on the No. 12 or 1.70-millimeter [mm] sieve) to abrasion, impact, and grinding in a rotating steel drum containing a specified number of steel spheres. After being subjected to the rotating drum, the weight of aggregate that is retained on a No. 12 (1.70 mm) sieve is subtracted from the original weight to obtain a percentage of the total aggregate weight that has broken down and passed through the No. 12 (1.70 mm) sieve. Therefore, an L.A. abrasion loss value of 40 indicates that 40% of the original sample passed through the No. 12 (1.70 mm) sieve. The standard Los Angeles abrasion test is AASHTO T 96 or ASTM C 131, Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine.

Low-ADT roadways and parking areas

Urban roads with average daily traffic (ADT) fewer than 7,500 vehicles, rural roads and freeways with ADT < 15,000 vehicles, and parking areas with both < 40 trip ends per 1,000 square feet of gross building area and < 100 total trip ends per day are considered low-use traffic areas. Examples include most residential parking and employee-only parking areas for small office parks or other commercial buildings. Urban roads are located within designated Urban Growth Management Areas; rural roads are located outside designated Urban Growth Management Areas. Freeways may be located either inside or outside Urban Growth Management Areas.

Low-flow channel

An incised or paved channel from inlet to outlet in a dry basin that is designed to carry low runoff flows and/or baseflow, directly to the outlet without detention.

Low impact development (LID)

A stormwater and land use management strategy that strives to mimic pre-disturbance hydrologic processes of infiltration, filtration, storage, evaporation, and transpiration by emphasizing conservation, use of on-site natural features, site planning, and distributed stormwater management practices that are integrated into a project design.

Low Impact Development Best Management Practices (LID BMPs)

Distributed stormwater management practices, integrated into a project design, that emphasize pre-disturbance hydrologic processes of infiltration, filtration, storage, evaporation and transpiration.

Low Impact Development (LID) Principles

Land use management strategies that emphasize conservation, use of on-site natural features, and site planning to minimize impervious surfaces, native vegetation loss, and stormwater runoff.

Low permeability liner

A layer of compacted earthen material, concrete, or a geomembrane.

Lowest floor

The lowest enclosed area (including basement) of a structure. An area used solely for parking of vehicles, building access, or storage, in an area other than a basement area, is not considered a building's lowest floor, provided that the enclosed area meets all of the structural requirements of the flood hazard standards.

- M -

Maintenance

Repair and maintenance includes activities conducted on currently serviceable structures, facilities, and equipment that involves no expansion or use beyond that previously existing and results in no significant adverse hydrologic impact. It includes those usual activities taken to prevent a decline, lapse, or cessation in the use of structures and systems. Those usual activities may include replacement of dysfunctional facilities, including cases where environmental permits require replacing an existing structure with a different type structure, as long as the functioning characteristics of the original structure are not changed. One example is the replacement of a collapsed, fish blocking, round culvert with a new box culvert under the same span, or width, of roadway. In regard to stormwater facilities, maintenance includes assessment to ensure ongoing proper operation, removal of built-up pollutants (i.e. sediments), replacement of failed or failing treatment media, and other actions taken to correct defects as identified in the BMP design guidance. See also Pavement Maintenance exemptions in 2.2 Exemptions.

Manning's equation

An equation used to predict the velocity of water flow in an open channel or pipelines:

$$V = \frac{1.486 R^{2/3} S^{1/2}}{n}$$

where:

V is the mean velocity of flow in feet per second

R is the hydraulic radius in feet

S is the slope of the energy gradient or, for assumed uniform flow, the slope of the channel in feet per foot; and

n is Manning's roughness coefficient or retardance factor of the channel lining.

MAP

Mean Annual Precipitation

Mass wasting

The movement of large volumes of earth material downslope.

Master drainage plan

A comprehensive drainage control plan intended to prevent significant adverse impacts to the natural and manmade drainage system, both on and off-site.

Maximum extent practicable

Refers to paragraph 402(p)(3)(B)(iii) of the federal Clean Water Act, which reads as follows: “Permits for discharges from municipal storm sewers shall require controls to reduce the discharge of pollutants to the maximum extent practicable, including management practices, control techniques, and system, design, and engineering methods, and other such provisions as the Administrator or the State determines appropriate for the control of such pollutants.”

MBFM

Mechanically Bonded Fiber Matrix

MDNS

Mitigated Determination of Nonsignificance (See DNS and Mitigation).

Mean annual water level fluctuation

Derived as follows:

1. Measure the maximum water level (e.g., with a crest stage gage, Reinelt and Horner 1990) and the existing water level at the time of the site visit (e.g., with a staff gage) on at least eight occasions spread through a year.
2. Take the difference of the maximum and existing water level on each occasion and divide by the number of occasions.

Mean depth

Average depth; cross-sectional area of a stream or channel divided by its surface or top width.

Mean velocity

The average velocity of a stream flowing in a channel or conduit at a given cross-section or in a given reach. It is equal to the discharge divided by the cross-sectional area of the reach.

Measuring weir

A shaped notch through which water flows are measured. Common shapes are rectangular, trapezoidal, and triangular.

Mechanical analysis

The analytical procedure by which soil particles are separated to determine the particle size distribution.

Mechanical practices

Soil and water conservation practices that primarily change the surface of the land or that store, convey, regulate, or dispose of runoff water without excessive erosion.

Metals

Elements, such as copper, mercury, lead, nickel, zinc, and cadmium that are of environmental concern because they do not degrade over time. Although many are necessary nutrients, they are sometimes magnified in the food chain, and they can be toxic to life in high enough concentrations. They are also referred to as heavy metals.

MFD

Media Filter Drain

Microbes

The lower trophic levels of the soil food web. They are normally considered to include bacteria, fungi, flagellates, amoebae, ciliates, and nematodes. These in turn support the higher trophic levels, such as mites and earthworms. Together they are the basic life forms that are necessary for plant growth. Soil microbes also function to bioremediate pollutants such as petroleum, nutrients, and pathogens.

Min.

Minimum

Mitigation

In the following order of preference, mitigation is defined as:

a. Avoiding the impact altogether by not taking a certain action or part of an action;

b. Minimizing impacts by limiting the degree or magnitude of the action and its implementation, by using appropriate technology, or by taking affirmative steps to avoid or reduce impacts;

c. Rectifying the impact by repairing, rehabilitating, or restoring the affected environment;

d. Reducing or eliminating the impact over time by preservation and maintenance operations during the life of the action; and

e. Compensating for the impact by replacing, enhancing, or providing substitute resources or environments.

Moderate-ADT roadways and parking areas

Urban roads with average daily traffic (ADT) between 7,500 and 30,000 vehicles; rural roads and freeways with ADT between 15,000 and 30,000 vehicles; and parking areas with either between 40 and 100 trip ends per 1,000 square feet of gross building area or between 100 and 300 total trip ends per day are considered moderate-use traffic areas. Examples include visitor parking for small to medium commercial buildings with a limited number of daily customers. Urban roads are located within designated Urban Growth Management Areas; rural roads are located outside designated Urban Growth Management Areas. Freeways may be located either inside or outside Urban Growth Management Areas.

Moderate-use sites

Moderate-use sites include moderate-ADT roadways and parking areas, primary access points for high-density residential apartments, most intersections controlled by traffic signals, and transit center bus stops.

Modified SCS Type IA design storm

An adapted application of the synthetic SCS Type IA design storm to more closely reflect historical precipitation patterns in eastern Washington. Antecedent moisture conditions and precipitation depths are modified to reflect more typical conditions. See 4.3.5 Modified SCS Type IA and Regional Design Storms for a complete description.

Modified wetland

A wetland where the physical, hydrological, or water quality characteristics have been purposefully altered for a management purpose, such as by dredging, filling, forebay construction, and inlet or outlet control.

Monitor

To systematically and repeatedly measure something in order to track changes.

Monitoring

The systematic collection of data by various methods for the purposes of understanding natural systems and features, evaluating the impacts of development proposals on such systems, and assessing the performance of mitigation measures imposed as conditions of development.

MS4

Municipal Separate Storm Sewer System

MTCA

Model Toxics Control Act

Mulch

A layer of organic material or aggregate applied to the surface of soil. Its purpose is any or all of the following:

- To conserve soil moisture or temperature
- To improve the fertility and health of the soil
- To reduce weed growth
- To hold fertilizer, seed, and soil in place
- To enhance the visual appeal of the area.

Types of mulches used in this manual include: Chipped site vegetation, compost, hydromulch, wood-based or wood straw, wood strand, straw, and aggregate.

Multifamily property

A parcel that contains four or more residential dwelling units.

Municipality

Every city, county, town, district, or other public agency thereof that is authorized by law to require the execution of public work, except drainage districts, diking districts, diking and drainage improvement districts, drainage improvement districts, diking improvement districts, consolidated diking and drainage improvement districts, consolidated drainage improvement districts, consolidated diking improvement districts, irrigation districts, or any such other districts as shall from time to time be authorized by law for the reclamation or development of waste or undeveloped lands.

Municipal Stormwater Permit

One of the following Permits, as issued by Ecology to the local jurisdiction (Permittee):

- Phase I Municipal Stormwater Permit (the National Pollutant Discharge Elimination System and State Waste Discharge General Permit for Discharges from Large and Medium Municipal Separate Storm Sewer Systems)
- Western Washington Phase II Municipal Stormwater Permit (the National Pollutant Discharge Elimination System and State Waste Discharge General Permit for Discharges from Small Municipal Separate Storm Sewers in Western Washington)
- Eastern Washington Phase II Municipal Stormwater Permit (the National Pollutant Discharge Elimination System and State Waste Discharge General Permit for Discharges from Small Municipal Separate Storm Sewers in Eastern Washington)

Mycorrhizal

Relating to the symbiotic association of the mycelium of a fungus with the roots of a seed plant.

- N -

National Pollutant Discharge Elimination System (NPDES)

The part of the federal Clean Water Act which requires point source dischargers to obtain permits. These permits are referred to as NPDES permits and, in Washington State, are administered by the Washington State Department of Ecology.

Native growth protection easement (NGPE)

An easement granted for the protection of native vegetation within a sensitive area or its associated buffer. The NPGE shall be recorded on the appropriate documents of title and filed with the county records division.

Native vegetation

Vegetation comprising plant species that are indigenous to eastern Washington and that reasonably could be expected to naturally occur on the site. Plant species classified as noxious weeds are excluded from this definition.

Natural conditions

Surface water quality present before any human-caused pollution. When estimating natural conditions in the headwaters of a disturbed watershed, it may be necessary to use the less disturbed conditions of a neighboring or similar watershed as a reference condition.

Natural location

The location of those channels, swales, and other non-manmade conveyance systems as defined by the first documented topographic contours existing for the subject property, either from maps or photographs, or such other means as appropriate. In the case of outwash soils with relatively flat terrain, no natural location of surface discharge may exist.

New development

Land disturbing activities, including Class IV-general forest practices that are conversions from timberland to other uses; structural development, including construction or installation of a building or other structure; creation of hard surfaces; and subdivision, short subdivision and binding site plans, as defined and applied in Chapter 58.17 RCW. Projects meeting the definition of redevelopment shall not be considered new development.

New hard surface

A surface that is:

- upgraded from dirt to gravel, a bituminous surface treatment (“chip seal”), asphalt, concrete, permeable pavement, a structure with a vegetated roof, or an impervious structure; or
- upgraded from gravel to chip seal, asphalt, concrete, permeable pavement, a structure with a vegetated roof, or an impervious structure; or
- upgraded from chip seal to asphalt, concrete, permeable pavement, a structure with a vegetated roof, or an impervious structure.

Note that if asphalt or concrete has been overlaid by a chip seal, the existing condition should be considered as asphalt or concrete.

New impervious surface

A surface that is:

- changed from a pervious surface to an impervious surface (e.g. resurfacing by upgrading from dirt to gravel, a bituminous surface treatment (“chip seal”), asphalt, concrete, or an impervious structure); or
- upgraded from gravel to chip seal, asphalt, concrete, or an impervious structure; or
- upgraded from chip seal to asphalt, concrete, or an impervious structure.

Note that if asphalt or concrete has been overlaid by a chip seal, the existing condition should be considered as asphalt or concrete.

NGPE

Native Growth Protection Easement

NGVD

National Geodetic Vertical Datum

Nitrate (NO_3)

A form of nitrogen that is an essential nutrient for plants. It can cause algal blooms in water if all other nutrients are present in sufficient quantities. It is a product of bacterial oxidation of other forms of nitrogen; it also comes from the atmosphere during electrical storms and from fertilizer manufacturing.

Nitrification

The two -step microbial process that oxidizes ammonia to nitrite and then nitrate. This process occurs in aerobic conditions by various groups of predominantly autotrophic bacteria and archaea. Nitrification is a slow and inefficient process compared to other nitrogen cycle processes, therefore, it is often the rate-limiting step for nitrogen removal and requires a relatively long incubation time. Coupled nitrification-denitrification is the main nitrogen removal process in aquatic ecosystems or wastewater treatment systems.

Nitrogen, Available

Usually ammonium, nitrite, and nitrate ions, and certain simple amines available for plant growth. A small fraction of organic or total nitrogen in the soil is available at any time.

NOEC

No Observed Effects Concentration

NOI

Notice Of Intent

Nonendangerment Standard

Activities that prevent the movement of fluid containing any contaminant into the groundwater if the contaminant may cause a violation of the Water Quality Standards for groundwaters of the state of Washington, Chapter 173-200 WAC, or may cause health concerns.

Non-fish-bearing stream

According to WAC 222-16-030: Type Ns waters are non-fish-habitat streams. Until fish habitat water type maps are available, an interim water typing system applies (see WAC 222-16-031): Type 5 waters are non-fish-habitat streams.

Nonpoint source pollution

Pollution that enters a waterbody from diffuse origins in the watershed and does not result from discernible, confined, or discrete conveyances.

Non-pollution-generating impervious surface (NPGIS)

NPGIS are considered insignificant sources of pollutants in stormwater runoff. Roofs that are subjected only to atmospheric deposition or normal heating, ventilation, and air conditioning vents are considered NPGIS, unless the roofing material is uncoated metal. The following may also be considered NPGIS: paved bicycle pathways and pedestrian sidewalks that are separated from and not subjected to drainage from roads for motor vehicles, fenced fire lanes, infrequently used maintenance access roads, and “in-slope” areas of roads. Sidewalks that are regularly treated with sand, salt, or other deicing and anti-icing chemicals are *not* considered NPGIS.

Normal depth

The depth of uniform flow. This is a unique depth of flow for any combination of channel characteristics and flow conditions. Normal depth is calculated using Manning's Equation.

NPDES

National Pollutant Discharge Elimination System

NPGIS

Non-Pollution-Generating Impervious Surface

NRCS

Natural Resources Conservation Service (formerly the Soil Conservation Service)

NRCS Method (formerly the SCS Method)

A single-event hydrologic analysis technique for estimating runoff based on the Curve Number method. The curve numbers are published by NRCS in *Technical Release No. 55: Urban Hydrology for Small Watersheds* (USDA et al., 1986). With the change in name from the Soil Conservation Service to the Natural Resource Conservation Service, the method may be referred to as the NRCS Method.

Nutrients

Essential chemicals needed by plants and animals for growth. Excessive amounts of nutrients can lead to degradation of water quality and algal blooms. Some nutrients can be toxic at high concentrations.

- O -

Off-line facilities

Water quality treatment facilities to which stormwater runoff is restricted to some maximum flow rate or volume by a flow splitter.

Off-site

Any area lying upstream of the site that drains onto the site and any area lying downstream of the site to which the site drains.

Off-system storage

Facilities for holding or retaining excess flows over and above the carrying capacity of the stormwater conveyance system, in chambers, tanks, lagoons, ponds, or other basins that are not a part of the subsurface sewer system.

OHWM

Ordinary High Water Mark

Oil

Oil of any kind or any form, including, but not limited to, petroleum, fuel oil, sludge, oil refuse, and oil mixed with wastes other than dredged spoil.

Oil and water separator

A vault, usually underground, designed to provide a quiescent environment to separate oil from water.

O&M

Operation and Maintenance

On-line facilities

Runoff Treatment facilities that receive all of the stormwater runoff from a drainage area. Flows greater than the water quality design flow rate or volume are passed through at a lower percentage of removal efficiency.

On-site

The entire property that includes the proposed development.

On-site stormwater management BMPs

Development and mitigation techniques that serve to infiltrate, disperse, and retain stormwater runoff on a project site. As used in this manual, a synonym for Low Impact Development BMPs.

Operational BMPs

Operational BMPs are a type of Source Control BMP. They are schedules of activities, prohibition of practices, and other managerial practices to prevent or reduce pollutants from entering stormwater. Operational BMPs include formation of a pollution prevention team, good housekeeping, preventive maintenance procedures, spill prevention and cleanup, employee training, inspections of pollutant sources and BMPs, and record keeping. They can also include process changes, raw material/product changes, and recycling wastes.

Ordinary high water mark (OHWM)

The line on the shore established by the fluctuations of water and indicated by physical characteristics such as a clear, natural line impressed on the bank; shelving; changes in the character of soil destruction on terrestrial vegetation, or the presence of litter and debris; or other appropriate means that consider the characteristics of the surrounding area.

The OHWM is found by examining the bed and banks of a stream and ascertaining where the presence and action of waters are so common and usual, and so long maintained in all ordinary years, as to mark upon the soil a character distinct from that of the abutting upland, in terms of vegetation. In any area where the OHWM cannot be found, the line of mean high water shall be substituted. In any area where neither can be found, the channel bank shall be substituted. In braided channels and alluvial fans, the OHWM or substitute shall be measured so as to include the entire stream feature.

Organic matter

Decomposed animal or vegetable matter, measured by ASTM D2974. Organic matter is an important reservoir of carbon and a dynamic component of soil and the carbon cycle. It improves soil and plant efficiency by improving soil physical properties including drainage, aeration, and other structural characteristics. It contains the nutrients, microbes, and higher-form soil food web organisms necessary for plant growth. The maturity of organic matter is a measure of its beneficial properties. Raw organic matter can release water-soluble nutrients (similar to chemical fertilizer). Beneficial organic matter has undergone a humification process, either naturally in the environment or through a composting process.

Orifice

An opening with closed perimeter, usually sharp-edged, and of regular form in a plate, wall, or partition through which water may flow, generally used for the purpose of measurement or control of water.

OSHA

Occupational Safety and Health Administration

Outlet

Point of water disposal from a stream, river, lake, tidewater, or artificial drain.

Outlet channel

A waterway constructed or altered primarily to carry water from structures, such as terraces, tile lines, and diversions.

Outwash soils

Soils formed from highly permeable sands and gravels.

Overflow

A pipeline or conduit device, together with an outlet pipe, that provides for the discharge of portions of combined sewer flows into receiving waters or other points of disposal, after a regular device has allowed the portion of the flow that can be handled by interceptor sewer lines and pumping and treatment facilities to be carried by and to such water pollution control structures.

Overflow rate

Detention basin release rate divided by the surface area of the basin. It can be thought of as an average flow rate through the basin.

Overtopping

To flow over the limits of a containment or conveyance element.

- P -

PAH

Polycyclic Aromatic Hydrocarbon

PAM

Polyacrylamide

Partially controlled limited access highway

A highway where the right of owner or occupants of abutting land or other persons to access, light, air, or view in connection with the highway is controlled to give preference to through traffic to a degree that, in addition to access connections with selected public roads, there may be some crossings and some private driveway connections at grade. (See WAC 468-58-010)

Particle size

The effective diameter of a particle as measured by sedimentation, sieving, or micrometric methods.

PCB

Polychlorinated Biphenyl

Peak discharge

The maximum instantaneous rate of flow during a storm, usually in reference to a specific design storm event.

Peak-shaving

Controlling post-development peak discharge rates to pre-development levels by providing temporary detention in a BMP.

Percolation

The movement of water through soil.

Percolation rate

The rate, often expressed in minutes/inch, at which clear water, maintained at a relatively constant depth, will seep out of a standardized test hole that has been previously saturated. The term percolation rate is often used synonymously with infiltration rate (short-term infiltration rate).

Perennial stream

A stream reach that does not go dry during a year of normal precipitation: the elevation of the water table is always above the bottom of the stream channel during a year of normal precipitation.

Permanent Stormwater Control Plan

A plan that includes permanent BMPs for preventing and controlling pollution of stormwater runoff. These BMPs will remain in place after construction and/or land-disturbing activity has been completed.

Permeable pavement

Pervious concrete, porous asphalt, permeable pavers, or other forms of pervious or porous paving material intended to allow passage of water through the pavement section. It often includes an aggregate base that provides structural support and acts as a stormwater reservoir.

Permeable soils

Soil materials with a sufficiently rapid infiltration rate to greatly reduce or eliminate surface and stormwater runoff. These soils are generally classified as SCS hydrologic soil groups A and B.

Person

Any individual, partnership, corporation, association, organization, cooperative, public or municipal corporation, agency of the state, or local government unit, however designated.

Pervious surface

Any surface material that allows stormwater to infiltrate into the ground. Examples include lawn, landscape, pasture, native vegetation areas, and permeable pavements.

Pesticide

A general term used to describe any substance - usually chemical - used to destroy or control organisms, including herbicides, insecticides, algicides, fungicides, and others. Many of these substances are manufactured and are not naturally found in the environment. Others, such as pyrethrum, are natural toxins that are extracted from plants and animals.

PGIS

Pollution-Generating Impervious Surface

PGPS

Pollution-Generating Pervious Surface

pH

A measure of the alkalinity or acidity of a substance which is conducted by measuring the concentration of hydrogen ions in the substance. A pH of 7.0 indicates neutral water. A pH of 6.5 is slightly acid.

Physiography

Characteristics of the natural physical environment (including hills).

PICP

Permeable Interlocking Concrete Pavement

PIF

Peak Intensity Factor

PIT

Pilot Infiltration Test

Plan approval authority

The department within a local jurisdiction that has been delegated authority to approve stormwater site plans.

Planned unit development (PUD)

A special classification authorized in some zoning ordinances, where a unit of land under control of a single project proponent may be used for a variety of uses and densities, subject to review and approval by the local governing body. The locations of the zones are usually decided on a case-by-case basis.

Plat

A map or representation of a subdivision showing the division of a tract or parcel of land into lots, blocks, streets, or other divisions and dedications.

Plunge pool

A device used to dissipate the energy of flowing water that may be constructed or made by the action of flowing. These facilities may be protected by various lining materials.

Point discharge

The release of collected and/or concentrated surface and stormwater runoff from a pipe, culvert, or channel.

Point of compliance

The location at which compliance with a discharge performance standard or a receiving water quality standard is measured.

Pollution

Contamination or other alteration of the physical, chemical, or biological properties of waters of the state, including a change in temperature, taste, color, turbidity, or odor; or such discharge of any liquid, gaseous, solid, radioactive, or other substance into any waters of the state as will, or is likely to, create a nuisance or render such waters harmful, detrimental, or injurious to the public health, safety, or welfare, or to domestic, commercial, industrial, agricultural, recreational, or other legitimate beneficial uses, or to livestock, wild animals, birds, fish, or other aquatic life.

Pollution-generating hard surface (PGHS)

Those hard surfaces considered to be a significant source of pollutants in stormwater runoff. See the listing of surfaces under pollution-generating impervious surface.

Pollution-generating impervious surface (PGIS)

Those impervious surfaces considered to be a significant source of pollutants in stormwater runoff. Such surfaces include those which are subject to any of the following:

- vehicular use (as further defined in this glossary).
- industrial activities (as further defined in this glossary).

- storage of erodible or leachable materials, wastes, or chemicals, and which receive direct rainfall or the run-on or blow-in of rainfall.
- metal roofs unless they are coated with an inert, non-leachable material (e.g. baked-on enamel coating).
- roofs that are subject to venting significant amounts of dusts, mists, or fumes from manufacturing, commercial, or other indoor activities.

Pollution-generating pervious surface (PGPS)

Any pervious surface subject to any of the following:

- vehicular use (as further defined in this glossary).
- industrial activities (as further defined in this glossary).
- 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.
- loss of soil.

Artificial turf is also considered to be PGPS.

Typical PGPS include permeable pavement subject to vehicular use, lawns and landscaped areas including: golf courses, parks, cemeteries, and sports fields (natural and artificial turf).

Potholing

Excavating a hole in the ground to observe buried utilities or facilities. Potholes are typically excavated with the use of a backhoe or by hand, depending on the environment.

POTW

Publicly Owned Treatment Works

Pre-developed condition

The native vegetation and soils that existed at a site prior to the influence of Euro-American settlement. Jurisdictions may choose to require that either the predeveloped condition or the “existing condition” be used to calculate runoff volumes to be compared to the runoff generated under the “proposed development condition.” Because there is limited information available to identify and confirm actual predeveloped conditions for many areas of eastern Washington, jurisdictions may choose to apply a reasonably determined set of conservative curve numbers for use in determining the runoff volume compared to that under the proposed development condition.

Prediction

For the purposes of this manual an expected outcome based on the results of hydrologic modeling and/or the judgment of a licensed engineer in the state of Washington or a registered geologist in the state of Washington with hydrogeology specialty.

Preservation/maintenance

A preservation or maintenance project is defined as preserving/protecting infrastructure by rehabilitating or replacing existing structures to maintain operational and structural integrity, and for the safe and efficient operation of the facility. Traffic area maintenance projects do not increase the traffic-carrying capacity of a roadway or parking area.

Pretreatment

A BMP that removes at least 50% solids. Typically installed upstream of a UIC well or a Runoff Treatment BMP.

Priority peat systems

Unique, irreplaceable fens that can exhibit water pH in a wide range from highly acidic to alkaline, including fens typified by Sphagnum species, Ledum groenlandicum (Labrador tea), Drosera rotundifolia (sundew), and Vaccinium oxycoccos (bog cranberry); marl fens; estuarine peat deposits; and other moss peat systems with relatively diverse, undisturbed flora and fauna. Bog is the common name for peat systems having the Sphagnum association described, but this term applies strictly only to systems that receive water income from precipitation exclusively.

Process wastewater

The used water and solids from an industrial source. This water should be directed to a treatment facility and kept separate from the stormwater generated from the site.

Professional civil engineer

A person registered with the state of Washington as a professional engineer in civil engineering.

Project

Any proposed action to alter or develop a site; or the proposed action of a permit application or an approval that requires drainage review.

Project site

That portion of a property, properties, and right-of-way subject to land disturbing activities, new hard surfaces, or replaced hard surfaces.

Properly functioning soil system

A natural system that has not been disturbed or modified or an engineered soil/landscape system designed to meet certain criteria.

Proposed development condition

The impervious surfaces, drainage systems, land cover, native vegetation, and soils that are proposed to exist at the site at the completion of the project (complete build-out).

PULD

Pilot Use Level Designation

- Q -

Qualified personnel

Someone who has had professional training in the aspects of stormwater management for which they are responsible and are under the functional control of the Permittee. Qualified Personnel may be staff members, contractors, or trained volunteers with professional certification. Permittees may train and certify volunteers.

- R -

R/D

Retention/Detention

Rain garden

A non-engineered shallow landscaped depression, with compost-amended native soils and adapted plants. The depression is designed to pond and temporarily store stormwater runoff from adjacent areas, and to allow stormwater to pass through the amended soil profile. See BMP T5.14: Rain Gardens.

Rare, threatened, endangered, or sensitive species

Plant or animal species that are relatively uncommon regionally, are nearing endangered status, or whose existence is in jeopardy and is usually restricted to highly specific habitats. Threatened, endangered or sensitive species are listed by federal or state authorities, whereas rare species are unofficial species of concern that fit the above definitions.

Rational method

A method of computing storm drainage flow rates (Q) using the formula Q = CIA, where C is a coefficient describing the physical drainage area, I is the rainfall intensity, and A is the area. In this manual, use of the Rational Method is limited to sizing only certain BMPs.

RCW

Revised Code of Washington

Reach

A length of channel with uniform characteristics.

Receiving waterbody or receiving waters

Bodies of surface water to which runoff is discharged via a point source or via sheet flow. Groundwater to which runoff is directed by infiltration.

Additional guidance for new development and redevelopment projects:

- An MS4 is not considered a receiving water. Examples of receiving waters include (but are not limited to) lakes, rivers, streams, wetlands, creeks, and groundwater.
- The project proponent must determine the FIRST receiving water encountered by the discharge(s) from the project site. This is the receiving water that must be considered when determining stormwater requirements per the Core Elements.
- Determining the receiving water that each discharge from the project ultimately reaches is a fundamental step of the stormwater design for the project. The receiving water must be determined in order to evaluate the appropriate levels of protection (i.e. which Core Elements apply, and what types of BMPs are appropriate to comply with those Core Elements). There are no distance thresholds that would negate the need to determine the receiving water for the project.

Recharge

The addition of water to the zone of saturation (i.e. an aquifer).

Recommended BMPs

Those source control BMPs that are not expected to be mandatory by local jurisdictions at new development and redevelopment sites. However, they may improve pollutant control efficiency, and may provide a more comprehensive and environmentally effective stormwater management program.

Redevelopment

On a site that is already substantially developed (i.e. has 35% or more of existing hard surface coverage), the creation or addition of hard surfaces; the expansion of a building footprint or addition or replacement of a structure; structural development including construction, installation or expansion of a building or other structure; replacement of hard surface that is not part of a routine maintenance activity; and land disturbing activities.

Regional

An action (here, for stormwater management purposes) that involves more than one discrete property.

Regional design storm

A custom synthetic design storm taken from the long-duration design storm that was based on a statistical analysis of historical precipitation data from gauging stations in eastern Washington. The four regional storms consist of the second, or larger precipitation event, of the two contained in each of the four long-duration storms identified for the four climate regions of eastern Washington.

Regional detention BMP

A detention BMP designed to correct existing stormwater runoff problems of a basin or subbasin. The area downstream has been previously identified as having existing or predicted significant and regional flooding and/or erosion problems.

This term is also used when a detention BMP is sited to detain stormwater runoff from multiple new developments or areas within a catchment.

Release rate

The computed peak rate of surface and stormwater runoff from a site.

Replaced hard surface

For structures, the removal down to (i.e. exposing the top of) the foundation and replacement. For other hard surfaces, the removal down to (i.e. exposing the top of) bare soil or base course and replacement.

Replaced impervious surface

For structures, the removal down to (i.e. exposing the top of) the foundation and replacement. For other impervious surfaces, the removal down to (i.e. exposing the top of) bare soil or base course and replacement.

Replaced pollution-generating impervious surface

A replaced impervious surface that is a pollution-generating impervious surface.

Residential density

The number of dwelling units per unit of surface area. Net density includes only occupied land. Gross density includes unoccupied portions of residential areas, such as roads and open space.

Restoration

Actions performed to reestablish wetland functional characteristics and processes that have been lost by alterations, activities, or catastrophic events in an area that no longer meets the definition of a wetland.

Retention

The process of collecting and holding surface and stormwater runoff with no surface outflow.

Retention/detention facility (R/D)

A type of stormwater facility designed either to hold stormwater runoff for a considerable length of time and then release it by evaporation, plant transpiration, and/or infiltration into the ground; or to hold stormwater runoff for a short period of time and then release it to the surface and stormwater management system.

Retrofitting

The renovation of an existing structure or facility to meet changed conditions or to improve performance.

Retrofit of a UIC Well

Application of source control activities and/or structural controls such as a treatment BMP or creation of separation between the base of the well and the top of the groundwater table, to reduce the pollutant load to a UIC well so as to meet the nonendangerment standard.

Return frequency or recurrence interval

A statistical term for the average expected time interval between events (e.g. flows, floods, droughts, or rainfall) that equal or exceed given conditions.

Rhizome

A modified plant stem that grows horizontally underground.

Riffles

Fast sections of a stream where shallow water races over stones and gravel. Riffles usually support a wider variety of bottom organisms than other stream sections.

Rill

A small intermittent watercourse with steep sides, usually only a few inches deep. Often rills are caused by an increase in surface water flow after the soil has been cleared of vegetation.

Riparian

Pertaining to the banks of streams, wetlands, lakes, or tidewater.

Riprap

A facing layer or protective mound of rocks placed to prevent erosion or sloughing of a structure or embankment due to flow of surface and stormwater runoff.

Riser

A vertical pipe extending from the bottom of a pond BMP that is used to control the discharge rate from a BMP for a specified design storm.

Rodenticide

A substance used to destroy rodents.

ROW

Right of Way

Runoff

Water originating from rainfall and other precipitation that is found in drainage facilities, rivers, streams, springs, seeps, ponds, lakes, and wetlands as well as shallow groundwater. As applied in this manual, it also means the portion of rainfall or other precipitation that becomes surface flow and interflow.

Runoff treatment BMP

A BMP that is intended to remove pollutants from stormwater. Examples include (but are not limited to) wetponds, oil and water separators, biofiltration swales, and constructed wetlands.

Rural road

A roadway located outside the boundary of an Urban Growth Area.

RUSLE

Revised Universal Soil Loss Equation

- S -

Salmonid

A member of the fish family Salmonidae. Chinook, Coho, chum, sockeye and pink salmon; cutthroat, brook, brown, rainbow, and steelhead trout; Dolly Varden, kokanee, and char are examples of salmonid species.

Sand filter

A man-made depression or basin with a layer of sand that treats stormwater as it percolates through the sand and is discharged via a central collector pipe.

Sanitary control area

The inner circle of a wellhead protection area maintained around a drinking water source to minimize direct contamination at the wellhead and reduce the possibility of surface flows reaching the wellhead and traveling down the casing (WAC 246-290-135).

Saturated hydraulic conductivity

The ability of a fluid to flow through a porous medium under saturated conditions, which is determined by the size and shape of the pore spaces in the medium and their degree of interconnection and by the viscosity of the fluid. Hydraulic conductivity can be expressed as the volume of fluid that will move during unit of time under a unit hydraulic gradient through a unit area measured at right angles to the direction of flow.

Saturation point

In soils, the point at which a soil or an aquifer will no longer absorb any amount of water without losing an equal amount.

SBUH

Santa Barbara Urban Hydrograph

SC

Spill Control

Scour

Erosion of channel banks due to excessive velocity of the flow of surface and stormwater runoff.

SCS

Soil Conservation Service (former name of the Natural Resources Conservation Service), U.S. Department of Agriculture

SCS method

See NRCS Method (formerly the SCS Method).

SDS

Safety Data Sheet

Seasonal high groundwater

Seasonal high groundwater is the highest annual groundwater elevation as determined by a qualified soil scientist, geohydrologist, or licensed engineer in the state of Washington based on monitoring wells or other recognized methods.

Seasonal stream

A stream or segment of a stream that normally dries up during a year of normal rainfall. Seasonal streams often receive water from springs and/or long-continued water supply from melting snow or other sources.

Sediment

Fragmented material that originates from weathering and erosion of rocks or unconsolidated deposits and is transported by, suspended in, or deposited by water.

Sedimentation

The depositing or formation of sediment.

Semiarid

A condition characterized by light rainfall; having approximately 10 to 20 inches of annual precipitation.

Sensitive area

Any area designated by a federal, state, or local jurisdictions to have unique or important environmental characteristics that may require special additional protective measures. These areas include, but are not limited to, wetlands and their buffer zones, stream riparian areas, wellhead protection areas, and geologic hazard areas. See also Critical areas.

Sensitive emergent vegetation communities

Assemblages of erect, rooted, herbaceous vegetation, excluding mosses and lichens, at least some of whose members have relatively narrow ranges of environmental requirements, such as hydroperiod, nutrition, temperature, and light. Examples include fen species such as sundew and, as well as a number of species of Carex (sedges).

Sensitive life stages

Stages during which organisms have limited mobility or alternatives in securing the necessities of life, especially including reproduction, rearing, and migration periods.

Sensitive scrub shrub vegetation communities

Assemblages of woody vegetation less than 6 meters in height, at least some of whose members have relatively narrow ranges of environmental requirements, such as hydroperiod, nutrition, temperature, and light. Examples include fen species such as Labrador tea, bog laurel, and cranberry.

SEPA

State Environmental Policy Act

Settleable solids

Suspended solids in stormwater that separate by settling when the stormwater is held in a quiescent condition for a specified time.

Sheet erosion

The relatively uniform removal of soil from an area without the development of conspicuous water channels.

Sheet flow

Runoff that flows over the ground surface as a thin, even layer, not concentrated in a channel.

Shoreline development

The proposed project as regulated by the Shoreline Management Act. Usually the construction over water or within a shoreline zone (generally 200 feet landward of the water) of structures such as buildings, piers, bulkheads, and breakwaters, including environmental alterations such as dredging and filling, or any project which interferes with public navigational rights on the surface waters.

Short circuiting

The passage of runoff through a BMP in less than the design treatment time.

Short-duration design storm

A synthetic 3-hour custom design storm that represents rainfall during a typical summer thunderstorm in eastern Washington. The storm is based on a statistical analysis of historical precipitation data from gauging stations in eastern Washington.

Short subdivision

Division or redivision of land into four or fewer lots, tracts, parcels, sites, or divisions for the purpose of sale, lease, or transfer of ownership. See RCW 58.17.020 for details.

Significant Contributor

A discharge that contributes a loading of pollutants considered to be sufficient to cause or exacerbate the deterioration of receiving water quality or instream habitat conditions.

Siltation

The process by which a river, lake, or other waterbody becomes clogged with sediment. Silt can clog gravel beds and prevent successful salmon spawning.

Site

The area defined by the legal boundaries of a parcel or parcels of land that is (are) subject to new development or redevelopment. For road 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 the new development or redevelopment project.

Site suitability criteria

Criteria that designers must consider for siting infiltration BMPs for Flow Control and/or Runoff Treatment purposes.

Slope

Degree of deviation of a surface from the horizontal; measured as a numerical ratio, percent, or in degrees. Expressed as a ratio, the first number is the horizontal distance (run) and the second is the vertical distance (rise), as 2:1. A 2:1 slope is a 50 percent slope. Expressed in degrees, the slope is the angle from the horizontal plane, with a 90° slope being vertical (maximum) and 45° being a 1:1 or 100 percent slope.

Sloughing

The sliding of overlying material. It is the same effect as caving, but it usually occurs when the bank or an underlying stratum is saturated or scoured.

Soil

The unconsolidated mineral and organic material on the immediate surface of the earth that serves as a natural medium for the growth of land plants. See also topsoil, engineered soil/landscape system, and properly functioning soil system.

Soil bulk density

The ratio of the mass of a given soil sample to the bulk volume of the sample.

Soil group, hydrologic

A classification of soils by the Soil Conservation Service into four runoff potential groups. The groups range from A soils, which are very permeable and produce little or no runoff, to D soils, which are not very permeable and produce much more runoff.

Soil horizon

A layer of soil, approximately parallel to the surface, which has distinct characteristics produced by soil-forming factors.

Soil permeability

The ease with which gases, liquids, or plant roots penetrate or pass through a layer of soil.

Soil profile

A vertical section of the soil from the surface through all horizons, including C horizons.

Soil stabilization

The use of measures such as rock lining, vegetation, or other engineering structures to prevent the movement of soil when loads are applied to the soil.

Soil stratigraphy

The sequence, spacing, composition, and spatial distribution of sedimentary deposits and soil strata (layers).

Soil structure

The relation of particles or groups of particles which impart to the whole soil a characteristic manner of breaking; some types are crumb structure, block structure, platy structure, and columnar structure.

Soil Texture Class

The relative proportion, by weight, of particle sizes, based on the USDA system, of individual soil grains less than 2 mm equivalent diameter in a mass of soil. The basic texture classes in the approximate order of increasing proportions of fine particles include: sand, loamy sand, sandy loam, loam, silt loam, silt, clay loam, sandy clay, silty clay, and clay.

Sorption

The physical or chemical binding of pollutants to sediment or organic particles.

Source control BMP

A structure or operation intended to prevent pollutants from coming into contact with stormwater through physical separation of areas or careful management of activities that are sources of pollutants. This manual separates source control BMPs into two types: structural and operational.

- *Structural Source Control BMPs* are physical, structural, or mechanical devices or facilities that are intended to prevent pollutants from entering stormwater.
- *Operational Source Control BMPs* are non-structural practices that prevent or reduce pollutants from entering stormwater.

SPCC

Spill Prevention Control and Countermeasures

Spill control device

A tee section or turn-down elbow designed to retain a limited volume of pollutant that floats on water, such as oil or antifreeze. Spill control devices are passive and must be cleaned out for the spilled pollutant to be removed.

Spillway

A passage such as a paved apron or channel for surplus water over or around a dam or similar obstruction. An open or closed channel, or both, used to convey excess water from a reservoir. It may contain gates, either manually or automatically controlled, to regulate the discharge of excess water.

SSC

Site Suitability Criteria (or Criterion)

SSP

Stormwater Site Plan

Stage-storage-discharge table

Relationship between the stage, or water surface elevation inside a stormwater BMP, and the available storage volume and discharge rates from the BMP. Available storage may include subsurface storage (e.g., storage within the voids of bioretention soil mix or aggregate reservoir layers), as well as surface ponding storage (e.g., surface ponding in a bioretention swale). Discharge may include infiltration to native soils, flow through underdrains, and/or flow-through overflow control structures, based on designs. The stage-storage-discharge table is developed by the designer for use in level-pool routing modeling to size LID BMPs.

State Environmental Policy Act (SEPA)

The Washington State law intended to minimize environmental damage. SEPA requires that state agencies and local governments consider environmental factors when making decisions on activities, such as development proposals over a certain size and comprehensive plans. As part of this process, environmental documents are prepared and opportunities for public comment are provided. See RCW 43.21c.

Steep slope

Slopes of 40 percent gradient or steeper within a vertical elevation change of at least ten feet. A slope is delineated by establishing its toe and top, and is measured by averaging the inclination over at least ten feet of vertical relief. For the purpose of this definition:

The toe of a slope is a distinct topographic break in slope that separates slopes inclined at less than 40% from slopes 40% or steeper. Where no distinct break exists, the toe of a steep slope is the lower-most limit of the area where the ground surface drops ten feet or more vertically within a horizontal distance of 25 feet; AND

The top of a slope is a distinct topographic break in slope that separates slopes inclined at less than 40% from slopes 40% or steeper. Where no distinct break exists, the top of a steep slope is the upper-most limit of the area where the ground surface drops ten feet or more vertically within a horizontal distance of 25 feet.

Storage routing

A method to account for the attenuation of peak flows passing through a detention BMP or other storage feature.

Storm drains

The enclosed conduits that transport stormwater and surface water, street wash, and other wash waters toward points of discharge (sometimes called storm sewers).

Storm frequency

The time interval between major storms of predetermined intensity and volumes of runoff for which storm sewers and other structures are designed and constructed to handle hydraulically without surcharging and backflooding; e.g., a 2-year, 10-year or 100-year storm.

Storm sewer

A sewer that carries stormwater and surface water, street wash and other wash waters or drainage, but excludes sewage and industrial wastes. Also called a storm drain.

Stormwater

That portion of precipitation and/or snowmelt that does not naturally percolate into the ground or evaporate, but flows via overland flow, interflow, pipes, and other features of a stormwater drainage system into a defined surface waterbody, or a constructed infiltration facility.

Stormwater drainage system

Constructed and natural features which function together as a system to collect, convey, channel, hold, inhibit, retain, detain, infiltrate, divert, treat or filter stormwater.

Stormwater facility

A constructed component of a stormwater drainage system, designed or constructed to perform a particular function or multiple functions. Stormwater facilities include, but are not limited to, pipes, swales, ditches, culverts, street gutters, detention ponds, retention ponds, constructed wetlands, infiltration devices, catch basins, oil and water separators, and biofiltration swales.

Stormwater Management Manual for Eastern Washington (SWMMEW)

Contains BMPs to prevent, control, or treat pollution in stormwater and to reduce other stormwater-related impacts on waters of the state. The SWMMEW is intended to provide guidance on measures necessary in eastern Washington to control the quantity and quality of stormwater runoff from new development and redevelopment.

Stormwater Management Manual for Western Washington (SWMMWW)

Contains BMPs to prevent, control or treat pollution in stormwater and to reduce other stormwater-related impacts on waters of the state. The SWMMWW is intended to provide guidance on measures necessary in western Washington to control the quantity and quality of stormwater runoff from new development and redevelopment.

Stormwater Site Plan (SSP)

The comprehensive report containing all of the technical information and analysis necessary for regulatory agencies to evaluate a proposed new development or redevelopment project for compliance with stormwater requirements. Contents of the SSP will vary with the type and size of the project and individual site characteristics. The SSP includes a Construction Stormwater Pollution Prevention Plan (Construction SWPPP) and a Permanent Stormwater Control Plan (PSC Plan). Guidance for preparing an SSP is provided in Chapter 3 - Preparation of Stormwater Site Plans.

Streambanks

The usual boundaries, not the flood boundaries, of a stream channel. Right and left banks are named facing downstream.

Stream gaging

The quantitative determination of stream flow using gages, current meters, weirs, or other measuring instruments at selected locations. See Gaging station.

Stream order

A dimensionless basin characteristic indicating the degree of stream channel branching, used in geomorphology and runoff studies. An *n*th order stream is formed by two or more streams of (*n*-1) order: a second order stream exists below the confluence of two first order streams, a third order stream exists below the confluence of two second order streams, and so on.

Streams

Those areas where surface waters flow sufficiently to produce a defined channel or bed. A defined channel or bed is an area that demonstrates clear evidence of the passage of water and includes, but is not limited to, hydraulically sorted sediments or the removal of vegetative litter or loosely rooted vegetation by the action of moving water. The channel or bed need not contain water year-round. This definition is not meant to include irrigation ditches, canals, stormwater runoff devices, or other entirely artificial watercourses unless they are used to convey streams naturally occurring prior to construction. Those topographic features that resemble streams but have no defined channels (i.e., swales) shall be considered streams when hydrologic and hydraulic analyses done pursuant to a development proposal predict formation of a defined channel after development.

Structural source control BMPs

Physical, structural, or mechanical devices or facilities that are intended to prevent pollutants from entering stormwater. Structural source control BMPs typically include:

- Enclosing and/or covering the pollutant source (building or other enclosure, a roof over storage and working areas, temporary tarp, etc.).

- Segregating the pollutant source to prevent run-on of stormwater, and to direct only contaminated stormwater to appropriate treatment BMPs.

Structure

A catchbasin or manhole in reference to a drainage system.

Stub-out

A short length of pipe provided for future connection to a drainage system.

Subbasin

A drainage area that drains to a receiving water that is named and noted on common maps and contained within a basin.

Subcatchment

A subdivision of a drainage basin (generally determined by topography and pipe network configuration).

Subdivision

The division or redivision of land into five or more lots, tracts, parcels, sites, or divisions for the purpose of sale, lease, or transfer of ownership. See RCW 58.17.020 for details.

Subdrain

A pervious backfilled trench containing aggregate or a pipe for intercepting groundwater or seepage.

Subgrade

A layer soil used as the underlying base for a BMP.

Subsoil

The B horizons of soils with distinct profiles. In soils with weak profile development, the subsoil can be defined as the soil below the plowed soil (or its equivalent of surface soil), in which roots normally grow. Although a common term, it cannot be defined accurately. It has been carried over from early days when "soil" was conceived only as the plowed soil and that under it as the "subsoil".

Substrate

The natural soil base underlying a BMP.

Surcharge

The flow condition occurring in closed conduits when the hydraulic grade line is above the crown of the sewer.

Surface and stormwater

Water originating from rainfall and other precipitation that is found in drainage facilities, rivers, streams, springs, seeps, ponds, lakes, and wetlands as well as shallow groundwater.

Surface and stormwater management system

Drainage facilities and any other natural features that collect, store, control, treat and/or convey surface and stormwater.

Surface waters of the state

All waters defined as “waters of the United States” in 40 CFR 122.2 that are within the boundaries of the state of Washington. This includes lakes, rivers, ponds, streams, inland waters, wetlands, ocean, bays, estuaries, sounds, and inlets.

Susceptibility

The ease with which contaminants can move from the land surface to the aquifer, based solely on the types of surface and subsurface materials in the area. Susceptibility usually defines the rate at which a contaminant will reach an aquifer unimpeded by chemical interactions with the vadose zone media.

Susceptible drinking water source

Sources rated highly susceptible by DOH and any drinking water source where a deep injection well will be placed within a groundwater protection area.

Suspended solids

Organic or inorganic particles that are suspended in and carried by the water. The term includes sand, mud, and clay particles (and associated pollutants), as well as solids in stormwater.

Swale

A shallow drainage conveyance with relatively gentle side slopes, generally with flow depths less than one foot.

SWPPP

Stormwater Pollution Prevention Plan

- T -

TAPE

Technology Assessment Protocol–Ecology

Terrace

An embankment or combination of an embankment and channel across a slope to control erosion by diverting or storing surface runoff instead of permitting it to flow uninterrupted down the slope.

TESC

Temporary Erosion and Sediment Control

TIA

Total Impervious Area

Tightline

A continuous length of pipe that conveys water from one point to another (typically down a steep slope) with no inlets or collection points in between.

Tile drainage

Land drainage by means of a series of tile lines laid at a specified depth and grade.

Tile, Drain

Pipe made of burned clay, concrete, or similar material, in short lengths, usually laid with open joints to collect and carry excess water from the soil.

Till

A layer of poorly sorted soil deposited by glacial action that generally has very low infiltration rates.

Time of concentration

The time period necessary for surface runoff to reach the outlet of a subbasin from the hydraulically most remote point in the tributary drainage area.

TMDL

Total Maximum Daily Load

Topography

General term to include characteristics of the ground surface such as plains, hills, mountains, degree of relief, steepness of slopes, and other physiographic features.

Topsoil

The upper portion of a soil, usually dark colored and rich in organic material. It is more or less equivalent to the upper portion of an A horizon in an ABC soil.

Total dissolved solids

The dissolved salt loading in surface and subsurface waters.

Total impervious area (TIA)

The total area of surfaces on a developed site that inhibit infiltration of stormwater. The surfaces include, but are not limited to, conventional asphalt or concrete roads, driveways, parking lots, sidewalks, alleys, and rooftops.

Total Maximum Daily Load (TMDL)

A calculation of the maximum amount of a pollutant that a waterbody can receive and still meet the water quality standards, and an allocation of that amount to the pollutant's sources. A TMDL (also known as a Water Cleanup Plan) is the sum of the allowable loads of a single pollutant from all contributing point and nonpoint sources. The calculation must include a margin of safety to ensure that the waterbody can be used for the purposes the state has designated. The calculation must also account for seasonable variation in water quality. Water quality standards are set by states, territories, and tribes. They identify the uses for each waterbody, for example, drinking water supply, contact recreation (swimming), and aquatic-like support (fishing), and the scientific criteria to support those uses. The Clean Water Act, Section 303, establishes the water quality standards and TMDL programs.

Total Petroleum Hydrocarbons (TPH)

TPH-Gx: The qualitative and quantitative method (extended) for volatile (“gasoline”) petroleum products in water; and TPH-Dx: The qualitative and quantitative method (extended) for semi-volatile (“diesel”) petroleum products in water.

Total solids

The solids in water, sewage, or other liquids, including the dissolved, filterable, and nonfilterable solids. The residue left when the moisture is evaporated and the remainder is dried at a specified temperature, usually 130°C.

Total suspended solids

That portion of the solids carried by stormwater that can be captured on a standard glass filter.

Toxic

Poisonous, carcinogenic, or otherwise directly harmful to life.

TPH

Total Petroleum Hydrocarbons

Tract

A legally created parcel of property designated for special nonresidential and noncommercial uses.

Transportation safety improvement projects

Projects that improve motorized and/or nonmotorized user safety that do not enhance the traffic capacity of a roadway.

Trash rack

A structural device used to prevent debris from entering a spillway or other hydraulic structure.

Travel time

The estimated time for surface water to flow between two points of interest.

TRC

Technical Review Committee

Treatment BMP or Facility

A BMP that is intended to remove pollutants from stormwater. A few examples of treatment BMPs are Wetponds, oil/water separators, biofiltration swales, and constructed wetlands.

Treatment liner

A layer of soil that is designed to slow the rate of infiltration and provide sufficient pollutant removal so as to protect groundwater quality.

Treatment soil

Existing or engineered combination of sands and organics that meet Site Suitability Criteria (SSC) for Runoff Treatment.

Treatment train

A combination of two or more Runoff Treatment BMPs connected in series.

Trip ends

The expected number of vehicles using a parking area. Projected trip end counts for the parking area are associated with the proposed land use. Trip end counts shall be estimated using the *Trip Generation Manual* published by the Institute of Transportation Engineers or a traffic study prepared by a licensed engineer in the state of Washington or a transportation specialist with expertise in traffic volume estimation. Trip end counts shall be made for the design year or expected life of the project (the intent is for treatment facilities to be added in the earliest period of disruptive construction). For project sites with seasonal or varied use, evaluate the highest period of expected traffic impacts.

TSD

Triangular Silt Dike

TSS

Total Suspended Solids

Turbidity

Dispersion or scattering of light in a liquid, caused by suspended solids and other factors; commonly used as a measure of suspended solids in a liquid.

- U -

UFC

Uniform Fire Code

UGA

Urban Growth Area

UIC

Underground Injection Control

U.S. EPA

United States Environmental Protection Agency

Underdrain

Plastic pipes with holes drilled through the top that are installed on the bottom of an infiltration BMP to collect and remove excess runoff.

Underground Injection Control (UIC) Program

A federal regulatory program established to protect underground sources of drinking water from UIC well discharges. In Washington, the U.S. EPA has granted Ecology authority to regulate UIC wells, except for UIC wells on tribal land.

Underground Injection Control (UIC) Well

A UIC well is defined as a structure built to discharge fluids from the ground surface into the subsurface; a bored, drilled, or driven shaft 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 that includes an assemblage of perforated pipes, drain tiles, or other similar mechanisms intended to distribute fluids below the surface of the ground. Examples of UIC wells or subsurface infiltration systems include drywells, drain fields, infiltration trenches with perforated pipe, storm chamber systems with the intent to infiltrate, french drains, bioretention systems intended to distribute water to the subsurface by means of perforated pipe installed below the treatment soil, and other similar devices that discharge to the ground.

Undisturbed buffer

A zone where development activity shall not occur, including logging, and/or the construction of utility trenches, roads, and/or surface and stormwater facilities.

Undisturbed low gradient uplands

Forested land, sufficiently large and flat to infiltrate surface and storm runoff without allowing the concentration of water on the surface of the ground.

Unstable slopes

Those sloping areas of land which have in the past exhibited, are currently exhibiting, or will likely in the future exhibit, mass movement of earth.

Unusual biological community types

Assemblages of interacting organisms that are relatively uncommon regionally.

Upgrade

The replacement of paved areas with a better surface or in a way that enhances the traffic capacity of the road.

Urban road

A roadway located inside the boundary of an Urban Growth Area.

Urban runoff

Stormwater from streets and adjacent domestic or commercial properties that may carry pollutants of various kinds into storm drains or drywells and/or receiving waters.

USACE

United States Army Corps of Engineers

U.S.C.

United States Code

USDA

United States Department of Agriculture

USDW

Underground Source of Drinking Water

USGS

United States Geological Survey

- V -

Values

Wetland processes or attributes that are valuable or beneficial to society (also see Functions). Wetland values include support of commercial and sport fish and wildlife species, protection of life and property from flooding, recreation, education, and aesthetic enhancement of human communities.

Variance

See Exception.

Vegetated flow path

A vegetated flow path consists of well-established lawn or pasture, landscaping with well-established groundcover, native vegetation with natural groundcover, or an area that meets BMP F6.61: Post-Construction Soil Quality and Depth. The groundcover shall be dense enough to help disperse and infiltrate flows and to prevent erosion.

Vegetation

All organic plant life growing on the surface of the earth.

Vehicular use

Regular use of an impervious or pervious surface by motor vehicles. The following are subject to regular vehicular use:

- roads,
- un-vegetated road shoulders,
- bike lanes within the traveled lane of a roadway,
- driveways,
- parking lots,
- unrestricted access fire lanes,
- vehicular equipment storage yards,
- railway lines, including light rail elevated and non-elevated guideways/tracks, and
- airport runways and other surfaces intended for movement and/or storage of aircraft.

The following are not considered subject to regular vehicular use:

- sidewalks not subject to drainage from roads for motor vehicles,
- paved bicycle pathways separated from and not subject to drainage from roads for motor vehicles,
- restricted access fire lanes, and
- infrequently used maintenance access roads.

Vulnerability

Vulnerability is a water source's potential for contamination. Two factors influence vulnerability:

1. **Physical susceptibility to contaminant infiltration.** Susceptibility depends on conditions that affect the movement of contaminants from the land surface into a water supply. This includes the depth of the well, its construction, the geology of the area, the pumping rate, the source(s) of groundwater recharge, and the aquifer material.
2. **The source's risk of exposure to contaminants.** The risk of exposure is measured by determining whether contaminants were used in the water supply area. However, each type of contaminant may behave differently in the environment, making it difficult to predict groundwater pollution from surface exposure accurately. For this reason, susceptibility is the key factor used in determining vulnerability. See *Washington State Wellhead Protection Program Guidance Document* (DOH, 2010).

- W -

WAC

Washington Administrative Code

Water cleanup plan

See Total Maximum Daily Load.

Water quality

A term used to describe the chemical, physical, and biological characteristics of water, usually in respect to its suitability for a particular purpose.

Water quality standards

Minimum requirements of purity of water for various uses; for example, water for agricultural use in irrigation systems should not exceed specific levels of sodium bicarbonate, pH, total dissolved salts, etc. In Washington, the Department of Ecology sets water quality standards.

Water table

The upper surface or top of the saturated portion of the soil or bedrock layer, indicating the uppermost extent of groundwater.

Waterbody

Surface waters including rivers, streams, lakes, marine waters, estuaries, and wetlands.

Water body segment

A stream reach or portion of a water body generally having the same characteristics. Water body segments may be defined by reaches between confluences with major tributaries or by section lines on a 1:24,000-scale topographical map.

Water quality criteria

Levels or measures of water quality considered necessary to protect a beneficial use.

Watershed

The land area that drains into a stream, lake, or other body of water. An area of land that contributes runoff to one specific delivery point. Large watersheds may be composed of several smaller subwatersheds, each of which contributes runoff to different runoff locations that ultimately combine at a common delivery point or receiving water. The words *watershed* and *basin* are often used interchangeably.

Waters of the state

Lakes, rivers, ponds, streams, inland waters, underground waters, salt waters, and all other surface waters and watercourses within the jurisdiction of the state of Washington.

WDFW

Washington State Department of Fish and Wildlife

Weir

Device for measuring or regulating the flow of water.

Weir notch

The opening in a weir for the passage of water.

Wellhead protection area

The area surrounding a drinking water source that is focused on protection from potential contamination that typically includes four or five zones: a sanitary control area, Zone 1 (1-year travel time), Zone 2 (5-year travel time), Zone 3 (10-year travel time), and an additional buffer zone (if warranted) (WAC 246-290-130 and WAC 246-290-135).

Wetland edge

Delineation of the wetland edge shall be based on the *Corps of Engineers Wetlands Delineation Manual* (Environmental Laboratory, 1987).

Wetland functions

The ecological (physical, chemical, and biological) processes or attributes of a wetland. Functions are often defined in terms of the processes that provide value to society, but they can also be defined based on processes that are not value based. Wetland functions include food chain support, provision of ecosystem diversity and fish and wildlife habitat, flood flow alteration, groundwater recharge and discharge, water quality improvement, and soil stabilization.

Wetlands

Those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas. Wetlands do not include those artificial wetlands intentionally created from non-wetland sites, including, but not limited to, irrigation and drainage ditches, grass-lined swales, canals, detention facilities, wastewater treatment facilities, farm ponds, and landscape amenities, or those wetlands created after July 1, 1990, that were unintentionally created as a result of the construction of a road, street, or highway. Wetlands may include those artificial wetlands intentionally created from non-wetland areas to mitigate the conversion of wetlands.

Wetponds and wetvaults

Runoff Treatment BMPs that contain permanent pools of water that are filled during the initial runoff from a storm event. They are designed to optimize water quality by providing retention time in order to settle out particles of fine sediment to which pollutants such as heavy metals adsorb, and to allow biologic activity to occur that metabolizes nutrients and organic pollutants.

Wetpool

A pond or constructed wetland that stores runoff temporarily and whose normal discharge location is elevated to maintain a permanent pool of water between storm events.

WISHA

Washington Industrial Safety and Health Act

WSDOT

Washington State Department of Transportation

WTR

Water Treatment Residual

- X -

- Y -

- Z -

Zoning ordinance

An ordinance based on the police power of government to protect the public health, safety, and general welfare. It may regulate the type of use and intensity of development of land and structures to the extent necessary for a public purpose. Requirements may vary among various geographically defined areas called zones. Regulations generally cover such items as height and bulk of buildings, density of dwelling units, off-street parking, control of signs, and use of land for residential, commercial, industrial, or agricultural purposes. A zoning ordinance is one of the major methods for implementation of a comprehensive plan.

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