Addendum to
the King County
Surface Water Design Manual

August 1, 2022

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Introduction

This addendum to the 2021 King County Surface Water Design Manual (KCSWDM) applies to development and redevelopment proposals within the City of SeaTac (City). The KCSWDM has been adopted to meet the requirements of the Clean Water Act, the Endangered Species Act and State Growth Management Act. This addendum includes minor revisions to the KCSWDM to address the differences between King County's and the city's organization and processes, as well as to address equivalency requirements. No major substantive changes have been made to the KCSWDM in order to maintain equivalency in the review requirements and level of protection provided by the manual.

[Note: Clarifications and interpretations to the KCSWDM or this addendum will be documented and made available through policy statements within the City's Development Standards.]

Addendum Organization

The information presented in this addendum is organized as follows:

- **Terminology:** At times King County and City of SeaTac use different terminology to describe or refer to equivalent subject matter. This section identifies these terms and the City of SeaTac's equivalent terminology.

- **Key Revisions:** This section specifically identifies the minor revisions the City has made to the KCSWDM. These revisions are necessary to maintain equivalency to the stormwater standards identified in the NPDES Phase II Permit, as well as to address deficiencies within the KCSWDM.

- **Supplemental Documents:** This section identifies technical guidance manuals and documents which shall be used to supplement the KCSWDM. These documents are necessary to maintain equivalency to the stormwater standards identified in the NPDES Phase II Permit, as well as to address deficiencies within the KCSWDM.

- **Code Reference Tables:** King County code is referenced in many places throughout the KCSWDM. This section identifies these code references and equivalent city code where applicable.

Supplemental information in the appendices includes the following:

- Appendix A: Hydrologic Analysis of the Des Moines Creek Regional Detention Facility (July 23, 2003 Memorandum from the Department of Ecology)

- Appendix B: Soil Amendment Requirements

- **Appendix C:** Design and Maintenance Criteria for BMPs/Facilities that may not be included in the KCSWDM

- **Appendix D:** Flow Control and Water Quality Applications Maps

Terminology

At times King County and City of SeaTac use different terminology to describe or to refer to equivalent subject matter. This section identifies these terms and the City of SeaTac's equivalent terminology.

Department of Natural Resources and Parks (DNRP) = City of SeaTac Parks & Recreation.

Department of Permitting and Environmental Review (DPER) = City of SeaTac Public Works and Community and Economic Development Departments.

Director = City of SeaTac Public Works Director.

Drainage facilities restoration and site stabilization guarantee and drainage defect and maintenance guarantee = SeaTac stormwater facilities restoration and site stabilization bond (Performance Bond) and defect and maintenance bond (Stormwater Maintenance Bond).

King County = City of SeaTac.

King County Code (KCC) = SeaTac Municipal Code (SMC). Check code reference table for equivalent code sections.

King County Designated/Identified Water Quality Problem - This determination is made on a case-by-case basis.

King County Road Standards = City of SeaTac Development Standards.

Master Drainage Planning - Not applicable, no SMC equivalent.

Sensitive Area Folio = In addition to the King County Sensitive Area Folio, Stream, Wetland and Steep Slope maps are also available through the City of SeaTac GIS Portal.

Urban Planned Development = Not applicable, no SMC equivalent.

Water and Land Resources (WLR) Division = City of SeaTac Public Works Department.

Zoning Classifications: Where the KCSWDM references Agricultural (A) Zoning, Forest (F) Zoning, or Rural (R) Zoning - These zoning classifications are intended for areas outside of the Urban Growth Boundary, therefore the City of SeaTac contains no equivalent zoning. Refer to City zoning maps to determine which zoning classifications apply to your project.

Key Revisions

This section specifically identifies the minor revisions the City has made to the KCSWDM. These revisions are necessary to maintain equivalency to the stormwater standards identified in the NPDES Phase II Permit, as well as to address deficiencies within the KCSWDM.

Mitigation of Impacts from Construction Site Runoff – Property owners and construction site managers are responsible for mitigating off-site impacts from construction regardless of the size of the project or whether a construction permit was required by the City of SeaTac.

Des Moines Creek Basin Flow Control – New and redevelopment projects may use the Basic Flow Control standard as identified in the KCSWDM, and the 1994 land use condition as the pre-development conditions for sizing flow control facilities. This adjustment is established based on the Des Moines Creek Basin Plan, the Des Moines Creek Regional Capital Improvement Project and the Hydrologic Analysis of the Des Moines Creek Regional Detention Facility as specified in a letter from the Department of Ecology, dated July 23, 2003 signed by Kevin Fitzpatrick (included in Appendix A).

Erosion Hazard Areas – For the purposes of site assessment and site planning and design, slopes greater than or equal to 15% are considered "Erosion Hazard Areas". Project designs and erosion sedimentation control plans must address these areas accordingly.

Soil Amendment Requirements – The City has developed a Soil Amendment Standards handout that is included in Appendix B of this document.

Continuous Modeling – SeaTac will allow the Western Washington Hydrology Model (WWHM), MGSFlood, or HSPF to be used to for sizing stormwater facilities to meet flow control, treatment, or the LID performance standard requirements. Explicit modeling of BMP infiltration for facility sizing is also allowed instead of applying the flow control BMP facility sizing credits included in Table 1.2.9.A in Chapter 1 of the KCSWDM.

Additional Flow Control Facility Options for Core Requirement #3 – The KCSWDM does not include vegetated roofs, but they are allowed in the City of SeaTac. Design and maintenance guidelines for vegetated roofs can be found in Appendix C of this document.

Additional Water Quality Facility Options for Core Requirement #8 – The following facilities are available as options on the Basic WQ Menu: Compost-amended Vegetated Filter Strips (CAVFS), Media Filter Drains (MFDs) (previously referred to as the Ecology Embankment), and Bioretention.

Emerging technologies currently approved by Ecology (http://www.ecy.wa.gov/programs/wq/stormwater/newtech/technologies.html) can be used as options on the Basic WQ Menu if they have received a General Use Level Designation (GULD) for Basic Treatment. Emerging technologies currently approved by Ecology can be used as options on the Enhanced WQ Menu if they have received a GULD for Enhanced Treatment.

Design and maintenance guidelines for CAVFS and MFDs can be found in Appendix C of this document. Design guidelines for Bioretention can be found in Appendix C of this document.

Maintenance guidelines for Bioretention can be found in the KCSWDM. Design and maintenance guidelines for emerging technologies should be requested from the manufacturer.

Additional Flow Control BMP Options for Core Requirement #9 – In addition to engineered bioretention facilities, non-engineered rain gardens are allowed for small lots in the City of SeaTac with less than 5,000 square feet of impervious surface. Rain gardens shall be sized to have a minimum horizontal projected surface area below the overflow which is at least 5% of the area draining to it. Design and maintenance guidelines for rain gardens can be found in the Rain Garden Handbook for Western Washington. [Note: Rain gardens can be used to meet Core Requirement #9, but cannot be used to meet Core Requirements #3 or #8.]

Overflows to City ROW – Where feasible based on topography, private stormwater facilities should be designed to overflow to the City Right-of-Way (ROW) or a receiving water.

Underdrains – Underdrains are allowed in permeable pavement designs. Underdrains are allowed for bioretention using the new bioretention soil mix approved per King County Reference 11-C in the KCSWDM.

Flow Control and Water Quality Applications Maps – City of SeaTac equivalents to the Flow Control Applications Map and Water Quality Applications Map can be found in Appendix D of this document. In lieu of a SeaTac equivalent to the County Landslide Hazard Drainage Areas Map, the City will rely on King County's map.

Interpretation or Modification of Standards - The Public Works Director or his/her designee is responsible for all interpretations and/or revisions to the surface water design standards as may be required for their implementation. These standards will be considered as reasonable minimum requirements, and will not be modified, except as may be permitted by the Public Works Director pursuant to a requested modification, adjustment, or variance, and subject to all applicable decision criteria. Such requests must be submitted in writing and provide a detailed explanation as to why a deviation from the standards is necessary and how the proposed modification/adjustment would be in compliance with the intent and purpose of the City's standards.

Supplemental Documents

This section identifies technical guidance manuals and documents which shall be used to supplement the KCSWDM. These documents are necessary to maintain equivalency to the stormwater standards identified in the NPDES Phase II Permit, as well as to address deficiencies within the KCSWDM.

King County Stormwater Pollution Prevention Manual – The most recent edition of the King County Stormwater Pollution Prevention Manual (KCSWPPM) shall be used as technical guidance for water quality best management practices (BMPs). This BMP manual shall also be used as the technical guidance for identifying and implementing source control measures for private residents, businesses, and industries when applying SMC 12.12 (Surface and Stormwater – Illicit Discharge Detection and Elimination Code).

Low Impact Development Technical Guidance Manual for Puget Sound – The 2012 Low Impact Development Technical Guidance Manual for Puget Sound created by the Puget Sound Partnership, or as hereafter amended, shall be used as the supplemental technical guidance for the KCSWDM for the use of LID principles and LID BMPs.

Rain Garden Handbook for Western Washington: A Guide for Design, Installation, and Maintenance - The 2013 Rain Garden Handbook created by Ecology, the Washington State University Extension, and Kitsap County, or as hereafter amended, shall be used as the supplemental technical guidance for the KCSWDM for the design, installation, and maintenance of rain gardens.

Stormwater Standard Plans – The City of Tacoma Standard Plans currently found at www.cityoftacoma.org/government/city_departments/public_works/engineering/city_of_tacoma_right_of_way_design_manual are approved by the City of SeaTac on a conceptual basis. City of SeaTac development review staff will work with applicants to review and implement these standard details.

Stormwater System Maintenance Standards – The Maintenance Standards for both public and private stormwater systems are identified in Chapter 6, Appendix A, and Appendix C of the KCSWDM and Appendix C of this document.

Supplemental Guidelines for Public Right of Way Operations and Maintenance – The most recent edition of the Regional Road Maintenance - Endangered Species Act Program Guidelines currently found at www.kingcounty.gov/depts/transportation/roads/endangered-species-act-reports.aspx, or as hereafter amended, shall be used to supplement the above mentioned stormwater system maintenance standards for work done in the public right of way, as well as public stormwater systems.

Supplemental Snow and Ice Policy – The City of SeaTac will use snow melt materials (i.e., salt brine) as often as necessary on public roads during snow and ice events to maintain safe travel on roadways while minimizing the potential of water quality impacts (i.e., debris entering the storm system).

Vegetation and Land Management Standards - The most recent edition of the City of SeaTac Integrated Pest and Vegetation Management Plan shall be used as guidance for pest, vegetation and land management activities for all properties or facilities owned or operated by the City of SeaTac.

Code Reference Tables

King County Code is referenced in many places throughout the KCSWDM. The following tables identify these code references and equivalent city code where applicable.

King County Code to SeaTac Municipal Code (SMC) Reference Table			
King County Code Reference	**Subject of Reference**	**SMC Equivalent**	**Comment**
KCC 2.98	Adoption Procedures	1.01	
KCC 2.98	Critical Drainage Areas (CDAs), adoption procedures	12.10.080	
Title 9	Surface Water Management	12.10 & 12.30	
KCC 9.04	Surface Water Run-off Policy: Variances	No Equivalent	The City relies on the adjustment process identified in the KCSWDM
KCC 9.04	Stormwater Runoff and Surface Water and Erosion Control	No Equivalent	In the absence of equivalent SMC, the City will use the King County Code for all general references to KCC 9.04
KCC 9.04.030	Definitions: Targeted Drainage Review/abbreviated evaluation	No Equivalent	In the absence of equivalent SMC, the City will use King County's definition
KCC 9.04.030	Drainage review – when required - type	No Equivalent	In the absence of equivalent SMC, the City will use King County's definition
KCC 9.04.030	Full Drainage Review	No Equivalent	The SMC does not list additional drainage review requirements and relies on the KCSWDM
KCC 9.04.050	Drainage review - requirements	No Equivalent	The SMC does not list additional drainage review requirements and relies on the KCSWDM
KCC 9.04.070	Engineering plans for the purposes of drainage review	Not Applicable	County Code refers to internal DDES procedures and is referenced only in definition of DDES
KCC 9.04.090	Construction timing and final approval	12.10.100	The City also has Subdivision Standard Plan Notes

King County Code to SeaTac Municipal Code (SMC) Reference Table			
King County Code Reference	**Subject of Reference**	**SMC Equivalent**	**Comment**
9.04.100	Liability insurance required	12.10.110 - 12.10.150	
KKCC 9.04.115	Drainage facilities accepted by King County for maintenance	No Equivalent	SeaTac generally does not accept stormwater facilities unless they are constructed in the public ROW
KCC 9.04.120	Drainage facilities not accepted by King County for maintenance	No Equivalent	SeaTac generally does not accept stormwater facilities unless they are constructed in the public ROW
K.C.C. 9.05.050	Drainage review - requirements	Not Applicable	King County Code section does not exist. Presumed typo. See KCC 9.04.050
KCC 9.12.025	Prohibited, allowable, and conditional discharges	12.12.020, 12.12.030, and 12.12.040	
KCC 9.12	Water Quality	No Equivalent	In the absence of equivalent SMC, the City will use the King County Code for all general references to KCC 9.12
KCC 9.12.035	Stormwater Pollution Prevention Manual	No Equivalent	Adopted via SeaTac Addendum to KCSWDM
Title 10	Seattle-King County Department of Public Health solid waste regulations	7.40	
KCC 16.62	Erosion and Sediment Control	Not Applicable	King County Code section does not exist. Presumed typo. See KCC 16.82 below.
KCC 16.82	Clearing and Grading Code: Bridge Design	No Equivalent	In the absence of City standards for bridge design, the City will rely on King County Road Design and Construction standards and the WSDOT Standard Specifications for Road, Bridge, and Municipal Construction
KCC 16.82	Clearing and Grading Code: Clearing Limit	No Equivalent	In the absence of City standards for clearing limits, the City will rely on King County standards.

King County Code to SeaTac Municipal Code (SMC) Reference Table			
King County Code Reference	**Subject of Reference**	**SMC Equivalent**	**Comment**
KCC 16.82.095(A)	Erosion and sediment control standards	No Equivalent	In the absence of City standards for seasonal construction limitations, the City will rely on King County standards
KCC 16.82.095(A)	Erosion and sediment control standards-seasonal limitation period	No Equivalent	In the absence of City standards for seasonal construction limitations, the City will rely on King County standards
KCC 16.82.100(F)	Grading Standards: Preservation of Duff Layer	No Equivalent	Appendix B of this addendum includes the City's Soil Amendment requirements
KCC 16.82.100(G)	Grading Standards: Soil Amendments	No Equivalent	Appendix B of this addendum includes the City's Soil Amendment requirements
KCC 16.82.150	Clearing standards for individual lots in the rural zone	Not Applicable	SMC does not contain rural zoning classification
KCC 16.82.150 (C)	Clearing standards for individual lots in the rural zone	Not Applicable	SMC does not contain rural zoning classification
KCC 16.85	Clearing and Grading Code: Flood protection facilities	Not Applicable	King County Code section does not exist. Presumed typo. See KCC 16.82 below.
KCC 20.20 or Title 20.20	Land Use Review Procedures	16A	
KCC 20.70.020	Critical aquifer recharge area map adoption	15.700	
KCC 21A or Title 21A	Critical Areas Requirements	15.700	
KCC 21A.06	Definitions: Erosion Hazard Area	15.700	
KCC 21A.06	Definitions: Flood Hazard Area	15.700	

King County Code to SeaTac Municipal Code (SMC) Reference Table			
King County Code Reference	**Subject of Reference**	**SMC Equivalent**	**Comment**
KCC 21A.06	Definitions: Landslide Hazard Area	No Equivalent	SMC does not contain an equivalent definition
KCC 21A.06	Definitions: Steep Slope Hazard Area	15.700	
KCC 21A.06	Definition: Structure	15.700	
KCC 21A.06	Definitions: Critical Aquifer Recharge Area	15.700	
KCC 21A.06	Definitions: (Nonconversion) Forest Practices	Not Applicable	City of SeaTac only reviews Type IV - Conversion, forest practice permits
K.C.C. 21A.06.1340	Urban planned development land use designation	Not Applicable	SMC contains no equivalent comprehensive plan land use designation
KCC 21A.08	Definitions: Land Zoned for Agriculture (A zoned lands)	Not Applicable	SMC does not contain agricultural zoning classification
KCC 21.A12	Definitions: Urban Residential Development	15.200	The City of SeaTac Zoning Map contains Urban Low Density Residential (UL), Urban Medium Density Residential (UM), and Urban High Density Residential (UH).
KCC 21A.12.030	Impervious Surface Coverage	15.400.015	Only one zone in the City (Business Park [BP]) contains a maximum impervious surface coverage development standard
KCC 21A.12.030	Impervious Surface Coverage for Residential Subdivisions	Not Applicable	The City does not have impervious surface coverage development standards for residential subdivisions
KCC 21A.14.180	Onsite recreational space	15.510.500 – 15.510.560	The City allows vegetated roofs that are accessible to the general public and permeable pavement trails to count towards multi-purpose outdoor recreation and open

King County Code to SeaTac Municipal Code (SMC) Reference Table			
King County Code Reference	**Subject of Reference**	**SMC Equivalent**	**Comment**
			space
KCC 21A.14.180.D	21A.14.180 On-site recreation - space required.	15.510.510	The City allows vegetated roofs that are accessible to the general public and permeable pavement trails to count towards multi-purpose outdoor recreation and open space
KCC 21A.24	Critical Areas Code: 100-Year Floodplain	15.700	
KCC 21A.24	Critical Areas Code: Bridge Design	No Equivalent	In the absence of City standards for bridge design, the City will rely on King County Road Design and Construction standards and the WSDOT Standard Specifications for Road, Bridge, and Municipal Construction
KCC 21A.24	Critical Areas Code: Bridge pier and abutment locations	No Equivalent	In the absence of City standards for bridge and pier location, the City will rely on King County Road Design and Construction standards and the WSDOT Standard Specifications for Road, Bridge, and Municipal Construction
KCC 21A.24	Critical Areas Code: Critical Area Buffers	15.700	
KCC 21A.24	Critical Areas Code: Building Setbacks	15.700	
KCC 21A.24	Critical Areas Code: Channel Migration Zone	No Equivalent	In the absence of City standards for channel migration zones, the City will rely on King County standards

King County Code to SeaTac Municipal Code (SMC) Reference Table			
King County Code Reference	**Subject of Reference**	**SMC Equivalent**	**Comment**
KCC 21A.24	Critical Areas Code: Definition Streams	15.700	
KCC 21A.24	Critical Areas Code: Requirements of crossing steams	15.700	
KCC 21A.24	Critical Areas Code: Definition Wetlands/Wetland Soils	15.700	
KCC 21A.24	Critical Areas Code: Fish Passage Requirements	15.700	
KCC 21A.24	Critical Areas Code: Flood Hazard Area regulations	15.700	
KCC 21A.24	Critical Areas Code: Floodplain/Floodway Delineation	15.700	
KCC 21A.24	Critical Areas Code: Floodplain Data	15.700	
KCC 21A.24	Critical Areas Code: Flood Protection facility	No Equivalent	In the absence of City standards for flood protection facilities, the City will rely on King County standards
KCC 21A.24	Critical Areas Code: Notice on Title	15.700	
KCC 21A.24	Critical Areas Code: Regulation of Wetlands	15.700	
KCC 21A.24	Critical Areas Code: zero-rise and compensatory storage provisions	15.700	In the absence of City standards for zero-rise and compensatory storage, the City will rely on King County standards
KCC 21A.24	Definitions: Critical Area Ordinance (CAO)	15.700	See - Environmentally Sensitive Areas Code
KCC 21A.24	Farm Management Plans	Not Applicable	The City does not have Farm Management Plan code.

King County Code to SeaTac Municipal Code (SMC) Reference Table			
King County Code Reference	**Subject of Reference**	**SMC Equivalent**	**Comment**
KCC 21A.24	Floodplain Development Standards: Bridges	No Equivalent	In the absence of City standards for bridge design, the City will rely on King County Road Design and Construction standards and the WSDOT Standard Specifications for Road, Bridge, and Municipal Construction
KCC 21A.24, KCC 16.82	Rural Stewardship Plan or Farm Management Plan	Not Applicable	
KCC 21A.24	Sensitive Area	15.700	
KCC 21A.24	Sensitive Area Tract	15.700	
KCC 21A.24.100	Critical Area Review	15.700	
KCC 21A.24.110	Critical Area Reports	15.700	
KCC 21A.24.170	Notice on Title	15.700	
KCC 21A.24.230	Floodplain and Flood Hazard Areas	15.700	
KCC 21A.24.270	FEMA Elevation Certification	15.700	
KCC 21A.24.275	channel migration zone development standards	Not Applicable	
KCC 21A.25	Shorelines code	Title 18	
KCC 25 or Title 25	Shoreline Management: Bridge Design	Not Applicable	In the absence of City standards for bridge design, the City will rely on King County standards

Appendix A – Hydrologic Analysis of the Des Moines Creek Regional Detention Facility (July 23, 2003 Memorandum from the Department of Ecology)

STATE OF WASHINGTON
DEPARTMENT OF ECOLOGY
Northwest Regional Office • 3190 160th Avenue SE • Bellevue, Washington 98008-5452 • (425) 649-7000

July 23, 2003

Mr. David Masters, Project Coordinator
Des Moines Creek Regional Detention Facility Planning Committee
P.O. Box 4008
Seattle, WA 98194

Dear Mr. Masters;

Re: Hydrologic Analysis of the Des Moines Creek Regional Detention Facility

We have reviewed the following reports submitted by you on behalf of the members of the Des Moines Creek Planning Committee:

- *Hydrologic Analysis of the Des Moines Creek Regional Detention Facility Using HSPF*
- *Des Moines Creek Regional Capital Improvement Project, Preliminary Design Report (including the Alternatives Analysis, Alternative Analyses Addendum, and Appendices A, B, D, and E).*
- *Des Moines Creek Basin Plan*

We find that these documents are responsive to the Department of Ecology's *Stormwater Management Manual for Western Washington, Appendix A, Guidance for Altering the Minimum Requirements Through Basin Planning*. The information submitted provides sufficient technical data to justify an alternative to the department's recommended minimum requirement for flow control within the Des Moines Creek Watershed. The alternative receiving the department's concurrence requires the implementation of three recommendations from the subject reports:

- A Des Moines regional detention facility in the Tyee Golf Course at the southern end of Sea-Tac airport, north of South 200th St., including two new stormwater detention ponds referred to as the Northwest Pond and the Approach Light Road Pond, as further described in the documents.
- Two bypass pipelines; a 48-inch diameter line to carry flow from the existing Tyee Regional Stormwater Pond to the Northwest Pond, and a 30-inch diameter line from the Tyee Pond to an abandoned sanitary sewer line that will be refurbished to carry stormwater to Puget Sound.

- Application of the King County Runoff Time Series (KCRTS) flow model or other DOE approved models, the King County Level 1 flow control standard, and the 1994 land use condition as the pre-developed condition for sizing flow control facilities for new development and redevelopment once the regional facilities and bypass lines are constructed and operational.

This concurrence should not be construed as the issuance of the necessary permits for construction of the above projects.

Because the planning documents do not provide alternative recommendations to the water quality treatment guidance provided in the 2001 Stormwater Management Manual for Western Washington, the Department of Ecology encourages the local governments to use the manual recommendations for new development and redevelopment. In addition, the Department encourages the Basin Committee to continue planning to address the existing water quality problems of the creek. The chemical parameters identified in the planning documents that exceed applicable water quality standards include: fecal coliform bacteria, temperature, dissolved copper and zinc. In addition, because of the relatively urbanized nature of the watershed, it is likely that concentrations of various polycyclic aromatic hydrocarbons and pesticides are periodically problematic.

We congratulate the local governments on their foresight, determination, and commitment to identify and implement a strategy that should give Des Moines Creek and its biologic resources a much improved chance at not only surviving, but thriving.

Sincerely,

Kevin C. Fitzpatrick

Kevin C. Fitzpatrick
Water Quality Manager
Northwest regional Office

KCF:ha:jc

Cc: Donald Althauser, P.E., King County
Ed O'Brien, P.E., DOE, Water Quality, HQ
Ed Abbasi, Water Quality, NWRO

Appendix B – Soil Amendment Requirements

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Soil Amendment Requirements

Effective February 15, 2010
Revised December 31, 2016

Preserving and Restoring Healthy Soils on Site Developments

Healthy soil is vital to a clean environment and healthy landscapes. Deep soil that is rich in organic material absorbs rainwater, helps prevent flooding and soil erosion, and filters out water pollutants. Healthy soil also stores water and nutrients for plants to use in dry times, promoting healthy plants that require less irrigation, toxic pesticides, and other resources. Land development and landscaping practices can damage these valuable soil functions by removing or compacting topsoil. The result is erosion, unhealthy landscapes that are difficult and expensive to maintain, polluted water, destroyed fish habitat, and increased need for costly stormwater management structures. (King County 2011 "Achieving the Post-construction Soil Standard")

Purpose

This document is intended to describe how to meet these soil amendment requirements, as well as provide clarifications and minor modifications to King County's soil amendment requirements in terms of seasonal restrictions and cash assignment requirements. Additional guidance for this BMP can be found in *Building Soil: Guidelines and Resources for Implementing Soil Quality and Depth BMP T5.13* (Stenn et al. 2012), which is available at www.buildingsoil.org.

Infeasibility Criteria

The following portions of the project area are considered to be infeasible for soil amendment:

- Areas covered by an impervious surface
- Areas incorporated into a drainage facility
- Areas that are subject to a state surface mine reclamation permit
- Structural fill or engineered slopes
- Till soils with slopes greater than 33 percent

Soil Amendment Requirements

The City of SeaTac's soil amendment requirements apply to projects that:

1. Create 2,000 square feet or more of new impervious surface, or
2. Result in 7,000 square feet or more of land disturbing activity.

KCC 16.82.100.F & G have been amended by the City of SeaTac to include the following:

- The duff layer and native topsoil shall be retained in an undisturbed state to the maximum extent practicable. Any duff layer or topsoil removed during grading shall be stockpiled on-site in a designated, controlled area not adjacent to public resources and critical areas. The material shall be reapplied to other portions of the site where feasible.

- Areas that have been cleared and graded shall have the soil moisture holding capacity restored to that of the original undisturbed soil native to the site to the maximum extent practicable. The soil in any area that has been compacted or that has had some or all of the duff layer or underlying topsoil removed shall be amended to mitigate for lost moisture-holding capacity.

- Soil amendment calculations and a site map indicating projected soil amendment areas are due at the time of project application submittal.

- Unlike King County, the City of SeaTac **does not** limit the installation of soil amendments to the growing season (May 1 – October 1). However, soil amendments, whether compost or topsoil, shall be installed in a manner that will prevent off-site impacts from construction site run-off. Further, soil amendments are subject to "Wet Season Construction" requirements (2016 KCSWDM).

- Cash Assignments:

  - Owners/contractors may provide a cash assignment for soil amendments if requesting final approval between October 1 – May 1 (during the rainy season)
  - Cash assignment amounts shall equal to 120% x (materials + labor)
  - Owners/contractors must provide documentation ensuring legal access to the site (via construction easement, condition of sale, etc.) to install soil amendments as a condition of cash assignment acceptance/approval
  - Cash assigned soil amendments shall take place during the growing season (May 2 – September 30) immediately following the date of the cash assignment

- Imported topsoil layer requirements:
  - Topsoil must be a minimum 8 inches thick
  - Topsoil must have an organic matter content of 5% dry weight in turf areas – and 10% dry weight in planting beds
  - Topsoil must have a suitable pH for proposed landscape plants
  - When feasible, the subsoil layer shall be scarified four to six inches with some incorporation of upper material to avoid stratified layers

- Compost used to achieve the required soil organic matter content must meet the definition of "composted materials" in WAC 173-350-220.

Table B-1. Optimal soil pH range for various plant types.

Plant Type	Soil pH Range
Lawn	5.5 to 7.5
Shrubs (except acid-tolerant plants)	5.5 to 7.0
Acid-tolerant shrubs (rhododendrons, azaleas, mountain laurels, camellias, blueberries, native plants)	4.5 to 5.5
Annual flower and vegetable gardens	6.0 to 7.0

Note: A nursery can provide specific information about suitable soil pH ranges for landscape plants.
Source: King County 2011 "Achieving Post-construction Soil Standard"

Options for Meeting Soil Amendment Requirements (Calculations)

1) Amend Existing Soils in Place

- Turf Areas
  - Import 6.17 cubic yards compost (in accordance with 2016 KCSWDM compost specifications) per 1,000 sq. ft. of disturbed soil area
  - Spread compost evenly over the disturbed soils in a 2 inch layer
  - Rototill compost in 12 inches deep where feasible (8 inch minimum depth)
- Planting Beds
  - Import 9.25 cubic yards compost (in accordance with 2016 KCSWDM compost specifications) per 1,000 sq. ft. of disturbed soil area
  - Spread compost evenly over the disturbed soils in a 3 inch layer
  - Rototill compost in 12 inches deep where feasible (8 inch minimum depth)

Soil Amendment Calculation Example

Amount of imported compost needed to amend soils on site equals the total square footage of disturbed site soils divided by 1,000 times 6.17 cubic yards.

(____________________/ 1,000) x 6.17 cubic yards = ____________________________

square feet disturbed soils   cubic yards of imported compost

Example: Single Family Home with 3,500 square feet of post construction disturbed soil
(3,500 square feet disturbed soils /1,000) x 6.17 cubic yard = imported compost needed
(3.5) x 6.17 cubic yards = imported compost needed
22 cubic yards = imported compost needed

Table B-2. Soil Amendment Calculation Examples.

Square Feet of Post Construction Disturbed Soils	Cubic Yards of Imported Compost Required for Turf Areas
5,000	31
4,500	28
4,000	25
3,500	22
3,000	19
2,500	15
2,000	12

2) Import Topsoil Mix

- Turf Areas
  - Scarify subsoil layer at least 4-6 inches deep where feasible
  - Import 24.7 cubic yards of topsoil containing 5% organic matter (approximately 25% compost) per 1,000 sq. ft. disturbed soil area
  - Spread topsoil evenly over the disturbed soils in an 8 inch layer
  - Rototill 2 inches of the topsoil into the subsoil.
- Planting Beds
  - Scarify subsoil layer at least 6 inches deep where feasible
  - Import 24.7 cubic yards of topsoil containing 10% organic matter (approximately 40% compost) per 1,000 sq. ft. disturbed soil area
  - Spread topsoil evenly over the disturbed soils in an 8 inch layer
  - Rototill 2 inches of the topsoil into the subsoil.

Topsoil Calculation Example
Amount of imported topsoil needed to satisfy the soil requirements on site equals the total square footage of disturbed site soils divided by 1,000 times 25 cubic yards.

(____________________/ 1,000) x 24.7 cubic yards = ________________________
square feet disturbed soils cubic yards of imported topsoil

Example: Single Family Home with 3,500 square feet of post construction disturbed soil
(3,500 square feet disturbed soils /1,000) x 24.7 cubic yard = imported topsoil needed
(3.5) x 24.7 cubic yards = imported topsoil needed
86 cubic yards = imported topsoil needed

Other Soil Amendment Options

King County's soil amendment guide "Achieving the Post-construction Soil Standard" identifies two additional options, which the City considers less feasible in an urban construction environment (i.e., non-native/disturbed soils, limited staging areas) and are not included in this document. However, these options are still available for projects within the City of SeaTac and can be found at: http://your.kingcounty.gov/solidwaste/greenbuilding/documents/Post-Construction-Soil-Standard.pdf. These options include:

- **Option 1: Leave native soil undisturbed, and protect from compaction during construction**
  [**Note:** This option is only available for sites which contain previously undisturbed native soils, such as undisturbed forested lots.]
- **Option 4: Stockpile site soil, reapply, and amend in place**

Inspection Approval of Soil Requirements

Soil amendments should take place at the final stage of construction, to ensure soil amendments are not damaged by construction activities. Contractors/property owners needing a soil amendment inspection should call the City at 206.973.4764 and request a Final Erosion Sedimentation Control Inspection (FESC).

- ➢ Call in FESC inspection after installation of soil amendments, prior to installation of landscaping.
- ➢ Provide City inspector with a site map indicating areas needing soil amendments, as well as soil amendment calculations (see calculation examples on previous pages).
- ➢ If amending soil in place, provide City inspector with copies of site specific receipts of delivered compost indicating the volume of materials delivered in cubic yards.
- ➢ If importing topsoil mix, provide City inspector with copies of site specific receipts of delivered materials indicating volumes in cubic yards and organic content of topsoil.
  - The contractor shall also provide documentation to confirm that the imported top soil is at an appropriate pH for the proposed landscaping (refer to Table B-2).
- ➢ The inspector may require random locations for test pits to be dug to confirm depths of soil amendments and scarification.
- ➢ If soil requirements have been met, the City inspector will indicate a partial approval "soil requirements met" on the Inspection Card.

Appendix C – Design and Maintenance Criteria for BMPs/Facilities not included in the KCSWDM

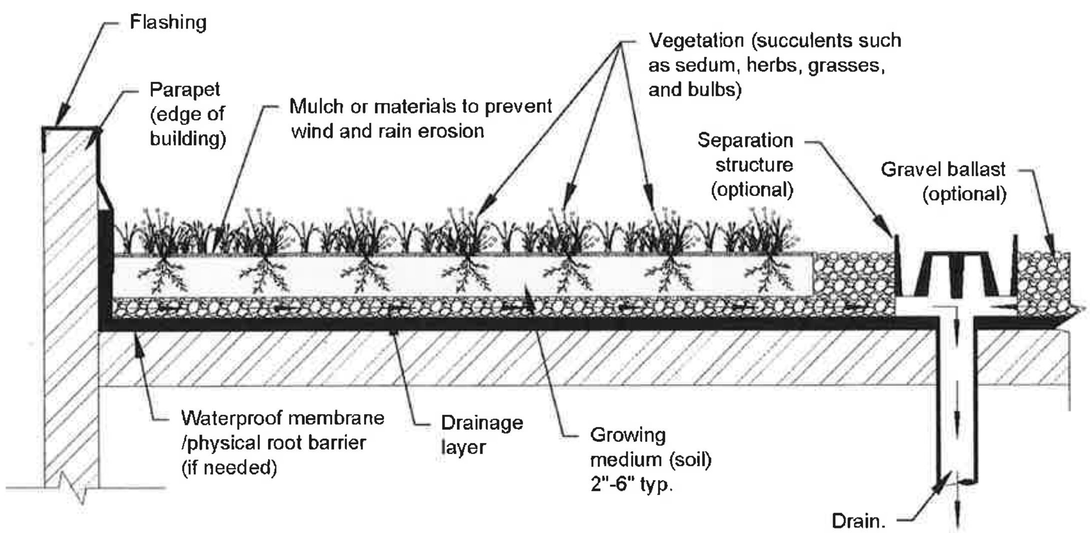
BMP T5.17: Vegetated Roofs

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. The range of benefits for a green 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.

All vegetated roofs consist of four basic components: a waterproof membrane, a drainage layer, a light-weight growth medium, and vegetation (see Figure V-11.2: Example of a Vegetated Roof Section). In addition to these basic components, many systems may also incorporate a protection layer and root barrier to preserve the integrity of the waterproof membrane, a separation/filter layer to stabilize fine particles, capillary mats and mulch/mats to retain moisture and prevent surface erosion due to rain and wind scour.

Figure V-11.2: Example of a Vegetated Roof Section



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Example of a Vegetated Roof Section

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Applications and Limitations

While vegetated roofs can be installed on slopes up to 40 degrees, slopes between 5 and 20 degrees (1:12 and 5:12) are most suitable and can provide natural drainage by gravity. Roofs with slopes greater than 10 degrees (2:12) require an analysis of engineered slope stability.

Vegetated roofs are not included as an option in the The List Approach within I-3.4.5 MR5: On-Site Stormwater Management. However, they are an option available to project designers who want to use other methods to meet the LID Performance Standard within I-3.4.5 MR5: On-Site Stormwater Management, or the Flow Control Performance Standard within I-3.4.7 MR7: Flow Control.

Design Criteria

The reader is directed to the *Low Impact Development Technical Guidance Manual for Puget Sound* (Hinman and Wulkan, 2012) for a more detailed description of the components of and design criteria for vegetated roofs. It also includes references to other sources of information and design guidance.

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)

Runoff Model Representation

When modeling the project using an approved continuous runoff model, use the element intended by the modeling software to represent a vegetated roof. If using WWHM2012, this is the "green roof" element. The user specifies the media thickness, vegetation type, roof slope, and length of drainage within the model.

Maintenance

Proper maintenance and operation are essential to ensure that 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 are for extensive roof systems and provide a general set of standards for prolonged vegetated roof performance.

General Maintenance Guidelines

- 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 vegetated roof.
- 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.
- The property owner should provide the maintenance and operation plan and inspection schedule.

- Written guidance and/or training for operating and maintaining vegetated roofs should be provided along with the operation and maintenance agreement to all property owners and tenants.
- All elements of an extensive roof installation should be inspected twice annually.
- 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., prior to major weed varieties dispersing seeds).

Refer to Appendix V-A: BMP Maintenance Tables for additional maintenance guidelines.

MAINTENANCE INSTRUCTIONS FOR VEGETATED ROOFS

Your property contains a stormwater management flow control BMP (best management practice) called a ***"vegetated roof,"*** which was installed to minimize the stormwater runoff impacts of the impervious surfaces on your property.

Vegetated roofs (also called green roofs) consist of a pervious growing medium, plants, and a moisture barrier. The benefits of this device are a reduction in runoff peaks and volumes due to the storage capabilities of the soil and increased rate of evapotranspiration.

MAINTENANCE RESTRICTIONS

- The composition and area of vegetated roof as depicted by the flow control BMP site plan and design details must be maintained and may not be changed without written approval either from the King County Water and Land Resources Division or through a future development permit from King County.
- Vegetated roofs must not be subject to any use that would significantly compact the soil.

INSPECTION FREQUENCY AND MAINTENANCE GUIDELINES

Vegetated roofs (also called green roofs) consist of a *pervious growing medium*, *plants*, and a *moisture barrier*:

- Vegetated roofs must be inspected annually for physical defects and to make sure the vegetation is in good condition.
- If erosion channels or bare spots are evident, they should be stabilized with additional soil similar to the original material.
- A supplemental watering program may be needed the first year to ensure the long-term survival of the roof's vegetation.
- Vegetation should be maintained as follows:

  (1) vegetated roofs must not be subject to any use that would significantly compact the soil;

  (2) replace all dead vegetation as soon as possible;

  (3) remove fallen leaves and debris;

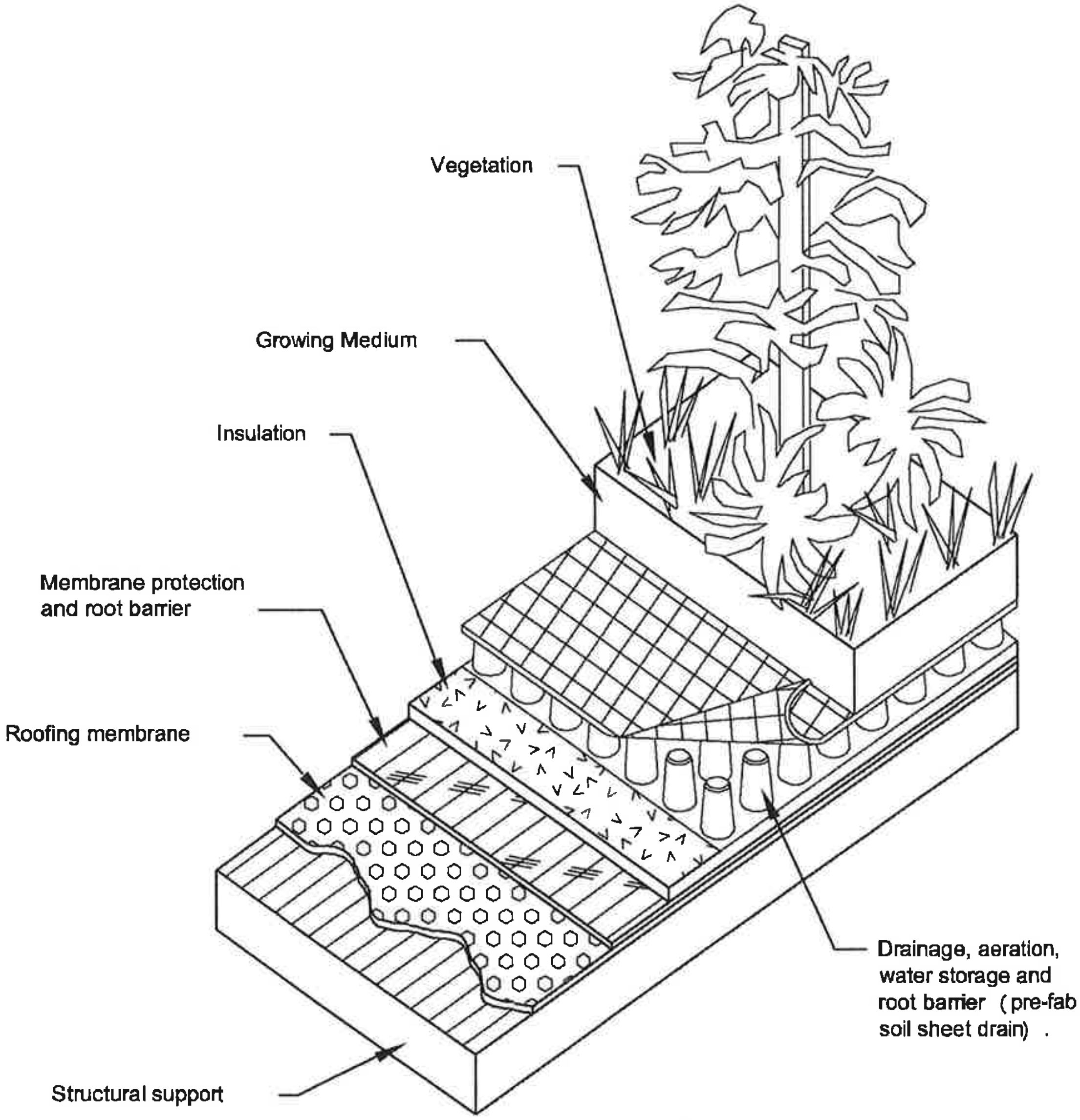
  (4) remove all noxious vegetation when discovered;

  (5) manually weed without herbicides or pesticides.

RECORDING REQUIREMENT

These vegetated roof flow control BMP maintenance and operation instructions must be recorded as an attachment to the required **declaration of covenant and grant of easement** per Requirement 3 of Section C.1.3.4 of the King County *Surface Water Design Manual*. The intent of these instructions is to explain to future property owners, the purpose of the BMP and how it must be maintained and operated. These instructions are intended to be a minimum; the King County Department of Local Services, Permitting Division (DLS-Permitting) may require additional instructions based on site-specific conditions. See King County's Surface Water Design Manual website for additional information and updates.

TYPICAL VEGETATED ROOF CROSS-SECTION



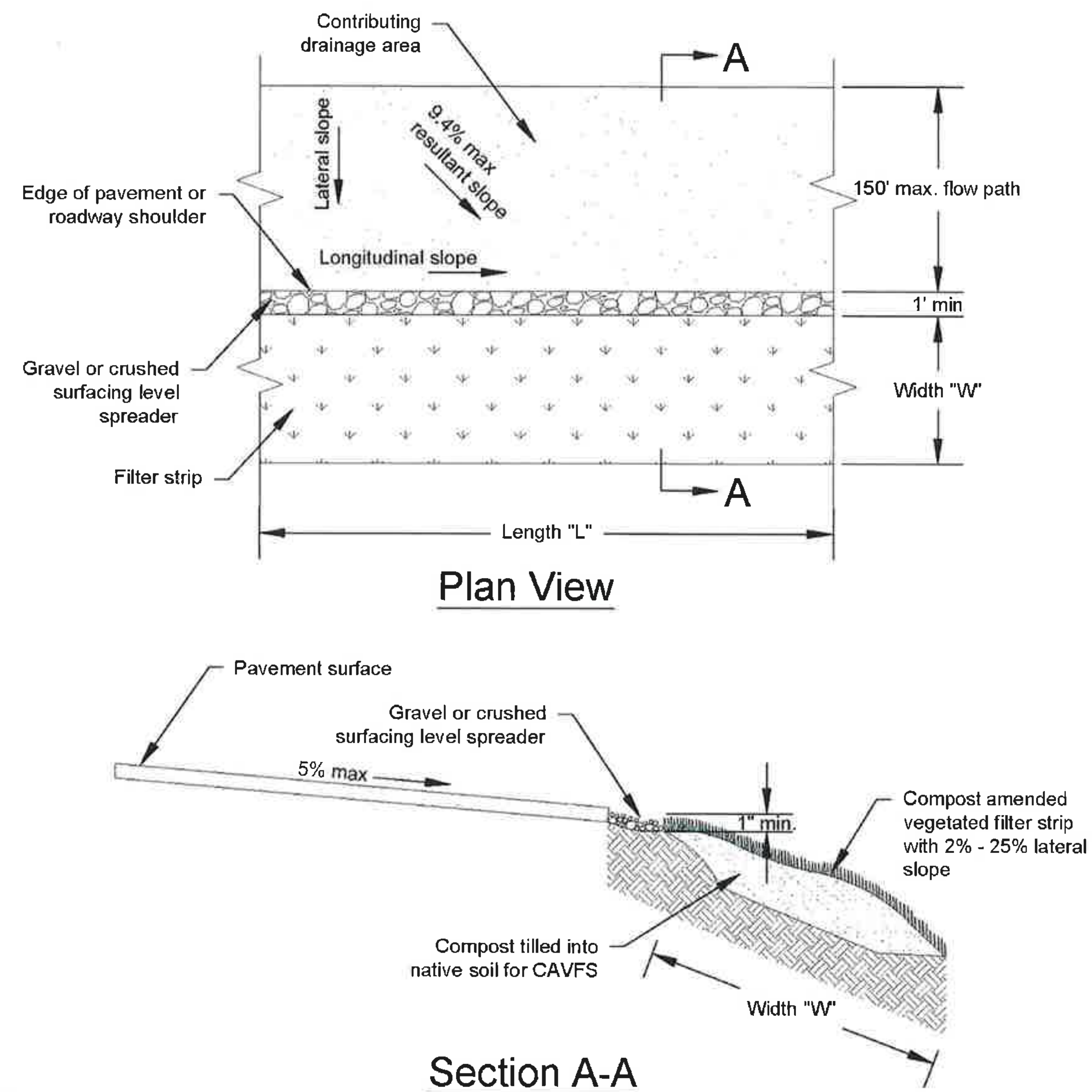
Note:
This example shows a two-part prefabricated soil sheet drain and protection board.

BMP T7.40: Compost-Amended Vegetated Filter Strips (CAVFS)

Description

The compost-amended vegetated filter strip (CAVFS) is a variation of BMP T9.40: Vegetated Filter Strip that adds soil amendments to the roadside embankment (See Figure V-7.1: Example of a Compost Amended Vegetated Filter Strip (CAVFS)). The soil amendments improve infiltration characteristics, increase surface roughness, and improve plant sustainability. Once permanent vegetation is established, the advantages of the CAVFS are higher surface roughness; greater retention and infiltration capacity; improved removal of soluble cationic contaminants through sorption; improved overall vegetative health; and a reduction of invasive weeds. CAVFS have somewhat higher construction costs than BMP T9.40: Vegetated Filter Strip due to more expensive materials, but require less land area for Runoff Treatment, which can reduce overall costs.

Figure V-7.1: Example of a Compost Amended Vegetated Filter Strip (CAVFS)



This drawing is only an example that needs to be adjusted and revised for each project.

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Example of a Compost Amended Vegetated Filter Strip (CAVFS)

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Applications

CAVFS can be used to meet basic and enhanced Runoff Treatment performance goals, as described in III-1.2 Choosing Your Runoff Treatment BMPs. It has practical application in areas where there is space for roadside embankments that can be built to the CAVFS specifications.

Design Criteria

The CAVFS design incorporates composted material into the native soils per the criteria in BMP T5.13: Post-Construction Soil Quality and Depth for turf areas. However, as noted below, the compost shall not contain biosolids or manure. The goal is to create a healthy soil environment for a lush growth of turf.

Soil/Compost Mix

- *Presumptive approach*: Place and rototill 1.75 inches of composted material into 6.25 inches of soil (a total amended depth of about 9.5 inches), for a settled depth of 8 inches. Water or roll to compact soil to 85% maximum. Plant grass.
- *Custom approach:* Place and rototill the calculated amount of composted material into a depth of soil needed to achieve 8 inches of settled soil at 5% organic content. Water or roll to compact soil to 85% maximum. Plant grass.

  The amount of compost or other soil amendments used varies by soil type and organic matter content. If there is a good possibility that site conditions may already contain a relatively high organic content, then it may be possible to modify the pre-approved rate described above and still be able to achieve the 5% organic content target.
- The final soil mix (including compost and soil) should have an initial saturated hydraulic conductivity less than 12 inches per hour, and a minimum long-term hydraulic conductivity of 1.0 inch/hour per ASTM Designation D 2434 (Standard Test Method for Permeability of Granular Soils) at 85% compaction per ASTM Designation D 1557 (Standard Test Method for Laboratory Compaction Characteristics of Soil Using Modified Effort).

  Infiltration rate and hydraulic conductivity are assumed to be approximately the same in a uniform mix soil. The long term saturated hydraulic conductivity of the soil mix is determined by applying the appropriate infiltration correction factors as explained in Determining the Bioretention Soil Mix Design Infiltration Rate within BMP T7.30: Bioretention.
- The final soil mixt should have a minimum organic content of 5% by dry weight per ASTM Designation D 2974 (Standard Test Method for Moisture, Ash and Organic Matter of Peat and Other Organic Soils) (Tackett, 2004).
- Achieving the above recommendations will depend on the specific soil and compost characteristics. In general, the recommendation can be achieved with 60% to 65% loamy sand mixed with 25% to 30% compost or 30% sandy loam, 30% coarse sand, and 30% compost.
- The final soil mixture should be tested prior to installation for fertility, micronutrient analysis, and organic material content.

- Clay content for the final soil mix should be less than 5%.
- Compost must not contain biosolids, manure, any street or highway sweepings, or any catch basin solids.
- The pH for the soil mix should be between 5.5 and 7.0 (Stenn, 2003). If the pH falls outside the acceptable range, it may be modified with lime to increase the pH or iron sulfate plus sulfur to lower the pH. The lime or iron sulfate must be mixed uniformly into the soil prior to use in LID areas (Low-Impact Development Center, 2004).
- The soil mix should be uniform and free of stones, stumps, roots, or other similar material larger than 2 inches.
- When placing topsoil, it is important that the first lift of topsoil is mixed into the top of the existing soil. This allows the roots to penetrate the underlying soil easier and helps prevent the formation of a slip plane between the two soil layers.

Soil Component

The texture for the soil component of the soil mix should be loamy sand (USDA Soil Textural Classification).

Compost Component

Follow the specifications for compost in BMP T7.30: Bioretention.

Runoff Model Representation

The CAVFS will have an "Element" in the approved continuous runoff model that must be used for determining the amount of water that is treated by the CAVFS. To fully meet Runoff Treatment requirements, Ninety-one percent of the influent runoff file must pass through the soil profile of the CAVFS. Water that merely flows over the surface is not considered treated. Approved continuous runoff models should be able to report the amount of water that it estimates will pass through the soil profile.

Maintenance

Compost, as with other filter mediums, can become plugged with fines and sediment, which may require removal and replacement. Including vegetation with compost helps prevent the medium from becoming plugged with sediment by breaking up the sediment and creating root pathways for stormwater to penetrate into the compost. It is expected that soil amendments will have a removal and replacement cycle; however, this time frame has not yet been established.

BMP T8.40: Media Filter Drain

Description

The media filter drain is a linear flow-through stormwater Runoff Treatment BMP that can be sited along highway side slopes (conventional design) and medians (dual media filter drains), borrow ditches, or other linear depressions. Cut-slope applications may also be considered. The media filter drain can be used where available right of way is limited, sheet flow from the highway surface is feasible, and lateral gradients are generally less than 25% (4H:1V). Although not a proprietary manufactured treatment device, the media filter drain completed Ecology's TAPE approval process and has a General Use Level Designation (GULD) for basic, enhanced, and phosphorus treatment (see V-10 Manufactured Treatment Devices as BMPs for more information about the TAPE approval process).

Media filter drains have four basic components: a gravel no-vegetation zone, a grass strip, the media filter drian mix bed, and a conveyance system for flows leaving the media filter drain mix. This conveyance system usually consists of a gravel-filled underdrain trench or a layer of crushed surfacing base course (CSBC). This layer of CSBC must be porous enough to allow treated flows to freely drain away from the media filter drain mix.

Typical media filter drain configurations are shown in Figure V-6.10: Media Filter Drain: Cross Section, Figure V-6.11: Dual Media Filter Drain: Cross Section, and Figure V-6.12: Media Filter Drain Without Underdrain Trench.

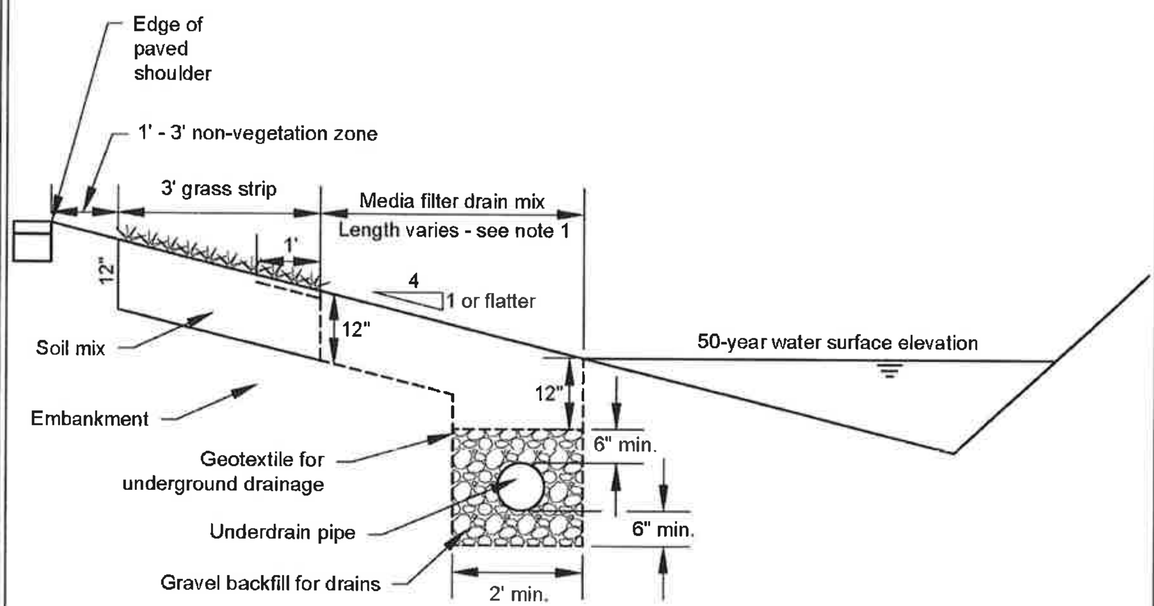
The media filter drain removes suspended solids, phosphorus, and metals from highway runoff through physical straining, ion exchange, carbonate precipitation, and biofiltration.

Runoff flowing through a media filter drain goes through the following treatment steps:

1. Stormwater runoff enters the media filter drain and is conveyed via sheet flow over a vegetation-free gravel zone to ensure sheet dispersion and provide some pollutant trapping.
2. Next, a grass strip, which may be amended with composted material, is incorporated into the top of the fill slope to provide pretreatment, further enhancing filtration and extending the life of the system.
3. The runoff is then filtered through a bed of porous, alkalinity-generating granular medium—the media filter drain mix. Media filter drain mix is a fill material composed of crushed rock (sized by screening), dolomite, gypsum, and perlite. The dolomite and gypsum additives serve to buffer acidic pH conditions and exchange light metals for heavy metals. Perlite is incorporated to improve moisture retention, which is critical for the formation of biomass epilithic biofilm to assist in the removal of solids, metals, and nutrients.
4. Treated water drains from the media filter drain mix bed into the conveyance system below the media filter drain mix. Geotextile lines the underside of the media filter drain mix bed and the conveyance system.

   The underdrain trench is an option for hydraulic conveyance of treated stormwater to a desired location, such as a downstream Flow Control BMP or stormwater outfall. The trench's perforated underdrain pipe is a protective measure to ensure free flow through the media filter drain mix and to prevent prolonged ponding. It may be possible to omit the underdrain pipe if it can be demonstrated that the pipe is not necessary to maintain free flow through the media filter drain mix and underdrain trench.

Figure V-6.10: Media Filter Drain: Cross Section



Notes:

1. See "structural design considerations"

Side Slope Application with Underdrain

This drawing is only a template and should be modified to fit each project application.

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Media Filter Drain: Cross Section

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Figure V-6.11: Dual Media Filter Drain: Cross Section

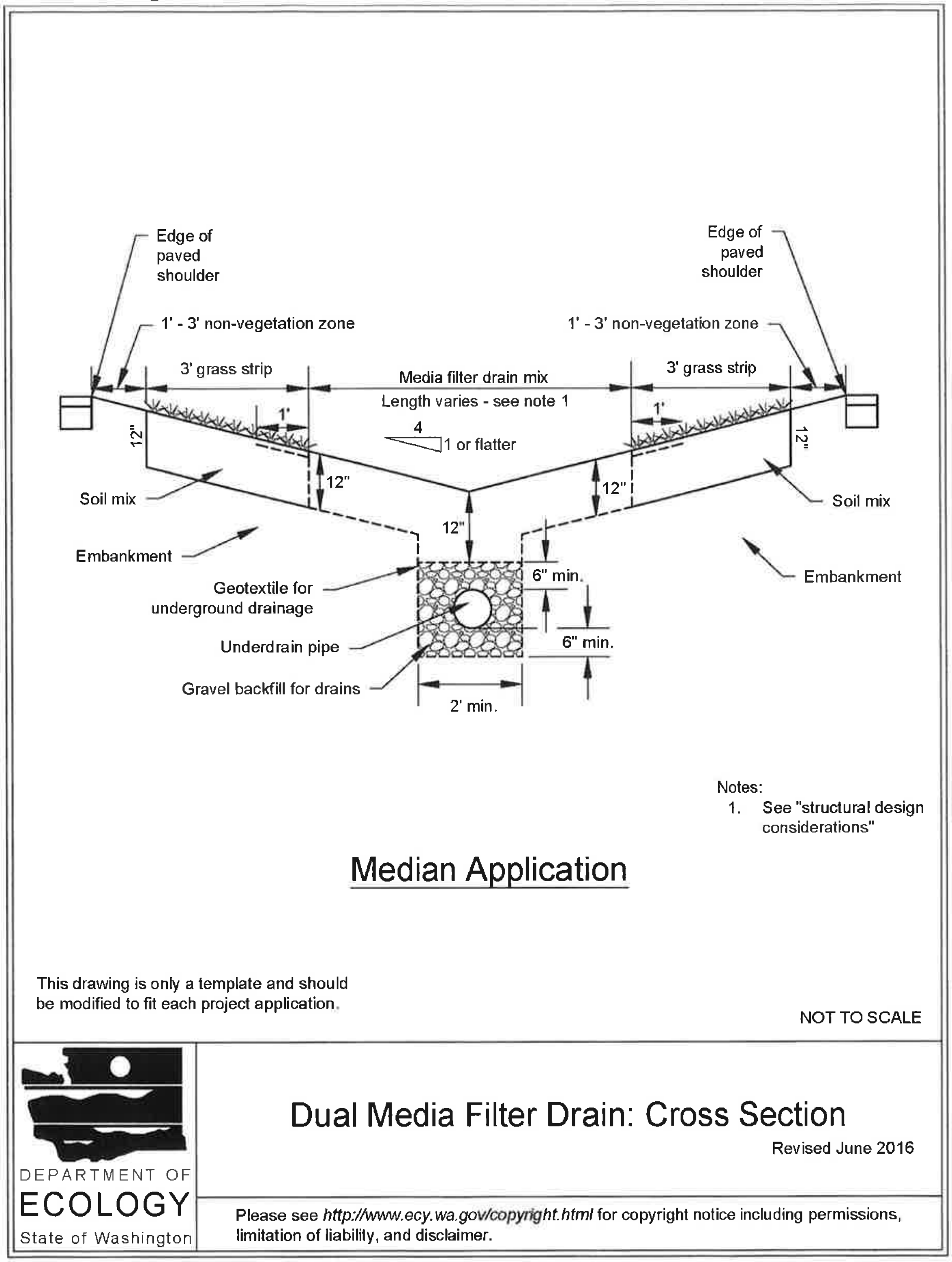
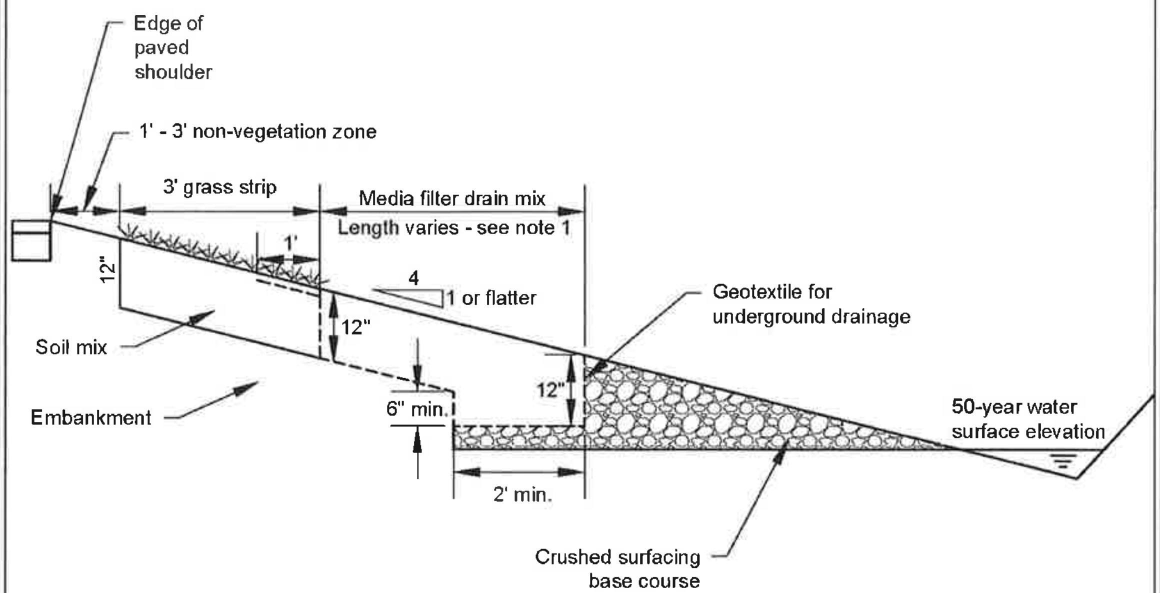


Figure V-6.12: Media Filter Drain Without Underdrain Trench



Notes:
1. See "structural design considerations"

Side Slope Application without Underdrain

This drawing is only a template and should be modified to fit each project application.

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Media Filter Drain without Underdrain Trench

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Applications and Limitations

In many instances, conventional Runoff Treatment is not feasible due to right of way constraints (such as adjoining wetlands and geotechnical considerations). The media filter drain and the dual media filter drain designs are Runoff Treatment options that can be sited in most right of way confined situations. In many cases, a media filter drain or a dual media filter drain can be sited without the acquisition of additional right of way needed for conventional Runoff Treatment BMPs.

Since maintaining sheet flow across the media filter drain is required for its proper function, the ideal locations for media filter drains in highway settings are highway side slopes or other long, linear grades with lateral side slopes less than 4H:1V and longitudinal slopes no steeper than 5%. As side slopes approach 3H:1V, without design modifications, sloughing may become a problem due to friction limitations between the separation geotextile and underlying soils. The longest flow path from the contributing area delivering sheet flow to the media filter drain should not exceed 150 feet.

If there is sufficient roadway embankment width, the designer should consider placing the grass strip and media filter drain mix downslope when feasible. The design should ensure the media filter drain does not intercept seeps, springs, or ground water.

The dual media filter drain is fundamentally the same as the side-slope version. It differs in siting and is more constrained with regard to drainage options. Prime locations for dual media filter drains in a highway setting are medians, roadside drainage or borrow ditches, or other linear depressions. It is especially critical for water to sheet flow across the dual media filter drain. Channelized flows or ditch flows running down the middle of the dual media filter drain (continuous off-site inflow) should be minimized.

The designer should consider the following limitations when considering a media filter drain for their project:

- Steep slopes: Avoid construction on longitudinal slopes steeper than 5%. Avoid construction on 3H:1V lateral slopes, and preferably use less than 4H:1V slopes. In areas where lateral slopes exceed 4H:1V, it may be possible to construct terraces to create 4H:1V slopes or to otherwise stabilize up to 3H:1V slopes.

- Wetlands: Do not construct in wetlands and wetland buffers. In many cases, a media filter drain (due to its small lateral footprint) can fit within the highway fill slopes adjacent to a wetland buffer. In those situations, where the highway fill prism is located adjacent to wetlands, an interception trench/underdrain will need to be incorporated as a design element in the media filter drain.

- Shallow ground water: Mean high water table levels at the project site need to be determined to ensure the media filter drain mix bed and the underdrain (if needed) will not become saturated by shallow ground water.

- Unstable slopes: In areas where slope stability may be problematic, consult a geotechnical engineer.

- Areas of seasonal ground water inundations or basement flooding: Site-specific piezometer data may be needed in areas of suspected seasonal high ground water inundations. The performance of the dual media filter drain may be compromised due to backwater effects and lack of sufficient hydraulic gradient.

- Narrow roadway shoulders: In areas where there is a narrow roadway shoulder that does not allow enough room for a vehicle to fully stop or park, consider placing the media filter drain farther down the embankment slope. This will reduce the amount of rutting in the media filter drain and decrease overall maintenance repairs.

Design Criteria

Flows to Be Treated

The basic design concept behind the media filter drain and dual media filter drain is to fully filter all runoff through the media filter drain mix. Therefore, the infiltration capacity of the media filter drain mix and the drainage below needs to match or exceed the hydraulic loading rate.

Vegetation-Free Gravel Zone

The vegetation-free gravel zone is a shallow gravel zone located directly adjacent to the highway pavement. The vegetation-free gravel zone is a crucial element in a properly functioning media filter drain. The vegetation-free gravel zone functions as a level spreader to promote sheet flow and a deposition area for coarse sediments. The vegetation-free gravel zone should be between 1 foot and 3 feet wide. Depth will be a function of how the roadway section is built from subgrade to finish grade; the resultant cross section will typically be triangular to trapezoidal. Within these bounds, width varies depending on maintenance spraying practices.

Grass Strip

The width of the grass strip is dependent on the availability of space within the highway side slope. The baseline design criterion for the grass strip component of the media filter drain is a 3-foot-minimum-width, but wider grass strips are recommended if additional space is available. The designer may consider adding aggregate to the soil mix to help minimize rutting problems from errant vehicles. The soil mix should ensure grass growth for the design life of the media filter drain. Composted material used in the grass strip shall meet the specifications for compost used in Bioretention Soil Mix (BSM). See BMP T7.30: Bioretention.

Media Filter Drain Mix Bed

The media filter drain mix is a mixture of crushed rock, dolomite, gypsum, and perlite. The crushed rock provides the support matrix of the medium; the dolomite and gypsum add alkalinity and ion exchange capacity to promote the precipitation and exchange of heavy metals; and the perlite improves moisture retention to promote the formation of biomass within the media filter drain mix. The combination of physical filtering, precipitation, ion exchange, and biofiltration enhances the Runoff Treatment capacity of the mix. The media filter drain mix has an estimated initial filtration rate of 50 inches per hour, and a long-term filtration rate of 28 inches per hour due to siltation. With an additional safety factor, the rate used to size the length of the media filter drain should be 10 inches per hour.

The width of the media filter drain mix bed is determined by the amount of contributing pavement routed to the embankment. The surface area of the media filter drain mix bed needs to be sufficiently large to fully infiltrate the Water Quality Design Flow Rate (as described in III-2.6 Sizing Your Runoff Treatment BMPs) using the long-term filtration rate of the media filter drain mix. For design purposes, a 50% safety factor is incorporated into the long-term media filter drain mix filtration rate to accommodate variations in slope, resulting in a design filtration rate of 10 inches per hour. The media filter drain mix bed should have a bottom width of at least 2 feet in contact with the conveyance system below the media filter drain mix.

The media filter drain mix used in the media filter drain mix bed consists of the amendments listed in Table V-6.4: Media Filter Drain Mix. Mixing and transportation must occur in a manner that ensures the materials are thoroughly mixed prior to placement and that separation does not occur during transportation or construction operations.

Table V-6.4: Media Filter Drain Mix

Amendment	Quantity

Mineral Aggregate: Aggregate for Media Filter Drain Mix
Aggregate for media filter drain mix shall be manufactured from ledge rock, talus, or gravel in accordance with Section 3-01 of the *Standard Specifications for Road, Bridge, and Municipal Construction (2002)*, which meets the following test requirements for quality. The use of recycled material is not permitted.
• Los Angeles Wear, 500 Revolutions: 35% max.
• Degradation Factor: 30 min.
• Aggregate for the media filter drain mix shall conform to the following requirements for grading and quality:
  ○ Sieve Size: Percent Passing (by weight)
    ▪ 1/2" square: 100
    ▪ 3/8" square: 90-100
    ▪ U.S. No. 4: 30-56
    ▪ U.S. No. 10: 0-10
    ▪ U.S. No. 200: 0-1.5
  ○ % fracture, by weight, min.: 75
    The fracture requirement shall be at least two fractured faces and will apply to material retained on the U.S. No. 10.
  ○ Static stripping test: Pass
Aggregate for the media filter drain shall be substantially free from adherent coatings. The presence of a thin, firmly adhering film of weathered rock shall not be considered as coating unless it exists on more than 50% of the surface area of any size between successive laboratory sieves.
	3 cubic yards

Perlite • Horticultural grade, free of any toxic materials)	1 cubic yard per 3 cubic yards of min-

Table V-6.4: Media Filter Drain Mix (continued)

Amendment	Quantity
• 0-30% passing US No. 18 Sieve • 0-10% passing US No. 30 Sieve	eral aggregate
Dolomite: CaMg(CO3)2 (calcium magnesium carbonate) • Agricultural grade, free of any toxic materials) • 100% passing US No. 8 Sieve • 0% passing US No. 16 Sieve	10 pounds per cubic yard of perlite
Gypsum: Noncalcined, agricultural gypsum CaSO4•2H2O (hydrated calcium sulfate) • Agricultural grade, free of any toxic materials) • 100% passing US No. 8 Sieve • 0% passing US No. 16 Sieve	1.5 pounds per cubic yard of perlite

Consider the following guidance when sizing the media filter drain mix bed:

- The media filter drain mix should be a minimum of 12 inches deep, including the section on top of the underdrain trench.
- For Runoff Treatment, sizing the media filter drain mix bed is based on the requirement that the Water Quality Design Flow Rate from the pavement area, $Q_{Highway}$, cannot exceed the long-term infiltration capacity of the media filter drain, $Q_{Infiltration}$:

  $$Q_{Highway} \leq Q_{Infiltration}$$

  See III-2.6 Sizing Your Runoff Treatment BMPs for more information about the Water Quality Design Flow Rate.
- The long-term infiltration capacity of the media filter drain is based on the following equation:

  $$\frac{LTIR \times L \times W}{C \times SF} = Q_{Infiltration}$$

  where:

  LTIR = Long-term infiltration rate of the media filter drain mix (use 10 inches per hour for design) (in/hr)

  L = Length of media filter drain (parallel to roadway) (ft)

  W = Width of the media filter drain mix bed (ft)

  C = Conversion factor of 43200 ((in/hr)/(ft/sec))

  SF = Safety Factor (equal to 1.0, unless unusually heavy sediment loading is expected)
- Assuming that the length of the media filter drain is the same as the length of the contributing

pavement, solve for the width of the media filter drain mix bed:

$$W \geq \frac{Q_{Highway} \times C \times SF}{LTIR \times L}$$

- Western Washington project applications of this design procedure have shown that, in almost every case, the calculated width of the media filter drain mix bed does not exceed 1.0 foot. Therefore, Table V-6.5: Western Washington Design Widths for Media Filter Drains was developed to simplify the design steps and should be used to establish an appropriate width.

Table V-6.5: Western Washington Design Widths for Media Filter Drains

Pavement width that contributes runoff to the media filter drain	Minimum media filter drain mix bed width*
≤ 20 feet	2 feet
≥ 20 and ≤ 35 feet	3 feet
> 35 feet	4 feet
* Width does not include the required 1–3 foot gravel vegetation-free zone or the 3-foot filter strip width (see Figure 8.5.8).	

Conveyance System/Underdrain Below Media Filter Drain Mix

The gravel underdrain trench provides hydraulic conveyance when treated runoff needs to be conveyed to a desired location such as a downstream Flow Control BMP or stormwater outfall.

In Group C and D soils, an underdrain pipe would help to ensure free flow of the treated runoff through the media filter drain mix bed. In some Group A and B soils, an underdrain pipe may be unnecessary if most water percolates into the subsoil from the underdrain trench. The need for an underdrain pipe should be evaluated in all cases. The underdrain trench should be a minimum of 2 feet wide for either the conventional or dual media filter drain.

The gravel underdrain trench may be eliminated if there is evidence to support that flows can be conveyed laterally to an adjacent ditch or onto a fill slope that is properly vegetated to protect against erosion. The media filter drain mix should be kept free draining up to the 50-year storm event water surface elevation represented in the downstream ditch.

These materials should be used in accordance with the following sections within WSDOT's *Standard Specifications for Road, Bridge, and Municipal Construction* (WSDOT, 2012):

- Gravel Backfill for Drains, 9-03.12(4)
- Underdrain Pipe, 7-01.3(2)
- Construction Geotextile for Underground Drainage, 9-33.1
- If the design is configured to allow the media filter drain to drain laterally into a ditch, the crushed surfacing base course below the media filter drain should conform to Section 9-03.9 (3).

Underdrain pipe can provide a protective measure to ensure free flow through the media filter drain mix and is sized similar to storm drains. For media filter drain underdrain sizing, an additional step is required to determine the flow rate that can reach the underdrain pipe. This is done by comparing the contributing basin flow rate to the infiltration flow rate through the media filter drain mix, and then using the smaller of the two to size the underdrain. The analysis described below considers the flow rate per foot of media filter drain, which allows the flexibility of incrementally increasing the underdrain diameter where long lengths of underdrain are required. When underdrain pipe connects to a drainage system, place the invert of the underdrain pipe above the 25-year water surface elevation in the storm drain to prevent backflow into the underdrain system.

The following describes the procedure for sizing underdrains installed in combination with media filter drains.

1. Calculate the flow rate per foot from the contributing basin to the media filter drain. The design storm event used to determine the flow rate should be relevant to the purpose of the underdrain. For example, if the media filter drain installation is in western Washington and the underdrain will be used to convey treated runoff to a detention BMP, size the underdrain for the 50-year storm event.

$$\frac{Q_{highway}}{ft} = \frac{Q_{highway}}{L_{MFD}}$$

where:

$\frac{Q_{highway}}{ft}$ = contributing flow rate per foot (cfs/ft)

L_{MFD} = length of media filter drain contributing runoff to the underdrain (ft)

2. Calculate the media filter drain flow rate of runoff per foot given an infiltration rate of 10 in/hr through the media filter drain mix.

$$Q_{\frac{MFD}{ft}} = \frac{f \times W \times 1ft}{ft} \times \frac{1ft}{12in} \times \frac{1hr}{3600\ \text{sec}}$$

where:

$Q_{\frac{MFD}{ft}}$ = flow rate of runoff through the media filter drain mix layer (cfs/ft)

W = width of underdrain trench (ft); the minimum width is 2 ft

f = infiltration rate though the media filter drain mix (in/hr) = 10 in/hr

3. Size the underdrain pipe to convey the runoff that can reach the underdrain trench. This is taken to be the smaller of the contributing basin flow rate or the flow rate through the media filter drain mix layer.

$$Q_{\frac{UD}{ft}} = smaller\left\{Q_{\frac{highway}{ft}} or Q_{\frac{MFD}{ft}}\right\}$$

where:

$Q_{\frac{UD}{ft}}$ = underdrain design flow rate per foot (cfs/ft)

4. Determine the underdrain design flow rate using the length of the media filter drain and a factor of safety of 1.2.

$$Q_{UD} = 1.2 \times Q_{\frac{UD}{ft}} \times W \times L_{MFD}$$

where:

Q_{UD} = estimated flow rate to the underdrain (cfs)

W = width of the underdrain trench (ft); the minimum width is 2 ft

LMFD = length of the media filter drain contributing runoff to the underdrain (ft)

5. Given the underdrain design flow rate, determine the underdrain diameter. Round pipe diameters up to the nearest standard pipe size and have a minimum diameter of 6 inches.

$$D = 16\left(\frac{(Q_{UD} \times n)}{s^{0.5}}\right)^{3/8}$$

where:

D = underdrain pipe diameter (inches)

n = Manning's coefficient

s = slope of pipe (ft/ft)

Length

In general, the length of a media filter drain or dual media filter drain is the same as the contributing pavement. Any length is acceptable as long as the surface area of the media filter drain mix bed is sufficient to fully infiltrate the Water Quality Design Flow Rate.

Cross Section

In profile, the surface of the media filter drain should preferably have a lateral slope less than 4H:1V (<25%). On steeper terrain, it may be possible to construct terraces to create a 4H:1V slope, or other engineering may be employed if approved by Ecology, to ensure slope stability up to 3H:1V. If sloughing is a concern on steeper slopes, consideration should be given to incorporating permeable soil reinforcements, such as geotextiles, open-graded/permeable pavements, or commercially available ring and grid reinforcement structures, as top layer components to the media filter drain mix bed. Consultation with a geotechnical engineer is required.

Inflow

Runoff is conveyed to a media filter drain using sheet flow from the pavement area. The longitudinal pavement slope contributing flow to a media filter drain should be less than 5%.

Although there is no lateral pavement slope restriction for flows going to a media filter drain, the designer should ensure flows remain as sheet flow.

Landscaping (Planting Considerations)

Landscaping for the grass strip is the same as for BMP T9.10: Basic Biofiltration Swale unless otherwise specified in the special provisions for the project's construction documents.

Signing

Nonreflective guideposts will delineate the media filter drain. This practice allows personnel to identify where the system is installed and to make appropriate repairs should damage occur to the system. If the media filter drain is in a critical aquifer recharge area for drinking water supplies, signage prohibiting the use of pesticides must be provided.

Construction Criteria

Keep effective erosion and sediment control measures in place until the grass strip is established.

Do not allow vehicles or traffic on the media filter drain to minimize rutting and maintenance repairs.

Operations and Maintenance

Maintenance will consist of routine roadside management. While herbicides must not be applied directly over the media filter drain, it may be necessary to periodically control noxious weeds with herbicides in areas around the media filter drain as part of a roadside management program. The use of pesticides may be prohibited if the media filter drain is in a critical aquifer recharge area for drinking water supplies. The designer should check with the local area water purveyor or local health department.

Replace areas of the media filter drain that show signs of physical damage.

BMP T7.30: Bioretention

Purpose

Ecology accepts bioretention as having the potential to meet I-3.4.5 MR5: On-Site Stormwater Management, I-3.4.6 MR6: Runoff Treatment and I-3.4.7 MR7: Flow Control for the tributary 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 less Flow Control benefits.

Description

Bioretention areas are shallow landscaped depressions, with a designed soil mix (the bioretention soil mix) and plants adapted to the local climate and soil moisture conditions, that receive stormwater from a contributing area.

Bioretention uses the imported bioretention soil mix as a treatment medium. As in infiltration, the pollutant removal mechanisms include filtration, adsorption, and biological action. Bioretention BMPs can be built within earthen swales or placed within vaults. Water that has passed through the bioretention soil mix (or approved equivalent) may be discharged to the ground or collected and discharged to surface water.

The term, bioretention, is used to describe various designs using soil and plant complexes to manage stormwater. The following terminology is used in this manual:

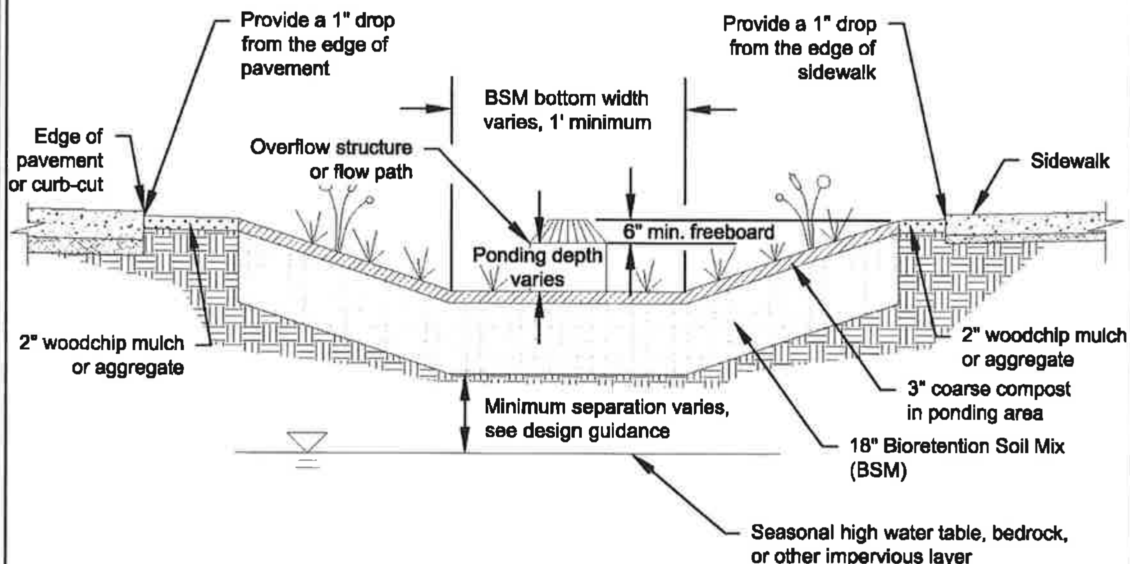
- *Bioretention cells:* Shallow depressions with a designed planting soil mix and a variety of plant material, including trees, shrubs, grasses, and/or other herbaceous plants. Bioretention cells may or may not have an underdrain and are not designed as a conveyance system.
- *Bioretention swales:* Incorporate 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 swales have relatively gentle side slopes and ponding depths that are typically 6 to 12 inches.
- *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 it 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 V-5.12: Typical Bioretention, Figure V-5.13: Typical Bioretention w/Underdrain, Figure V-5.14: Typical Bioretention w/Liner (Not LID), and Figure V-5.15: Example of a 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 V-10 Manufactured Treatment Devices as BMPs for more information on manufactured treatment devices.

Figure V-5.12: Typical Bioretention



Notes:

1. Scarify subgrade 3" min. before bioretention soil installation
2. Compact BSM to 85% per ASTM 1577

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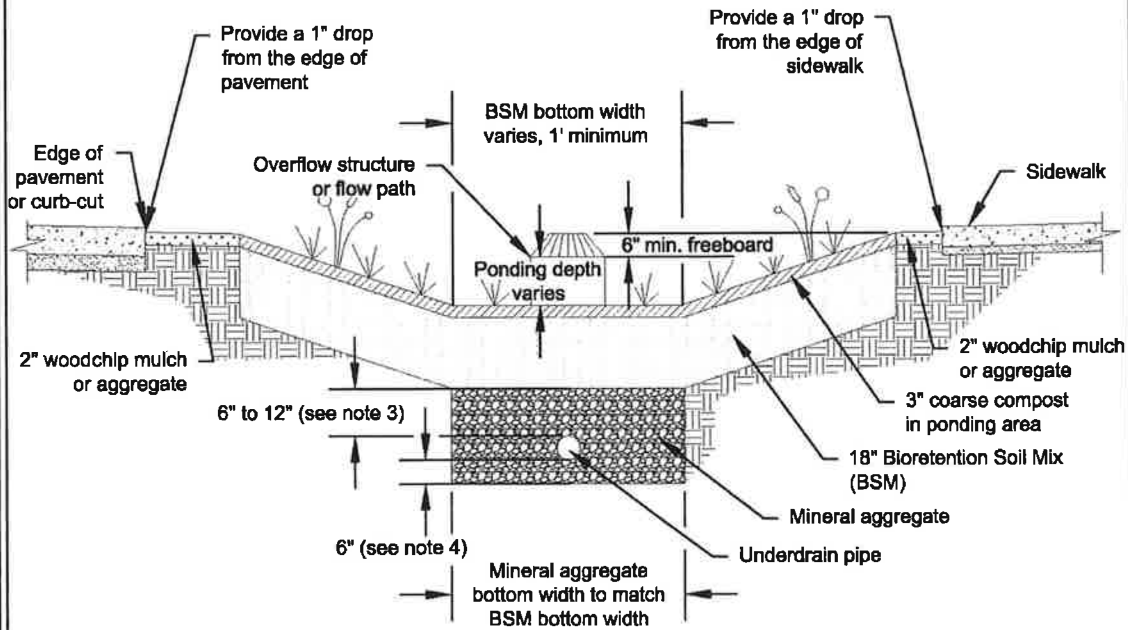
Typical Bioretention

Revised January 2019

Figure V-5.13: Typical Bioretention w/Underdrain



Notes:

1. Scarify subgrade 3" min. before BSM installation
2. Compact BSM to 85% per ASTM 1577
3. 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.
4. If depth to the seasonal high ground water allows, this distance may be larger.
5. 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

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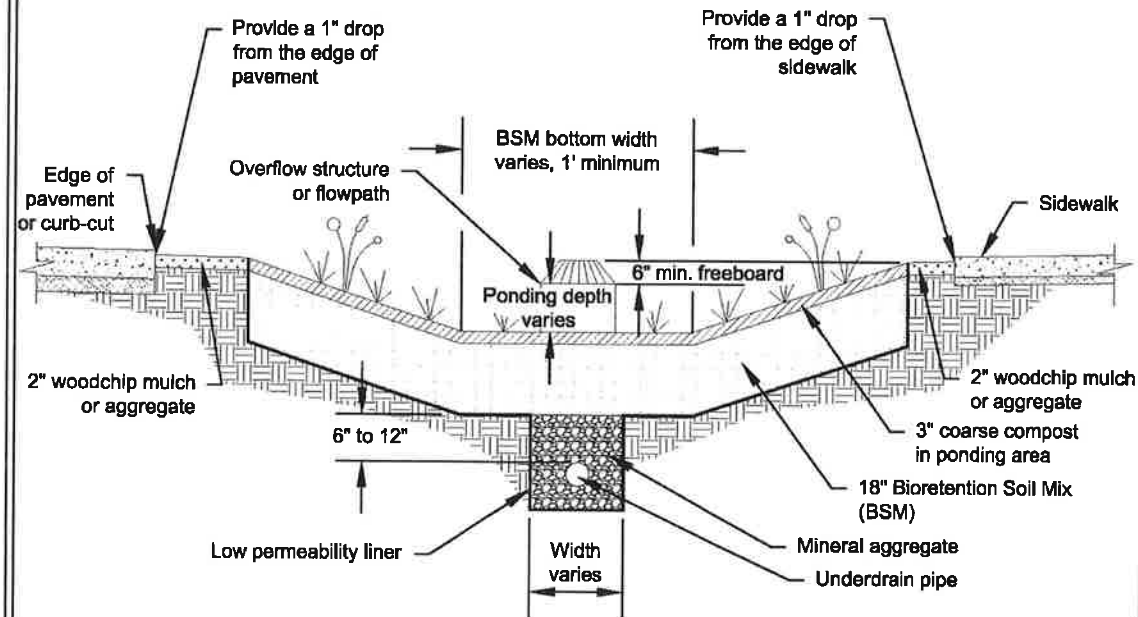
Figure V-5.14: Typical Bioretention w/Liner (Not LID)



Notes:

1. Scarify subgrade 3" min. before bioretention soil installation
2. Compact BSM to 85% per ASTM 1577

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Typical Bioretention w/Liner (Not LID)

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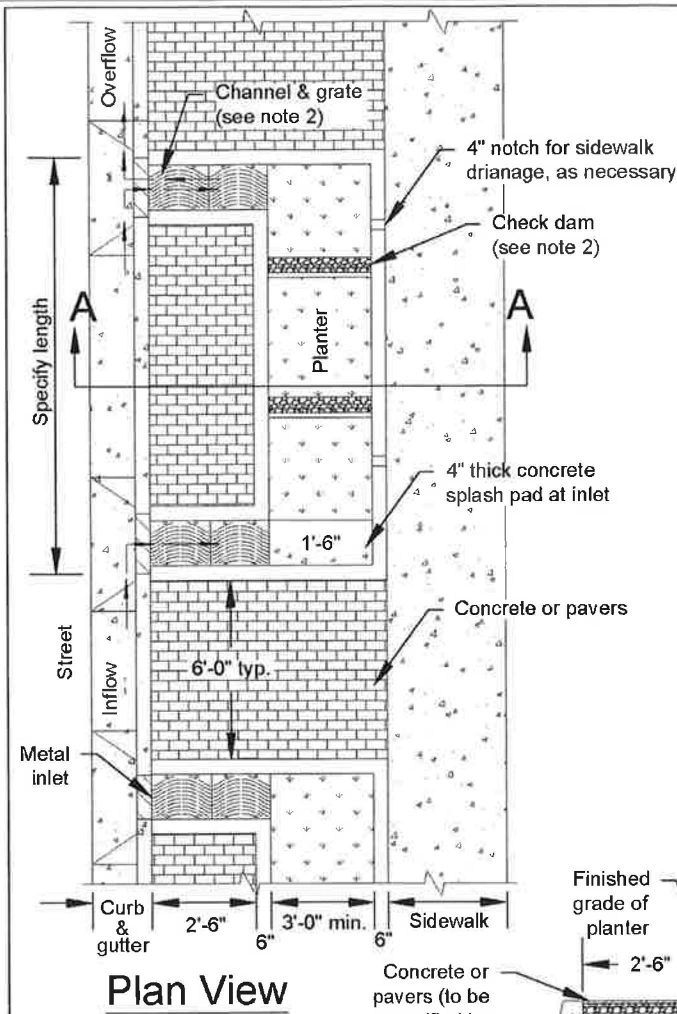
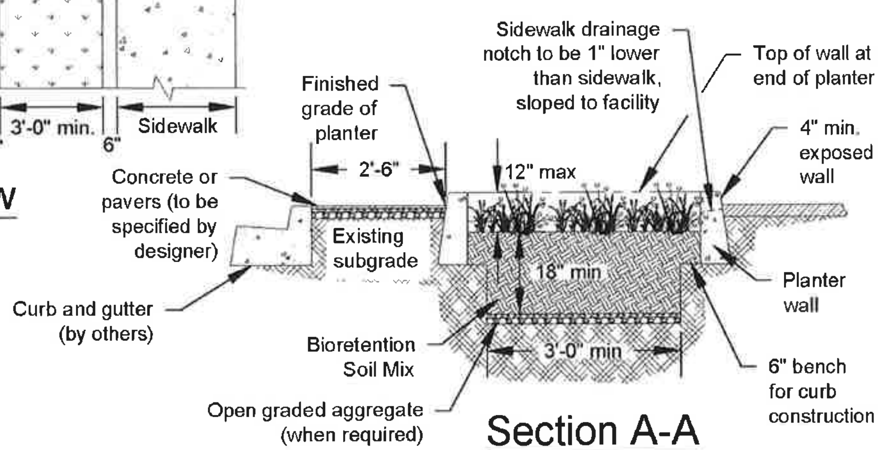
Figure V-5.15: Example of a Bioretention Planter





DESIGNER INFORMATION:

1. Adapt plan view example to your engineered design.
2. Include beginning and ending stations for each facility. Provide stations and/or dimensions and elevations at every inlet, outlet, check dam, planter corner and sidewalk notch.
3. Longitudinal slope of planter matches road.
4. Sidewalk elevation must be set above inlet and outlet elevations to allow overflow to drain to street before sidewalk.
5. Minimum interior planter width is 3 feet. A minimum of 4 feet interior planter width is required for street trees in planter.
6. Existing utility lines must be sleeved or relocated. Proposed utility lines to be located out of the facility.
7. Area and depth of facility are based upon engineering calculations and right-of-way constraints.
8. May use concrete or pavers.

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Example of a Bioretention Planter

Revised October 2016

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 requirement to treat 91% of the stormwater runoff file (the Water Quality Design Volume, as described in III-2.6 Sizing Your Runoff Treatment BMPs) 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 91% volume that must be treated to meet I-3.4.6 MR6: 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 the Flow Control Performance Standard of I-3.4.7 MR7: Flow Control. Because they typically do not have an orifice restricting overflow or underflow discharge rates, they typically don't fully meet I-3.4.7 MR7: Flow Control. However, their performance contributes to meeting the standard, and that can result in much smaller additional Flow Control BMPs at the bottom of the project site. Bioretention can also help achieve compliance with the LID Performance Standard of I-3.4.5 MR5: On-Site Stormwater Management.

Bioretention constructed with imported composted material 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 V-5.6 Site Suitability Criteria (SSC). Preliminary monitoring indicates that new bioretention BMPs 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.

Applications with or without underdrains vary extensively and can be applied in new development, redevelopment and retrofits. Typical applications include:

- Individual lots for rooftop, driveway, and other on-lot impervious surfaces.
- Shared facilities located in common areas for individual lots.
- Areas within loop roads or cul-de-sacs.
- Landscaped parking lot islands.
- Within right-of-ways along roads (often linear bioretention swales or cells).
- Common landscaped areas in apartment complexes or other multifamily housing designs.
- Planters on building roofs, patios, and as part of streetscapes.

Infeasibility Criteria

The following infeasibility criteria describe conditions that make bioretention infeasible when applying The List Approach within I-3.4.5 MR5: On-Site Stormwater Management. If a project proponent wishes to use a bioretention BMP even though one of the infeasibility criteria within this section are met,, they may propose a functional design to the local government.

Criteria with setback distances are as measured from the bottom edge of the bioretention soil mix.

Any of the following circumstances allow the designer to determine bioretention as "infeasible" when applying the The List Approach within I-3.4.5 MR5: On-Site Stormwater Management:

- 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 ground water 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 ground water 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 ground water modeling indicates infiltration will likely increase or change the direction of the migration of pollutants in the ground water;
- 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.
- 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.

  If the measured native soil infiltration rate is less than 0.30 in/hour, bioretention should not be used to meet the The List Approach of I-3.4.5 MR5: On-Site Stormwater Management. In these slow draining soils, a bioretention BMP with an underdrain may be used to treat pollution-generating surfaces to help meet I-3.4.6 MR6: Runoff Treatment. If the underdrain is elevated within a base course of gravel, the bioretention BMP will also provide some modest flow reduction benefit that will help achieve the LID Performance Standard within I-3.4.5 MR5: On-Site Stormwater Management and/or the Flow Control Performance Standard within I-3.4.7 MR7: Flow Control.

- 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 ground water 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 Criteria

General Design Criteria

- Utility conflicts: Consult local jurisdiction requirements for horizontal and vertical separation required for publicly-owned utilities, such as water and sewer. Consult the appropriate franchise utility owners for separation requirements from their utilities, which may include communications and gas. When 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.
- 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 local jurisdiction requirements.
- Ponding depth and surface water draw-down: Flow Control needs, as well as location in the development, and mosquito breeding cycles will determine draw-down timing. For example, front yards and entrances to residential or commercial developments may require rapid surface dewatering for aesthetics. In no case shall draw down time exceed 48 hours.
- 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 applications.
- Visual buffering: Bioretention BMPs can be used to buffer structures from roads, enhance privacy among residences, and for an aesthetic site feature.
- Site growing characteristics and plant selection: 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 bioretention soil mix with no nutrient or pesticide inputs and 2-3 years irrigation for establishment. Invasive species and noxious weed control will be required as typical with all planted landscape areas.
- Project submission requirements: Submit the results of infiltration (K_{sat}) testing and ground water 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 runoff modeling.
- 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). Refer to that document for additional explanations and background.

Note that the *Low Impact Development Technical Guidance Manual for Puget Sound* (Hinman and Wulkan, 2012) is for additional information 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).

- Geotechnical analysis is an important first step to develop an initial assessment of the variability of site soils, infiltration characteristics and the necessary frequency and depth of infiltration tests. See V-5.2 Infiltration BMP Design Steps.

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 when using a continuous runoff model.

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 ground water.

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 V-5.4 Determining the Design Infiltration Rate of the Native Soils for further guidance on the methods to determine the 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. Small-scale pilot infiltration test (PIT) as described in V-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 V-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 V-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 pit-

s/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 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 V-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, 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 are 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.

If the site subsurface characterization, including soil borings across the development site, indicate consistent soil characteristics and depths to seasonal high ground water conditions or a hydraulic restriction layer, the number of test locations may be reduced to a frequency recommended by a geotechnical professional.

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 ground water have or will be determined by another method. This overexcavation is to determine if there are restrictive layers or ground water. Observe whether water is infiltrating vertically or only spreading horizontally because of ground water or a restrictive soil layer. Observations through a wet season can identify a seasonal ground water restriction.

If a single bioretention BMP serves a drainage area exceeding 1 acre, a ground water mounding analysis may be necessary in accordance with V-5.2 Infiltration BMP Design Steps.

Assignment of Appropriate Correction Factors to the Native Soil

If the design requires determination of a long-term (design) infiltration rate of the native soils (for example, to demonstrate compliance with the LID Performance Standard and/or the Flow Control Performance Standard), refer to V-5.4 Determining the Design Infiltration Rate of the Native Soils and the following additional guidance specific to bioretention BMPs:

- The overlying bioretention soil mix provides excellent protection for the underlying native soil from sedimentation. Accordingly, when using The Simplified Approach to Calculating the Design Infiltration Rate of the Native Soils as described in V-5.4 Determining the Design Infiltration Rate of the Native Soils, the correction factor for the sub-grade soil does not have to take into consideration the extent of influent control and clogging over time. The correction factor to be applied to in-situ, small-scale infiltration test results for bioretention sites is determined by the site variability and number of locations tested as well as the method used to determine initial K_{sat}. Using Table V-5.1: Correction Factors to be Used With In-Situ Saturated Hydraulic Conductivity Measurements to Estimate Design Rates, the correction factor for bioretention design is revised based on this guidance as:

$$\text{Total Correction Factor, } CF_T = CF_V \times CF_t$$

- Tests should be located and be at an adequate frequency capable of producing a soil profile characterization that fully represents the infiltration capability where the bioretention areas are to be located. The partial correction factor CF_V depends on the level of uncertainty that variable subsurface conditions justify. If a pilot infiltration test is conducted for all bioretention areas or 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 may be adequate to justify a CF_V of one. If the level of uncertainty is high, a CF_V near the low end of the range may be appropriate. Two example scenarios where low CF_Vs may be appropriate include:
    - Site conditions are highly variable due to a deposit of ancient landslide debris, or buried stream channels. In these cases, even with many explorations and several pilot infiltration tests, the level of uncertainty may still be high.
    - Conditions are variable, but few explorations and only one pilot infiltration test is conducted. That is, the number of explorations and tests conducted do not match the degree of site variability anticipated.

Determining the Bioretention Soil Mix Design Infiltration Rate

1. Determine the initial saturated hydraulic conductivity (K_{sat}) based on the type of bioretention soil mix, as follows:
    - If using Ecology's default bioretention soil mix (detailed below), the initial K_{sat} is 12 inches per hour (30.48 cm/hr).
    - If using a custom bioretention soil mix (per the guidance for custom mixes below), use ASTM D 2434 Standard Test Method for Permeability of Granular Soils (Constant Head) with a compaction rate of 85 percent using ASTM D1557 Test Method for Laboratory Compaction Characteristics of Soil Using Modified Effort. See the additional guidance below for specific procedures for conducting ASTM D 2434. The designer must enter the derived K_{sat} value into the continuous modeling software.
2. After determining the initial K_{sat}, determine the appropriate safety factor:
    - If the contributing area to the bioretention BMP is equal to or exceeds any of the following limitations:

    - 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 pre-treatment BMP for solids removal, use 2 as the K_{sat} safety factor.

3. The continuous runoff model has a field for entering K_{sat} and the appropriate safety factor.

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).

Default Bioretention Soil Mix (BSM)

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

Percent Fines: A range of 2 to 4 percent passing the #200 sieve is ideal and fines should not be above 5 percent for a proper functioning specification according to ASTM D422.

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 V-5.2: General Guideline for Mineral Aggregate Gradation provides a gradation guideline for the aggregate component of the default bioretention soil mix (Hinman, 2009). The sand gradation below is often supplied as a well-graded utility or screened. With compost this blend provides enough fines for adequate water retention, hydraulic conductivity within recommended range (see below), pollutant removal capability, and plant growth characteristics for meeting design guidelines and objectives.

Table V-5.2: General Guideline for Mineral Aggregate Gradation

Sieve Size	Percent Passing
3/8"	100
#4	95-100
#10	75-90
#40	25-40
#100	4-10
#200	2-5

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).

Custom Bioretention Soil Mix

Projects which prefer to create a custom bioretention soil mix rather than using the default bioretention soil mix described above 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 less than 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 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.

Flow Entrance and Presettling

Flow entrance design will depend on topography, flow velocities and volume entering the pre-treatment and bioretention area, adjacent land use and site constraints. Flow velocities entering bioretention should be less than 1.0 ft/second to minimize erosion potential. Flow entrances should be placed with adequate separation from outlets to ensure that the influent stormwater is treated prior to reaching the overflow. Five primary types of flow entrances can be used for bioretention:

- *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.
- *Dispersed or sheet flow across pavement or gravel and past wheel stops for parking areas.*
- *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", and provide an area for settling and periodic removal of sediment and coarse material before flow dissipates to the remainder of the bioretention area.

  Curb cuts used for bioretention areas in high use parking lots or roadways require an increased level of maintenance due to high coarse particulates and trash accumulation in the flow entrance and associated bypass of flows. The following are methods recommended for areas where heavy trash and coarse particulates are anticipated:

- Curb cut width: 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 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.

- *Pipe flow entrance:* Piped entrances should include rock or other erosion protection material in the channel entrance to dissipate energy and disperse flow.
- *Catch basin:* 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.
- *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.

Woody plants can restrict or concentrate flows and can be damaged by erosion around the root ball and should not be placed directly in the bioretention entrance flow path.

Bottom Area and Side Slopes

Bioretention areas are highly adaptable and can fit various settings such as rural and urban roadsides, ultra urban streetscapes and parking lots by adjusting bottom area and side slope configuration. Recommended maximum and minimum dimensions include:

- 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. 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 and 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 at bottom widths less than 2 feet.
- Bioretention areas should have a minimum shoulder of 12 inches (30.5 cm) between the road edge and beginning of the bioretention side slope where flush curbs are used. Compaction effort for the shoulder should 90 percent proctor.

Ponding Area

Ponding depth recommendations:

- Maximum ponding depth: 12 inches (30.5 cm).
- Surface pool drawdown time: 24 hours

For design on projects subject to I-3.4.5 MR5: On-Site Stormwater Management, and choosing to use The List Approach of that requirement, the bioretention BMP shall have a horizontally projected surface area below the overflow which is at least 5% of the area draining to it.

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; provide proper soil conditions for biodegradation and retention of pollutants. Maximum designed depth of ponding (before surface overflow to a pipe or ditch) must be considered in light of drawdown time.

For bioretention areas with underdrains, elevating the drain to create a temporary saturated zone beneath the drain is advised to promote denitrification (conversion of nitrate to nitrogen gas) and prolong moist soil conditions for plant survival during dry periods (see the Underdrain (optional) section below for details).

Surface Overflow

Surface overflow can be provided by vertical stand pipes that are connected to underdrain systems, by horizontal drainage pipes or armored overflow channels installed at the designed maximum ponding elevations. Overflow can also be provided by a curb cut at the down-gradient 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.

Soil Depth

The bioretention soil mix depth must be 18 inches to provide Runoff Treatment and good growing conditions for selected plants. Ecology does not recommend bioretention soil mix depths greater than 18 inches due to preliminary monitoring results indicating that phosphorus can leach from the bioretention soil mix.

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.

Underdrain (optional)

Where the underlying native soils have a measured initial K_{sat} between 0.3 and 0.6 inches per hour, bioretention BMPs without an underdrain, or with an elevated underdrain directed to a surface outlet, may be used to satisfy The List Approach of I-3.4.5 MR5: On-Site Stormwater Management. Underdrained bioretention BMPs must meet the following criteria if they are used to satisfy The List Approach of I-3.4.5 MR5: On-Site Stormwater Management:

- the invert of the underdrain must be elevated 6 inches above the bottom of the aggregate bedding layer. A larger distance between the underdrain and bottom of the bedding layer is desirable, but cannot be used to trigger infeasibility due to inadequate vertical separation to the seasonal high water table, bedrock, or other impermeable layer.
- the distance between the bottom of the bioretention soil mix and the crown of the underdrain pipe must be not less than 6 but not more than 12 inches;
- the aggregate bedding layer must run the full length and the full width of the bottom of the bioretention BMP;
- the BMP must not be underlain by a low permeability liner that prevents infiltration into the native soil.

Figure V-5.13: Typical Bioretention w/Underdrain depicts a bioretention BMP with an elevated underdrain. Figure V-5.14: Typical Bioretention w/Liner (Not LID) depicts a bioretention BMP with an underdrain and a low permeability liner. The latter is not considered a low impact development BMP. It cannot be used to implement The List Approach of I-3.4.5 MR5: On-Site Stormwater Management.

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 in the continuous runoff model for dead storage volume that provides Flow Control benefit. Assume a 40% void volume for the Type 26 mineral aggregate specified below.

Underdrain systems should only be installed when the bioretention BMP is:

- 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 system dewater rates, or are below a minimum rate allowed by the local government.

The underdrain can be connected to a downstream bioretention swale, to another bioretention cell as part of a connected treatment system, daylight to a dispersion area using an effective flow dispersion practice, or 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.

Underdrain pipe recommendations:

- Minimum pipe diameter: 4 inches (pipe diameter will depend on hydraulic capacity required, 4 to 8 inches is common).
- Slotted subsurface drain PVC per ASTM D1785 SCH 40.
- Slots should be cut perpendicular to the long axis of the pipe and be 0.04 to 0.069 inches by 1 inch long and be spaced 0.25 inches apart (spaced longitudinally). Slots should be arranged in four rows spaced on 45-degree centers and cover ½ of the circumference 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 percent unless otherwise specified by an engineer.

Perforated PVC or flexible slotted HDPE pipe cannot be cleaned with pressurized water or root cutting equipment, are less durable and are not recommended. Wrapping the underdrain pipe in filter fabric increases chances of clogging and is not recommended. A 6-inch rigid non-perforated 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.

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.

Table V-5.3: 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).	

- 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).

Orifice and Other Flow Control sStructures

The minimum orifice diameter should be 0.5 inches to minimize clogging and maintenance requirements.

Check Dams and Weirs

Check dams are 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 right-of-ways and aesthetics. Optimum spacing is determined by Flow Control benefit (modeling) in relation to cost consideration. See the *Low Impact Development Technical Guidance Manual for Puget Sound* (Hinman and Wulkan, 2012) for displays of typical designs.

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 I-4 UIC Program.

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 V-1.3.3 Low Permeability Liners for guidelines.
- Geomembrane liners completely block infiltration to subgrade soils and are used for ground water 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. Where geomembrane liners are used to line the entire BMP, underdrain systems are necessary. See V-1.3.3 Low Permeability Liners for guidelines.

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). Accordingly, wetland plants may be used in the lower areas, if saturated soil conditions exist for appropriate periods, and drought-tolerant species planted on the perimeter of the facility or on mounded areas. See the *Low Impact Development Technical Guidance Manual for Puget Sound* (Hinman and Wulkan, 2012) for additional guidance and recommended plant species. See also City of Seattle's ROW bioretention plant lists found in Seattle's GSI Manual, Appendix G, at the following web address:

https://www.seattle.gov/util/cs/groups/public/@spu/@engineering/documents/webcontent/1_079167.pdf

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.

Mulch Layer

You can design bioretention areas with or without a mulch layer. When used, mulch shall be:

- Medium compost in the bottom of the BMP (compost is less likely to float during cell inundation). Compost shall not include biosolids or manures.
- 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.

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).

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.

Runoff Model Representation

Note that if the project is using bioretention to only meet The List Approach within I-3.4.5 MR5: On-Site Stormwater Management, there is no need to model the bioretention in a continuous runoff model. Size the bioretention as described above in Ponding Area.

The guidance below is to show compliance with the LID Performance Standard in I-3.4.5 MR5: On-Site Stormwater Management, or the standards in I-3.4.6 MR6: Runoff Treatment, I-3.4.7 MR7: Flow Control, and/or I-3.4.8 MR8: Wetlands Protection.

Continuous runoff modeling software include modeling elements for bioretention.

The equations used by the elements are intended to simulate the wetting and drying of soil as well as how the soils function once they are saturated. This group of LID elements uses the modified Green

Ampt equation to compute the surface infiltration into the amended soil. The water then moves through the top amended soil layer at the computed rate, determined by Darcy's and Van Genuchten's equations. As the soil approaches field capacity (i.e., gravity head is greater than matric head), the model determines when water will begin to infiltrate into the second soil layer (lower layer). This occurs when the matric head is less than the gravity head in the first layer (top layer). The second layer is intended to prevent loss of the amended soil layer. As the second layer approaches field capacity, the water begins to move into the third layer – the gravel underlayer. For each layer, the user inputs the depth of the layer and the type of soil.

Within the WWHM continuous runoff model, for the Ecology-recommended soil specifications for each layer in the design criteria for bioretention, the model will automatically assign pre-determined appropriate values for parameters that determine water movement through that soil. These include: wilting point, minimum hydraulic conductivity, maximum saturated hydraulic conductivity, and the Van Genuchten number.

For bioretention with underlying perforated drain pipes that discharge to the surface, the only volume available for storage (and modeled as storage as explained herein) is the void space within the aggregate bedding layer below the invert of the drain pipe. Use 40% void space for the Type 26 mineral aggregate specified in Underdrain (optional) (above).

Modeling:

It is preferable to enter each bioretention device and its drainage area into the approved computer models for estimating their performance.

However, where site layouts involve multiple bioretention facilities, the modeling schematic can become extremely complicated or not accommodated by the available schematic grid.

In those cases, multiple bioretention facilities with similar designs (i.e., soil depth, ponding depth, freeboard height, and drainage area to ponding area ratio), and infiltration rates (Ecology suggests within a factor of 2) may have their drainage areas and ponded areas be combined, and represented in the runoff model as one drainage area and one bioretention device. In this case, use a weighted average of the design infiltration rates at each location. The averages are weighted by the size of their drainage areas.

For bioretention with slide slopes of 3H:1V or flatter, infiltration through the side slope areas can be significant. Where side slopes are 3H:1V or flatter, bioretention can be modeled allowing infiltration through the side slope areas to the native soil. In WWHM, modeling of infiltration through the side slope areas is accomplished by switching the default setting for "Use Wetted Surface Area (sidewalls): from "NO" to "YES."

Installation Criteria

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.

Soil Placement

On-site soil mixing or placement shall not be performed if 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 (0.5 cm) of water per 1 inch (2.5 cm) 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 during design, construction sequencing and construction should be made to prevent sediment from entering bioretention BMPs. However, bioretention areas are often distributed throughout the project area and can present unique challenges during construction. 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 annual plant, soil, and mulch layer maintenance to ensure optimum infiltration, storage, and pollutant removal capabilities. In general, bioretention maintenance requirements are typical landscape care procedures and include:

- 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 reassessed: (1) flow volumes from contributing areas and bioretention cell sizing; (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 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.
- 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.
- Nutrient 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 BMPs are located in areas where phosphorous and nitrogen levels may be elevated and these should not be limiting nutrients. If in question, have 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 (likely 3 to 5 years) 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 V-A: BMP Maintenance Tables for additional maintenance guidelines.

Appendix D – Flow Control and Water Quality Applications Maps

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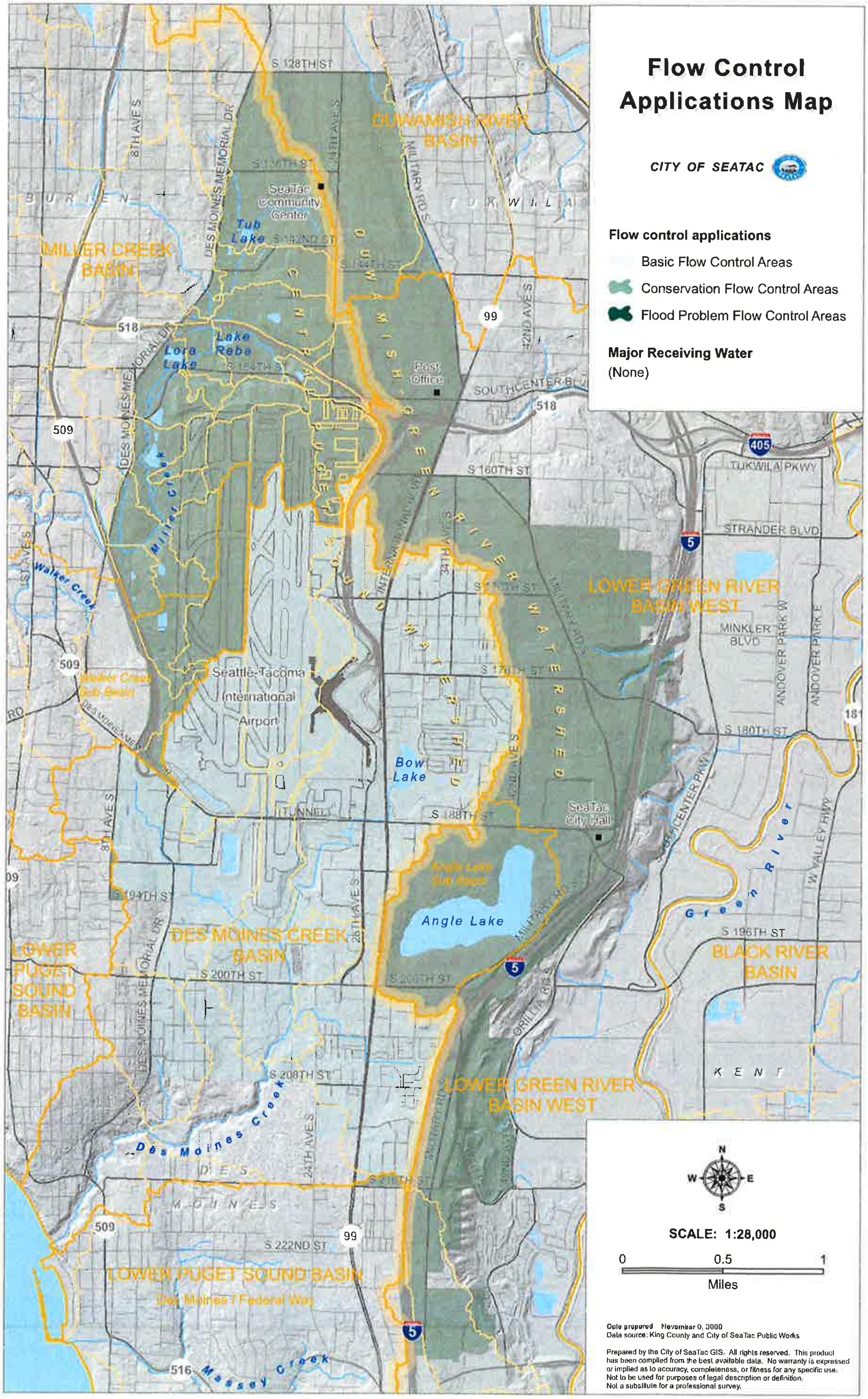
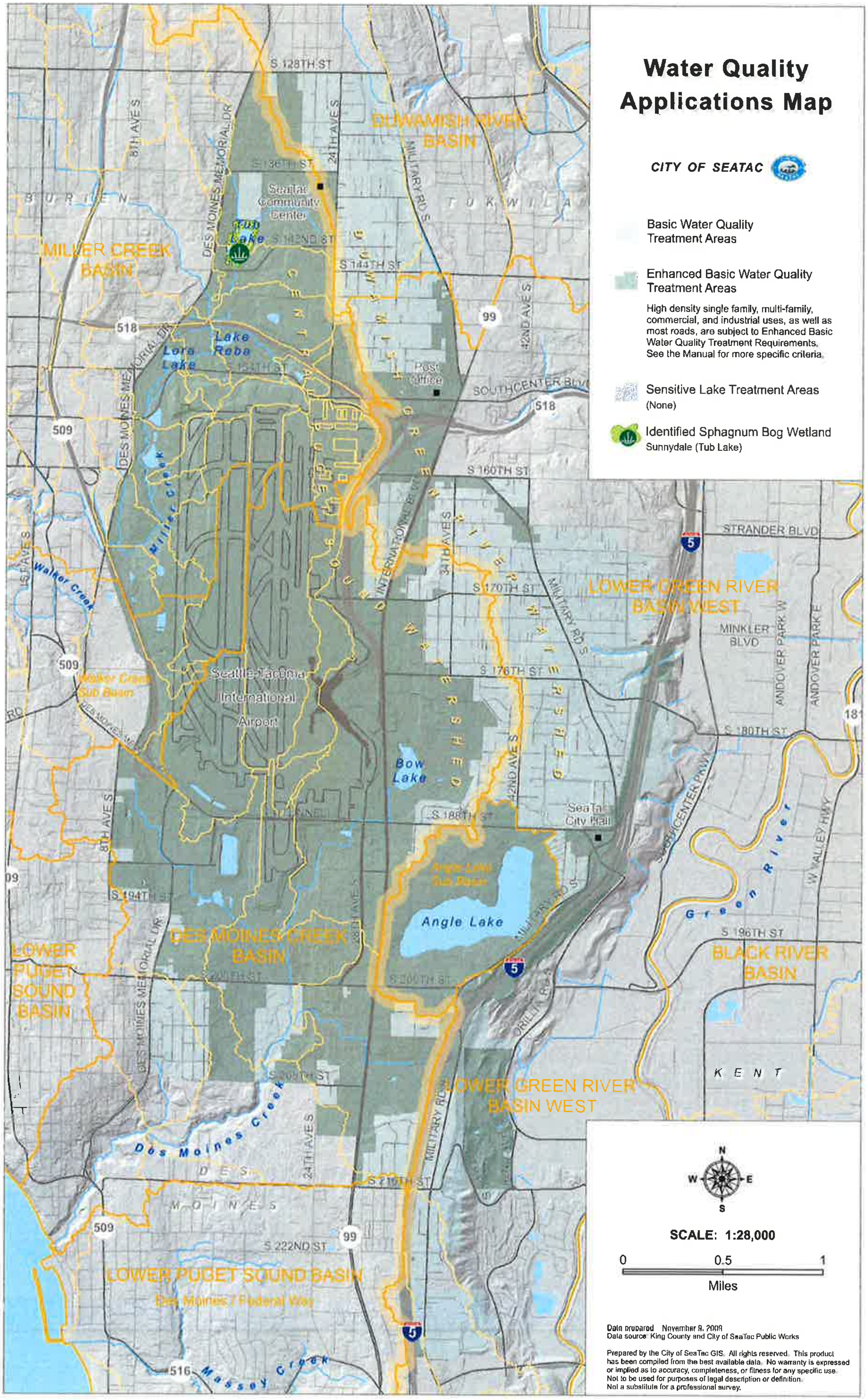


Flow Control Applications Map
CITY OF SEATAC
Flow control applications
Basic Flow Control Areas
Conservation Flow Control Areas
Flood Problem Flow Control Areas
Major Receiving Water
(None)
DUWAMISH RIVER BASIN
MILLER CREEK BASIN
CENTRAL DUWAMISH
DUWAMISH / GREEN RIVER WATERSHED
LOWER GREEN RIVER BASIN WEST
DES MOINES CREEK BASIN
LOWER PUGET SOUND BASIN
BLACK RIVER BASIN
LOWER PUGET SOUND BASIN
Des Moines / Federal Way
BURIEN
TUKWILA
DES MOINES
KENT
Seattle-Tacoma International Airport
SeaTac Community Center
Post Office
SeaTac City Hall
Tub Lake
Lake Reba
Lora Lake
Bow Lake
Angle Lake
Miller Creek
Walker Creek
Des Moines Creek
Massey Creek
Green River
S 128TH ST
S 136TH ST
S 142ND ST
S 144TH ST
S 154TH ST
S 160TH ST
S 170TH ST
S 180TH ST
S 188TH ST
S 194TH ST
S 196TH ST
S 200TH ST
S 208TH ST
S 216TH ST
S 222ND ST
DES MOINES MEMORIAL DR
MILITARY RD S
INTERNATIONAL BLVD
SOUTHCENTER BLVD
TUKWILA PKWY
STRANDER BLVD
MINKLER BLVD
ANDOVER PARK W
ANDOVER PARK E
W VALLEY HWY
ORILLIA RD S
8TH AVE S
24TH AVE S
42ND AVE S
TUNNEL
509
518
99
405
5
516
N
W
E
S
SCALE: 1:28,000
0
0.5
1
Miles
Data source: King County and City of SeaTac Public Works
Prepared by the City of SeaTac GIS. All rights reserved. This product has been compiled from the best available data. No warranty is expressed or implied as to accuracy, completeness, or fitness for any specific use. Not to be used for purposes of legal description or definition. Not a substitute for a professional survey.


Water Quality Applications Map
CITY OF SEATAC
Basic Water Quality Treatment Areas
Enhanced Basic Water Quality Treatment Areas
High density single family, multi-family, commercial, and industrial uses, as well as most roads, are subject to Enhanced Basic Water Quality Treatment Requirements. See the Manual for more specific criteria.
Sensitive Lake Treatment Areas
(None)
Identified Sphagnum Bog Wetland
Sunnydale (Tub Lake)
MILLER CREEK BASIN
DUWAMISH RIVER BASIN
LOWER GREEN RIVER BASIN WEST
DES MOINES CREEK BASIN
LOWER PUGET SOUND BASIN
BLACK RIVER BASIN
LOWER PUGET SOUND BASIN
Des Moines / Federal Way
Walker Creek Sub Basin
Angle Lake Sub Basin
Seattle-Tacoma International Airport
SeaTac Community Center
Post Office
SeaTac City Hall
Angle Lake
Bow Lake
Lake Reba
Lora Lake
Tub Lake
Miller Creek
Walker Creek
Des Moines Creek
Massey Creek
Green River
BURIEN
TUKWILA
KENT
DES MOINES
S 128TH ST
S 136TH ST
S 142ND ST
S 144TH ST
S 154TH ST
S 160TH ST
S 170TH ST
S 176TH ST
S 180TH ST
S 188TH ST
S 194TH ST
S 196TH ST
S 200TH ST
S 208TH ST
S 216TH ST
S 222ND ST
SOUTHCENTER BLVD
STRANDER BLVD
MINKLER BLVD
DES MOINES MEMORIAL DR
INTERNATIONAL BLVD
MILITARY RD S
8TH AVE S
24TH AVE S
34TH AVE S
42ND AVE S
ANDOVER PARK W
ANDOVER PARK E
W VALLEY HWY
SOUTHCENTER PKWY
ORILLIA RD S
518
509
99
5
516
N
W
E
S
SCALE: 1:28,000
0
0.5
1
Miles
Date prepared November 9, 2009
Data source King County and City of SeaTac Public Works
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