City of Bellevue Post Office Box 90012 •Bellevue, Washington • 98009 9012

Date: **December 8, 2011**

From: **Wes Jorgenson**
Assistant Director for Engineering
City of Bellevue Utilities

Subject: **Utilities Engineering Standards Amendment**

Effective immediately, the following amendment is made to the City of Bellevue Utilities Engineering Standards, last updated January 1, 2011.

This amendment to the Surface Water Engineering Standards incorporates corrections that:

1. Clarify that the minimum infiltration rate means the minimum ***design*** infiltration rate (measured infiltration rate with the appropriate correction factors applied).

2. Correct the minimum design infiltration rate to 0.25 inches per hour from 0.1 inch per hour.

3. Revise values for the sizing factors in Table 6.13.

The following revisions supersede the corresponding uncorrected text currently in the Surface Water Engineering Standards. Revised sections are marked by a bar along the left margin. Revisions are displayed with colored text (strikethrough font for deleted text and underline font for added text).

Under D4-06.7 Infiltration Systems, Section D. Infiltration Test Requirement, revise bullets under the heading Site Suitability or Infiltration Rate as follows (pages D4-80 and D4-81):

Site Suitability or Infiltration Rate

- Divide the number of inches of standing water initially added to the hole by the number of hours it takes for the water to drain out completely. The resulting number is the measured (short term) infiltration rate in inches per hour.
- Select a correction factor based on site conditions between 5.5 and 18 from the DOE Manual, Volume III, Table 3.9. If the site conditions are unknown or uncertain, use a higher correction factor. Correction factors are not needed for bioretention facilities, infiltration trenches, or infiltration drywells.
- Divide the measured infiltration rate by the correction factor. The resulting number is the long term infiltration rate (design infiltration rate) in inches per hour.
- If the measured infiltration rate is greater than 10 inches per hour (drains in less than one hour), use a maximum design infiltration rate of 10 inches per hour.

- If the measured infiltration rate is less than 0.~~1~~25 inches per hour (takes more than ~~100~~ 40 hours to drain a 10-inch deep column of water), the site is not suitable for a rain garden. If the long term infiltration rate is less than 0.25 inches per hour, the site is not suitable for ~~or~~ pervious pavement. ~~without an approved overflow and underdrain.~~
- For bioretention facilities, the design infiltration rate used to size the facility will be whichever is lower: the measured infiltration rate of the native soil beneath the facility site, or infiltration rate of the bioretention soil mix layer. For infiltration trenches and drywells, use the measured infiltration rate. To design other infiltration facilities, use the long-term infiltration rate of the underlying native soil.

CHAPTER D6 – ON-SITE STORMWATER MANAGEMENT, replace entire chapter with the attached revised document:

CHAPTER D6 – ON-SITE STORMWATER MANAGEMENT

TABLE OF CONTENTS

TABLES

FIGURES

CHAPTER D6 – ON-SITE STORMWATER MANAGEMENT

D6-01 GENERAL

On-site stormwater management BMPs infiltrate, disperse, and retain stormwater on-site in order to reduce the volume, peak flow rates, and amount of pollutants in stormwater runoff leaving a developed project site. The following on-site stormwater management BMPs are required where site conditions allow without causing erosion or flooding: Roof Downspout Control BMPs functionally equivalent to those described in Chapter 3 of Volume III of the DOE Manual; and Dispersion and Soil Quality BMPs functionally equivalent to those in Chapter 5 of Volume V of the DOE Manual.

Natural Drainage Practices (NDPs) are included here as a sub-set of on-site stormwater management BMPs, and include bioretention, pervious pavement, rain recycling, and vegetated roofs. These NDPs are encouraged as an integral part of site designs. New BMPs that DOE approves in writing as functionally equivalent to those listed in this chapter or that DOE has approved for General Use (GULD) under DOE's emerging technology program, per Chapter 12, Volume V of the DOE Manual, are also allowed. Using NDPs in addition to or in place of the required on-site BMPs (where NDP substitution is allowed) can significantly enhance the overall hydrologic performance of the developed site and further reduce downstream flooding, erosion, water quality impacts, and long-term maintenance requirements. NDPs can also enhance site sustainability and aesthetics, and may add points under LEED and Built Green certification programs.

This chapter provides detailed guidance on how to use the criteria set forth in Section 24.06.065(G) of the Storm and Surface Water Utility Code and design guidelines in the LID Technical Guidance Manual and Chapter 3 of Volume III and Chapter 5 of Volume V of the DOE Manual, as modified herein, to plan, design and construct on-site stormwater management BMPs and NDPs. The remainder of this section describes how to apply on-site stormwater management BMPs to meet Minimum Requirement 5 (On-Site Stormwater Management), MR6 (Runoff Treatment), and MR7 (Flow Control).

D6-01.1 Using On-Site Stormwater Management to meet Storm and Surface Water Utility Code Requirements

Under the Storm and Surface Water Utility Code (BCC 24.06.065), new development, redevelopment, and construction activities that meet the thresholds defined in Section D2-05 are required to provide on-site stormwater management (MR5), runoff treatment (MR6), and/or flow control (MR7). This section describes how on-site stormwater management BMPs may be used to meet those minimum requirements.

A. On-Site Stormwater Management (Minimum Requirement 5)

Required for projects with new, replaced, or new plus replaced impervious surface areas equal to or greater than 2,000 square feet.

Following is a tiered list of Best Management Practices (BMPs) that must be evaluated for each project that triggers on-site stormwater management (Figure 6.1). The BMPs must be evaluated and implemented in the order presented within each of three tiers:

- Tier 1 – Minimize Runoff Generation (Table 6.1);

- Tier 2 – Retain Runoff On-Site (Tables 6.2A and 6.2B); and
- Tier 3 – Infiltrate or Disperse Runoff Prior to Discharge (Table 6.3).

After required on-site stormwater management BMPs are implemented to the extent feasible, additional BMPs from Table 6.2B may be implemented as site conditions allow. On-site stormwater management BMPs, including NDPs, may be used to reduce runoff treatment and/or flow control requirements when designed and sized per Section D6-03.

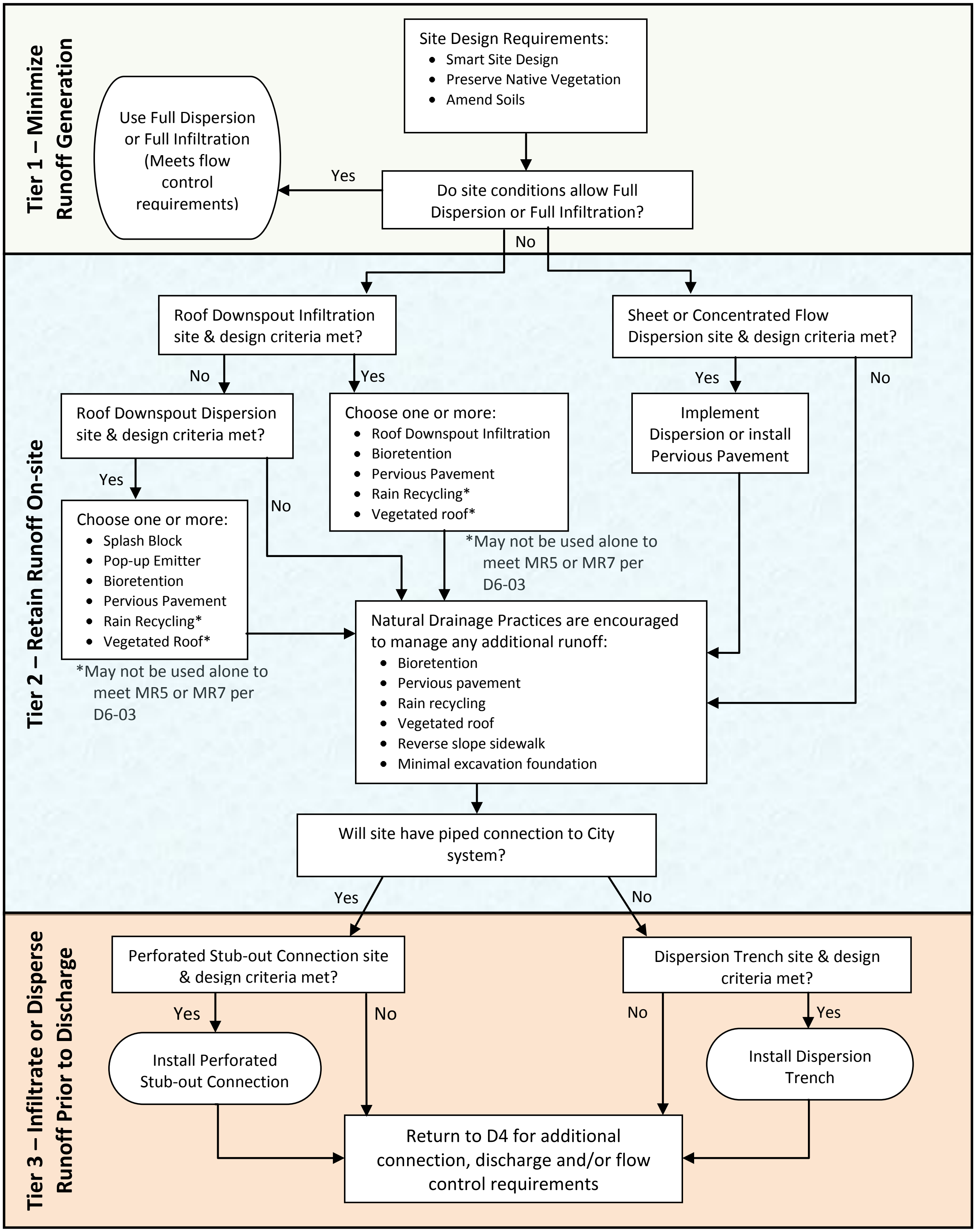

Figure 6.1. On-site Stormwater Management Facility Selection for MR5 and MR7.

Tier 1 - Minimize Runoff Generation

The first priority in managing stormwater runoff on-site is to minimize the amount of stormwater runoff that is generated. Each project is required to evaluate these Tier 1 BMPs in the order presented in Table 6.1 and must implement all Tier 1 techniques that are applicable to the site without causing erosion or flooding on-site or downstream.

Table 6.1. Required Tier 1 On-site Stormwater Management BMPs

BMP	Description	Applicability	Requirements
Smart Site Design	Site layout and design techniques that minimize disturbance of the hydrologic cycle	All projects	Comply with LUC 20.20.460 – Impervious surface limits. Comply with Section D6-03.1 B
Preserve Native Vegetation	Set aside native growth areas in Native Growth Protection Easement (NGPE); preserve significant trees	All projects	Comply with LUC 20.20.900 – Tree Preservation, exceed where feasible. If possible, record NGPE against property per LUC 20.25H.030.B.2. Restore previously disturbed areas with native vegetation. Comply with Section D6-03.1 C
Full Dispersion or Full Infiltration	Full Dispersion: Disperse runoff from 90-100 percent of impervious surfaces; in some cases, retain 35-65% native vegetation in a Native Growth Protection Easement Full Infiltration: Infiltrate 100% of site runoff	Limited applicability – see Requirements	No runoff treatment or flow control required if site fully dispersed or fully infiltrated. Comply with Section D6-03.1 A
Amended Soils	Preserve native soils or amend with compost	All projects	Required for all disturbed pervious areas. Comply with Section D6-03.1 D

Tier 2 - Retain Runoff On-site

After all Tier 1 BMPs have been evaluated and implemented per the requirements in Table 6.1, the following Tier 2 BMPs must be evaluated for implementation in the order presented to retain runoff that is generated by the project. All runoff from impervious surfaces should be managed with at least one of the following BMPs from Table 6.2A as site conditions allow, without causing erosion or flooding on-site or downstream. NDPs may be substituted for the required roof downspout controls and dispersion BMPs or used in addition to those required BMPs wherever site conditions allow and design criteria can be met (Table 6.2B).

Maximizing on-site stormwater management through the use of roof downspout control and dispersion BMPs in combination with NDPs may eliminate or substantially reduce flow control requirements (MR7), thereby reducing construction costs and long-term maintenance requirements, as well as help reduce local and regional flooding.

Table 6.2A. Required Tier 2 On-site Stormwater Management BMPs

BMP	Description	Applicability	Requirements
Roof Downspout Infiltration	Infiltration Trench or Drywell Allowable alternatives include minimal excavation foundation or directing roof runoff to bioretention or pervious pavement; can also combine with rain recycling or vegetated roof. See Table 6.2B	Residential and small commercial lots	Required where design criteria and setbacks are met Comply with Section D6-03.1 E
Roof Downspout Dispersion – Splash Blocks or Pop-up Drainage Emitter	Connect roof downspouts to splash blocks or pop-up drainage emitters Allowable alternatives include minimal excavation foundation or directing roof runoff to bioretention or pervious pavement; can also combine with rain recycling or vegetated roof. See Table 6.2B	Residential and small commercial lots	Required where design criteria and setbacks are met if Downspout Infiltration is not feasible. Comply with Section D6-03.1 F
Concentrated and Sheet Flow Dispersion	Flow dispersion for pavement, patios and other impervious surfaces, and roofs without gutters Allowable alternatives include pervious pavement, minimal excavation foundations, and reverse slope sidewalks where conditions allow. See Table 6.2B	Residential and small commercial lots, roads	Required where design criteria and setbacks are met Comply with Section D6-03.1 G

Table 6.2B. Natural Drainage Practices (NDPs) Allowed as Alternatives to or in Addition to Required Tier 2 BMPs

NDP	Description	Applicability	Requirements
Bioretention	Rain Garden; Bioretention Swale; or Downspout Planter Box	All projects	Comply with Section D6-03.2 A
Pervious Pavement	Pervious concrete or asphalt; Modular block; underlying aggregate stores water Roof runoff may be directed to pervious pavement	All projects	Comply with Section D6-03.2 B LUC 20.20.460(G) may apply (impervious surface limits)
Rain Recycling	Rain barrels or cisterns for flow control, irrigation, or indoor reuse of harvested water	All projects	Comply with Section D6-03.2 C
Vegetated Roof	Roof with light-weight soil mix and plants	All projects	Comply with Section D6-03.2 D
Reverse Slope Sidewalk	Sidewalk or walkway sloped towards wide vegetated area	All projects	Comply with Section D6-03.2 E
Minimal Excavation Foundation Systems	Building, deck or walkway supported by pin, pile or post systems, minimal grading of native soil	All projects	Comply with Section D6-03.2 F

Tier 3 - Infiltrate or Disperse Runoff Prior to Discharging

After evaluating and implementing all possible techniques and BMPs from Tiers 1 and 2, the following techniques must be implemented in the order presented below and used to infiltrate or disperse as much of the remaining runoff as possible, as site conditions allow, without causing flooding or erosion.

Table 6.3. Required Tier 3 BMPs

BMP	Description	Applicability	Requirements
Perforated Stub-out Connection	Runoff to existing storm pipe directed via underground perforated pipe in a rock trench.	All projects with storm conveyance system connection	Required for any connection to a storm conveyance system, where design criteria are met. Comply with Section D6-03.1 H
Dispersion Trench	Gravel-filled trench with adequate vegetated flow path. May include pump if site conditions require.	Use only where other BMPs do not fully mitigate runoff	Required as an outfall when connection to a storm conveyance system is not available and design criteria are met. Comply with Section D6-03.1 F

Refer to Sections D6-03.1 and D6-03.2 for design, sizing, construction, and maintenance methods for on-site BMPs and NDPs. Sizing Factors for determining the minimum sizes necessary to meet on-site stormwater management requirements, based on the amount of impervious area draining to each facility, are provided in Section D6-03.3C.

B. Runoff Treatment (Minimum Requirement 6)

Full dispersion and Infiltration NDPs, including bioretention and pervious pavement, are preferred methods for meeting water quality treatment requirements.

Full dispersion may be applied to entire sites or portions of sites with at least 35% of native vegetation preserved in a dedicated NGPE, or to road projects meeting the requirements for full dispersion credit in Section 7.2 of the LID Manual. Sites that correctly implement full dispersion in accordance with all applicable design requirements do not need additional runoff treatment.

Bioretention can be used to meet basic and enhanced water quality treatment requirements. The bioretention facility must be sized to infiltrate at least 91 percent of the average annual runoff from the contributing pollution-generating surface area into the bioretention soil mix layer. The bioretention soil mix layer must meet the *Soil Physical and Chemical Suitability for Treatment* requirements in Chapter 3 of Volume III of the DOE Manual. Underdrains may be used, if needed, to meet facility drawdown requirements. See Section D6-03.2(A) for bioretention design criteria.

Pervious pavement can also be used to meet basic and enhanced water quality treatment requirements if it is sized to infiltrate at least 91 percent of the average annual runoff from the contributing PGIS area into underlying soils that meet the *Soil Physical and Chemical Suitability for Treatment* requirements in Chapter 3 of Volume III of the DOE Manual. Underdrains may be used, if needed, to meet facility drawdown requirements provided that a "treatment layer" is installed over the underdrains in accordance with Section 4.4.2 of Volume V of the DOE Manual. See Section D6-03.2(B) for pervious pavement design criteria.

Some of the required on-site stormwater BMPs, including amended soil and dispersion, can be used to partially satisfy runoff treatment requirements; for example, runoff can be dispersed through areas with amended soils. In addition, site design practices and vegetation retention be used to reduce the amount of PGIS and PGPS requiring treatment. Rain recycling and vegetated roofs cannot be used to satisfy runoff treatment. No on-site stormwater BMPs can be used for oil/water separation.

Table 6.4 summarizes the type of water quality treatment for which each on-site stormwater management BMP may be used and provides references to the appropriate design and sizing criteria.

Table 6.4. On-site Stormwater Management BMPs for Runoff Treatment

BMP	Oil/Water Separation	Phosphorous Treatment	Enhanced Treatment	Basic Water Quality Treatment	Design and Sizing Criteria
Amended Soil[a]	No	No	No	No	DOE Manual Chapter 5 of Vol. V; Soils for Salmon[b]
Full Dispersion	No	Yes	Yes	Yes	LID Manual Chapter 7
Full Infiltration	No	Yes	Yes	Yes	DOE Manual, Volume III, 3.3.9(A)
Bioretention	No	No	Yes	Yes	D6-03.2 A
Pervious Pavement	No	No	Yes[c]	Yes[c]	D6-03.2 B
Rain Recycling	No[d]	No[d]	No[d]	No[d]	D6-03.2 C
Vegetated Roofs	No[d]	No[d]	No[d]	No[d]	D6-03.2 D
Reverse Slope Sidewalks	No[d]	No[d]	No[d]	No[d]	D6-03.2 E
Minimal Excavation Foundation Systems	No[d]	No[d]	No[d]	No[d]	D6-03.2 F

a. Areas meeting the criteria for full dispersion or full infiltration credit shall be excluded from runoff treatment requirements. Amended soil areas shall be modeled as landscape unless used to meet full dispersion requirements.

b. Source: (Guidelines and Resources for Implementing Soil Quality and Depth BMP T5.13 in WDOE Stormwater Management Manual for Western Washington, 2009 Edition).

c. Provides treatment if underlain by soils that meet *Soil Physical and Chemical Suitability for Treatment* requirements in Chapter 3 of Volume III of the DOE Manual, including minimum depth (18 inches), minimum cation exchange capacity, minimum organic content and maximum infiltration rate.

d. These BMPs are not capable of meeting water quality treatment requirements. Further, some of these NDPs typically receive only roof runoff, which does not require treatment.

Refer to Sections D6-03.1 and D6-03.2 for design, sizing, construction, and maintenance methods for BMPs and NDPs. See also Chapter D5 for more information on water quality treatment BMPs. Sizing Factors for meeting runoff treatment are provided in Section D6-03.3 C. ***While these factors may be used as a guideline in preliminary sizing and/or as a simplified check for the reviewer, the NDPs must be designed by a professional engineer to satisfy runoff treatment requirements (MR6)***.

C. Flow Control (Minimum Requirement 7)

Dispersion and infiltration BMPs, including the Infiltration NDPs (bioretention and pervious pavement), are highly effective in controlling runoff volumes, peak flow rates, and the duration of erosive flows. These BMPs are preferred for meeting flow control requirements. See Section D3-05 of these Standards for flow control exemptions. Full dispersion or full infiltration may be used to satisfy all flow control requirements on residential sites or road projects where design criteria are met. Infiltration BMPs may be applied to fully or partially meet flow control requirements. Partial infiltration BMPs, including infiltration trenches and bioretention with underdrains, can also be used to partially or fully satisfy flow control, depending on native soil design infiltration rates and facility geometry. Rain recycling cisterns with orifice-controlled outlets can also be effective at detaining peak flows, while rain recycling facilities that incorporate extensive reuse (indoor and/or outdoor) of harvested rainwater can effectively reduce stormwater runoff volumes and peak durations. (Note: indoor use of rainwater must conform to plumbing regulations.) Finally, vegetated roofs can absorb and evapotranspirate some of the rain that falls onto the surface, thereby reducing peak flow rates and providing some flow volume reduction.

Refer to Sections D6-03.1 and D6-03.2 for design, sizing, construction, and maintenance methods for on-site BMPs, including NDPs. Sizing Factors to meet flow control requirements are provided in Section D6-03.3. ***While these factors may be used as a guideline in preliminary sizing and/or as a simplified check for the reviewer, the NDPs must be designed by a professional engineer to satisfy flow control requirements (MR7).*** Flow Control Credits that can be applied to reduce the size of downstream flow control facilities are provided in Section D6-03.4.

D6-02 SITE SUITABILITY AND BMP SELECTION

D6-02.1 Introduction

This section contains guidelines to aid designers and reviewers in characterizing development sites, in selecting the most appropriate BMPs for the site, and in meeting on-site stormwater management requirements.

These guidelines contain three steps for on-site BMP site assessment and selection:

1) Characterize Site Infiltration Capabilities, 2) Site Layout and Use, and 3) Runoff Sources and BMP Selection.

D6-02.2 Step 1: Characterize Site Infiltration Capabilities

During Step 1, the Developer must map the development site according to its potential infiltration capabilities, categorizing site areas based on the topographic and soil conditions that constrain the use and appropriateness of on-site stormwater BMPs. In general, infiltration BMPs are more effective in flatter areas than steeper areas. While outwash soils typically have higher infiltration rates than till soils, soils with design infiltration rates as low as 0.25~~1~~ inches per hour can be well suited for small-scale infiltration or partial infiltration BMPs that receive runoff from small contributing drainage areas relative to the BMP footprint size.

Step 1 entails three sub-steps, including Step 1a: Identify Site Slopes and Critical Areas, Step 1b: Identify Depth to Groundwater, and Step 1c: Characterize Site Soils and Determine Infiltration Rates. Each of these sub-steps is described below.

A. Step 1a: Identify Site Slopes and Critical Areas

Using the boundary and topographic survey for the site, identify areas that have slopes between 0 to 15% slopes, >15% to 33% slopes, and greater than 33% slopes based on the existing contours. Where grading is planned for proposed pavement or landscaped areas of the site, use the proposed contours shown on the grading plan instead of the existing contours for this sub-step. Steep slope areas that are classified as Critical Areas (Steep Slopes or Landslide Hazard areas) must also be indentified on the map, along with required buffers. Refer to LUC 20.25H for more information on Critical Areas.

Proposed Buildings

For buildings, identify the proposed slope and structural capacity of the roofs and whether vegetated roofs are being considered for the site. Vegetated roofs are permitted on roofs with up to 20 percent slopes. A licensed structural Engineer must design the vegetated roof and demonstrate that the building has sufficient structural capacity to support the expected loads. Refer Section D6-03.2 D for design guidance on vegetated roofs.

B. Step 1b: Identify Depth to Groundwater

The next step is to identify areas where shallow seasonal groundwater will limit the infiltration capacity of the site or not allow sufficient water quality treatment prior to discharge to the groundwater table. Section D4-06.7(C) provides instructions for evaluating the depth to groundwater. Projects that do not trigger runoff treatment (MR6) or flow control (MR7) are not required to monitor groundwater levels and may rely on observations made using the simple infiltration test (Section D4-06.7(D)) and/or preliminary data available from the Pacific Northwest Center for Geologic Mapping Studies, at the GeoMapNW web site (see Section D1-03).

C. Step 1c: Characterize Site Soils and Determine Infiltration Rates

In areas where there is sufficient depth to the groundwater table, determine the soil type, texture, and infiltration rate of site soils in various locations where infiltration facilities such as rain gardens, pervious pavement, or infiltration trenches may be constructed. If modeling will be used, determine soil type categories as Natural Resource Conservation Services (NRCS, formerly Soil Conservation Service): Hydrologic Soil Group A/B (outwash), C/D (till), or saturated (wetland). While both till and outwash soils are capable of meeting flow control requirements, till soils typically have lower infiltration rates and larger facility sizes may be required. However, ***the minimum design infiltration rate for which Infiltration NDPs (bioretention, pervious pavement) may be used is 0.25~~1~~ inches per hour***, which many till soils may exhibit. For sites with relatively low infiltration rates, it is important to keep the size of the contributing drainage area relatively small with respect to the available footprint for the infiltration BMP. Section D6-03.3 provides Sizing Factors for infiltration BMPs for design infiltration rates ranging from 0.25~~1~~ inches per hour to 1.0 inch per hour or greater. All infiltration rates in Table 6.13 ~~are the~~ represent design infiltration rates (measured infiltration rates ~~after~~with appropriate correction factors ~~are~~ applied).

Refer to Sections D2-06 (Site Planning and Submittals) and D4-06.7 (Infiltration Systems) for methods to be used for identifying site soils and determining the infiltration rates for the native soils. For projects not required to meet runoff treatment or flow control standards, a simplified method for infiltration testing may be used, per D4-06.7(D). See Section D6-03 for on-site BMP sizing.

D6-02.3 Step 2: Site Layout and Use

Development projects that trigger on-site stormwater management must use Smart Site Design practices (Section D6-03.1 B).

In addition to these Smart Site Design practices, site layout and use also includes consideration of setback requirements (Section D4-07) and locating BMPs to take advantage of existing topography and soils. Consideration is also given in this step for where run-on is allowed (e.g., pervious pavement, dispersal areas) and not allowed (e.g., roadways).

D6-02.4 Step 3: Runoff Sources and BMP Selection

In this step, the designer will select appropriate on-site BMPs using Table 6.5. Because development impacts are greatest where impervious surfaces will be created, it is most efficient to first identify the appropriate BMPs to control runoff from each impervious surface on a case-by-case basis. The nature of the runoff source is important in determining the appropriate BMP to use. For example, vegetated roofs are obviously appropriate only for mitigating roof runoff. Runoff from streets or other traffic areas should ideally drain to facilities that can treat runoff.

To use the BMP selection matrix, first divide the proposed site into the various runoff sources: roofs, streets (including parking areas and driveways), pedestrian hardscapes (such as sidewalks), and lawns/landscaping. Then look at the proposed impervious areas (roofs, streets, and sidewalks) and determine if BMPs at the source are possible (e.g., pervious pavement) or where runoff may be conveyed. Finally, for each potential area where runoff can be conveyed, identify the character and use of the receiving location. The BMPs to be considered are summarized in the appropriate cells of the selection matrix. If on-site stormwater BMPs are not feasible due to site limitations and design requirements, return to the appropriate section of Chapters D3, D4 or D5 of these Standards to proceed with standard requirements. This process may be repeated for developed pervious areas (lawns/landscaping) if additional runoff mitigation is required.

Table 6.5. On-site Stormwater BMP Selection Matrix.

Step 1: Characterize Site Infiltration Capabilities Finished Slope/Design Infiltration Rate	Step 2: Site Layout and Use Use of Proposed BMP Location	Step 3: Runoff Sources and BMP Selection Roof	Driveway/ Street/ Parking Lot (not High Vehicle Traffic Area)	Pedestrian/ Bike Hardscape	Landscape or Lawn
0-15% Slope ≥ 0.~~.~~25~~1~~ inch/hour ~~or higher~~ Infiltration	Natural Vegetation[1]	Splash Block, Pop-up Emitter, Sheet Flow Dispersion, Rain Recycling, Minimal Excavation Foundation	Concentrated or Sheet Flow Dispersion	Concentrated or Sheet Flow Dispersion, Reverse Slope Sidewalk	Amended Soils, Concentrated or Sheet Flow Dispersion
	Landscape/Lawn	Roof Downspout Infiltration, Roof Downspout Dispersion, Rain Recycling, Bioretention, Sheet Flow Dispersion, Perforated Stub-out Connection, Minimal Excavation Foundation	Amended Soils, Concentrated or Sheet Flow Dispersion, Bioretention, Pervious Pavement[2]	Amended Soils, Concentrated or Sheet Flow Dispersion, Bioretention, Pervious Pavement[2], Reverse Slope Sidewalk, Minimal Excavation Foundation	Amended Soils, Bioretention, Pervious Pavement[2, 3]
	Pedestrian/Bike	Roof Downspout Infiltration, Pervious Pavement[2], Rain Recycling, Perforated Stub-out Connection	Pervious Pavement[2], Concentrated or Sheet Flow Dispersion	Concentrated or Sheet Flow Dispersion, Pervious Pavement[2]	Pervious Pavement[2]
	Traffic	Roof Downspout Infiltration, Pervious Pavement[2], Rain Recycling	Pervious Pavement[2]	Pervious Pavement[2]	Pervious Pavement[2]
0-15% Slope <0.25~~1~~ inch/hour Infiltration	Natural Vegetation[1]	Splash Block, Pop-up Emitter, Sheet Flow Dispersion, Rain Recycling, Minimal Excavation Foundation	Concentrated or Sheet Flow Dispersion	Concentrated or Sheet Flow Dispersion, Reverse Slope Sidewalk[2]	Amended Soils, Concentrated or Sheet Flow Dispersion
	Landscape/Lawn	Splash Block, Pop-up Emitter, Bioretention, Rain Recycling, Dispersion Trench, Perforated Stub-out Connection	Amended Soils, Concentrated or Sheet Flow Dispersion, Bioretention	Amended Soils, Concentrated or Sheet Flow Dispersion, Bioretention, Reverse Slope Sidewalk[2], Minimal Excavation Foundation	Amended Soils, Concentrated or Sheet Flow Dispersion, Bioretention
	Pedestrian/Bike	Rain Recycling, Perforated Stub-out Connection	Concentrated or Sheet Flow Dispersion	Concentrated or Sheet Flow Dispersion	Not applicable
	Traffic (not high-use site)	Rain Recycling	Not applicable	Not applicable	Not applicable

Table 6.5. On-site Stormwater BMP Selection Matrix.

Step 1: Characterize Site Infiltration Capabilities Finished Slope/Design Infiltration Rate	Step 2: Site Layout and Use Use of Proposed BMP Location	Step 3: Runoff Sources and BMP Selection Roof	 Driveway/ Street/ Parking Lot (not High Vehicle Traffic Area)	 Pedestrian/ Bike Hardscape	 Landscape or Lawn
>15-33% Slope ≥~~All Infiltration Rates~~ ~~greater than or equal to~~ 0.25 ~~inches per hour~~inch/hour infiltration	Natural Vegetation[1]	Splash Block[2], Pop-up Emitter[2], Sheet Flow Dispersion[2], Rain Recycling, Minimal Excavation Foundation	Concentrated or Sheet Flow Dispersion[2]	Concentrated or Sheet Flow Dispersion[2]	Concentrated or Sheet Flow Dispersion[2]
	Landscape/Lawn	Splash Block[2], Pop-up Emitter[2], Rain Recycling, Dispersion Trench[2], Perforated Stub-out Connection[2], Minimal Excavation Foundation	Amended Soils, Concentrated or Sheet Flow Dispersion[2]	Concentrated or Sheet Flow Dispersion[2]	Amended Soils
	Pedestrian/Bike	Rain Recycling, Perforated Stub-out Connection[2]	Concentrated or Sheet Flow Dispersion[2]	Concentrated or Sheet Flow Dispersion[2]	Concentrated or Sheet Flow Dispersion[2]
	Traffic (not high-use site)	Rain Recycling	Not applicable	Not applicable	Not applicable
>33% Slope or High Groundwater	All	Vegetated Roofs, Rain Recycling, and Minimal Excavation Foundation Systems are recommended. Infiltration and dispersion BMPs are prohibited.			
Roof 0-20% with Excess Load Capacity		Vegetated Roof	Not applicable	Not applicable	Not applicable
Roof >20% and/or No Excess Load Capacity		Vegetated Roof prohibited	Not applicable	Not applicable	Not applicable

[1] Natural vegetation areas may not be disturbed for BMP installation, but may be used as vegetated flow paths.

[2] See Section D6-03 for additional slope restrictions.

[3] Grass paving in accordance with Standard Detail NDP-12.

D6-03 DESIGN, SIZING, CONSTRUCTION AND MAINTENANCE

D6-03.1 Required On-Site Stormwater Management Practices

Projects meeting the thresholds in D2-05 shall employ the required On-site Stormwater Management Practices in this section, or other practices approved in writing by DOE as functionally equivalent, to infiltrate, disperse and retain stormwater runoff on site to the maximum extent practicable without causing flooding or erosion impacts.

A. Full Dispersion and Full Infiltration

<u>Description, Applicability and Limitations</u>

Full dispersion should be considered for large residential developments, parks, commercial, and road projects meeting the criteria in the LID Manual, Section 7.2. These criteria generally include substantial native vegetation, long vegetated flow paths, particular soil types, low-volume roads for road projects, deep groundwater, and slope restrictions. Dispersion may be considered for runoff from roofs, pavement, and other impervious surfaces; approved methods for roads include sheet flow or collecting and re-dispersing stormwater.

Sites that can achieve full infiltration per the DOE Manual Volume III, Section 3.3.9, or full dispersion per the DOE Manual Volume V, Chapter 5, BMP T5.30 and Section 7.2 of the LID Manual are not required to provide additional runoff treatment (MR6) or flow control (MR7) facilities.

Design and Sizing

Design and size full dispersion per the DOE Manual, Volume V, Section 5.3.3, BMP T5.30 Full Dispersion, and the LID Manual, Section 7.2.

Full Dispersion credit will be given to sites with a maximum of 10% effective (connected) impervious area that is dispersed through 35 to 65% of the site maintained in natural vegetation and protected with a Native Growth Protection Easement (see LUC 20.25H.030.B.2).

Impervious surfaces that are not fully dispersed should be partially dispersed to the maximum extent practicable. See Section D6-03.4 for hydrologic modeling procedures to be used for determining Flow Control Credits for partial dispersion. Partial Flow Control Credit shall be given for sites that can implement partial dispersion per Section 7.2.3 in the LID Manual or per Section D6-03.4.

Design and size full infiltration per the DOE Manual, Volume III, Chapter 3, as modified herein per Section D4-06.7, Infiltration Systems.

Full infiltration credit towards flow control applies when 100% of the runoff is infiltrated per the DOE Manual, Volume III, Section 3.3.9.

Maintenance

Dispersion facilities shall be maintained per DOE Manual Volume IV, Chapter 2, BMPs for Maintenance of Stormwater Drainage and Treatment Systems.

Infiltration facilities shall be maintained per the Bellevue Maintenance Standards.

B. Smart Site Design

Description and Applicability

When considering site layout, use the principles of BMP T5.21, Better Site Design as described in the DOE Manual, Volume V, Section 5.3.2 to the maximum extent practicable in order to mitigate the development impact on stormwater quantity and quality. Practices include:

- Define Development Envelope and Protected Areas
- Minimize Directly Connected Impervious Areas
- Maximize Permeability
- Build Narrower Streets
- Maximize Choices for Mobility
- Use Drainage as a Design Element

- Comply with LUC 20.20.460, Impervious Surface Limits.

C. Preserve Native Vegetation

Apply BMP T5.20, Preserving Native Vegetation, as described in the DOE Manual, Volume V, Section 5.3.2 and comply with LUC 20.20.900, Significant Tree Retention.

Partial flow credit for retaining or planting trees can be achieved in accordance with the requirements in Section D6-03.4.

D. Amended Soil

Description and Applicability

For all disturbed pervious surfaces, amend soils to meet the specifications of BMP T5.13, Post-Construction Soil Quality and Depth, per the current "Guidelines and Resources for Implementing Soil Quality and Depth BMP T5.13" at www.SoilsforSalmon.org. See Standard Detail NDP-1.

Maintenance

Maintain amended soils per the Bellevue Maintenance Standards.

E. Roof Downspout Infiltration

Description, Applicability and Limitations

Roof downspout infiltration systems can consist of either an infiltration trench or infiltration drywell. They will be considered before other BMPs per Section D6-02, and used wherever site conditions allow, including required setbacks (per D4-07) and without causing flooding or erosion. If site conditions allow infiltration, direct roof runoff to one or more of the following: infiltration trench, infiltration drywell, rain garden, bioretention swale or planter, or pervious pavement. A vegetated roof or rain barrels or rain harvesting cistern may be used in addition, as long as the overflow is directed to one of the BMPs above.

Design and Sizing

Design and size infiltration trenches or drywells and apply Flow Control Credits per Volume III, Sections 3.1.1 and 3.3 of the DOE Manual and Standard Detail D-41. If an alternative NDP is selected, see the appropriate section for design criteria. Sections of the roof that drain to different downspouts may be treated with different Infiltration BMPs.

Maintenance

Maintain infiltration systems per the DOE Manual, Volume III, Section 3.3.11.

F. Roof Downspout Dispersion

Description, Applicability and Limitations

If the site and design criteria for Roof Downspout Infiltration cannot be met as described above, next evaluate the site for Roof Downspout Dispersion.

If the design criteria listed in the DOE Manual for splash blocks (Volume III, Section 3.1.2, Downspout Dispersion Systems) or sheet flow dispersion (Volume V, 5.3.1 Dispersion and Soil Quality BMPs, BMP T5.12) can be met, install one of the following at each downspout: splash block; pop-up emitter; rain barrel(s), rain harvesting cistern or vegetated roof with a splash block at the overflow; or direct roof runoff to a bioretention facility, or pervious pavement. For surfaces that do not have concentrated flows, use Sheet Flow Dispersion per Section D6-03.1(G).

Dispersion trenches should only be considered as an option to manage roof runoff if site and design conditions are not met for any of the BMPs listed prior in Tables 6.2A or 6.2B, whether for a particular downspout or all roof runoff, and a storm stub is not available or is too high.

Design and Sizing

Design splash blocks per the DOE Manual, Volume III, Section 3.1.2 as modified by Section D6-04.7.

Design pop-up emitters per Standard Detail NDP-20 and Section D6-04.6. A maximum of 700 square feet of roof area may drain to each splash block or pop-up emitter. Vegetated flow paths requirements for splash blocks apply to pop-up emitter discharge areas, or runoff can be directed to a bioretention facility. A catch basin or yard drain at the base of the downspout upslope of the pop-up emitter is recommended.

Design dispersion trenches per Standard Detail D-40, and size and apply flow credits per Volume III, Section 3.1.2 of the DOE Manual.

Maintenance

To maintain splash blocks and pop-up emitters, inspect for appropriate placement after a rain event, and if flooding or erosion occurred, regrade or place 2-4” washed rock or river rock at the discharge point if erosion is occurring. Inspect splash blocks and pop-up emitters annually for placement, erosion and flooding, and clear debris from downspouts and gutters. Direct water downslope and away from structures.

Maintain dispersion trenches per Volume IV, Section 2.2 of the DOE Manual. Dispersion trenches shall be provided with access for ongoing maintenance at least three (3) feet in width.

G. Concentrated and Sheet Flow Dispersion

Description, Applicability and Limitations

For impervious surfaces that are not managed using the Roof Downspout techniques above, evaluate the site for the use of Concentrated Flow Dispersion (BMP T5.11) or Sheet Flow Dispersion (BMP T5.12). Evaluate all unmanaged impervious surfaces meeting the criteria in the DOE Manual, Volume V, Section 5.3.1, including sport courts, driveways, roofs without gutters, sloped areas cleared of vegetation, non-native landscaping, or roadways.

Design and Sizing

Design concentrated and sheet flow dispersion and apply flow credits per the DOE Manual, Volume V, Section 5.3.1. Alternatively, partial flow credits per Section D6-03.4 may be applied.

Maintenance

Provide necessary maintenance if erosion or flooding on-site or on downstream properties results.

Contributing impervious areas shall be kept free of oils, soap, and other substances considered Prohibited Discharges per BCC 24.06.125(B).

H. Perforated Stub-out Connection

Description, Applicability, Design and Sizing

If a connection to a storm pipe is being made, and the site meets the design criteria, install a Perforated Stub-out Connection if per the DOE Manual, Volume III, Section 3.1.3. The stub-out connection should be installed between the roof downspouts and the storm drain lot stub if roof downspout infiltration and dispersion are not feasible per above. It should also be installed for any residential or small lot drain or storm facility that has a piped connection to the storm drain lot stub.

Maintenance

Maintain per M2-07, Energy Dissipaters Requirements for Dispersion Trench, Bellevue Maintenance Standards.

Perforated stub-out connections shall be provided with access for ongoing maintenance at least three (3) feet in width.

D6-03.2 Natural Drainage Practices (NDPs)

This section provides a brief description and discussion of the applicability, limitations, design requirements, and sizing for the following NDPs:

- Bioretention – rain gardens, bioretention planters, and bioretention swales
- Pervious Pavement
- Rain Recycling – cisterns and rain barrels
- Vegetated Roof

Other BMPs that DOE approves in writing as functionally equivalent to the NDPs listed here, or that attain DOE’s General Use Level Designation (GULD) rating are also allowed, provided that they are installed per DOE’s requirements.

Maintain NDPs in accordance with the Bellevue Maintenance Standards and/or per manufacturer’s recommendation for BMPs approved by DOE.

A. Bioretention

1. Rain Garden and Bioretention Swale

   Rain gardens are shallow landscaped depressions containing an amended soil mix and native plants that receive stormwater runoff (see Standard Details NDP-2, 6, 7, 8, 9, 10). Rain gardens can be designed to mimic natural conditions, where the soils and plants work together to store, treat, infiltrate, and slow runoff. Rain gardens are a landscape amenity that can be applied in various settings.

Bioretention swales are similar to rain gardens, except that they are typically linear (e.g., narrower and longer than a rain garden, see Standard Detail NDP-3), and the bottom may be sloped. Bioretention swales can be designed with or without underdrains.

i. Applicability

- Residential, commercial, and mixed-use sites such as lawns that receive roof runoff, planter islands in parking lots, and along the sides of roads
- Well-suited to retrofit applications
- Can complement existing landscaping
- For sites with lower infiltration rates, underdrain systems can be installed to accommodate water that exceeds the infiltration capacity of the surrounding soil.

ii. Limitations

- Seasonal high groundwater must be more than 1 foot below the bottom of the rain garden. (Where the depth to groundwater is less than 3 feet below the bottom of the facility, the contributing impervious drainage area must be no greater than 5000 square feet.) Refer to Chapter D4 for methods to evaluate groundwater level.
- Critical Area restrictions may apply.
- Rain gardens and bioretention swales shall meet setback requirements per Chapter D4-07.
- Rain gardens must have relatively flat bottom slopes.
- Bioretention swales must have bottom slopes less than eight (8) percent. Check dams or weirs must be installed for slopes greater than two (2) percent.
- In some situations for bioretention swales, the engineer may specify liners or soil barriers to avoid excessive hydrologic loading to adjacent structures (such as basements, crawl spaces, utilities or steep slopes).

iii. Design Requirements

The following are design requirements and considerations for each component of a rain garden or bioretention swale. Some or all of the components may be used for a given application depending on the site characteristics and restrictions, pollutant loading, and design objectives.

<u>Flow Inlet</u>

- Maximum side slope shall be 25 percent (4:1) where sheet flow enters the facility.
- Absolute maximum side slope shall be 40 percent (2.5:1) for planted slopes. If steeper side slopes are necessary, modular block walls, concrete walls, or geotextile retaining wall systems may be used.

- Inflows from pipes must be protected from erosion using flow energy dissipation (e.g., rock pad, pop-up drainage emitter or flow dispersion weir).

Cell Ponding Area

- The ponding depth shall be a minimum of 2 inches for Single Family Residential lots and a minimum of 6 inches and maximum of 12 inches for non-Single Family Residential projects;
- The minimum bottom width shall be 1 foot.
- Maximum drawdown time for the ponded area shall be 72 hours when flow control is required.

Bioretention Soil

- Imported bioretention soil shall meet the requirements of Section D6-04.1 and shall have a minimum depth (uncompacted) of 12 inches for flow control, or a minimum depth of 18 inches for basic and enhanced water quality treatment or when MR5 only applies.
- If native soil meets the BSM aggregate specification in the Section D6-04.1, it may be amended with compost per the specification rather than importing bioretention soil mix materials.

Underdrain (Optional)

For sites with lower infiltration rates, underdrain systems can be installed in the base of the facility to drain excess stormwater when the infiltration capacity of the surrounding soil is insufficient to meet minimum ponding drawdown time requirements. When specified by the project engineer, the design requirements shall include:

- Slotted, thick-walled plastic pipe or other underdrain materials as specified in Section D6-04.3 shall be used.
- The underdrain shall be placed in the retention zone at least 6 inches above the bottom, and with at least 1 foot of retention zone material above the top of the pipe (i.e., minimum retention zone depth of 22 inches for a 4-inch-diameter pipe and 26 inches for an 8-inch-diameter pipe).
- Retention zone aggregate shall meet specifications in Section D6-04.1 and placed to a minimum uncompacted depth of 12 inches without an underdrain, or 22 inches with an underdrain.

Liner or Soil Barrier for Hydraulic Restriction (Optional)

Adjacent roads, foundations, slopes, utilities, or other infrastructure may require that infiltration pathways are restricted to prevent excessive hydrologic loading. Where clay or geomembrane liners are used for this purpose, underdrain systems are required. Two types of restricting layers can be incorporated into bioretention designs: clay liners or geomembrane liners.

- Clay (bentonite) liners are low permeability soil barriers. When specified by the project engineer, design requirements shall include:
  - Liner thickness shall be 12 inches minimum.
  - Clay shall be compacted to 95% minimum dry density, modified proctor method (ASTM D-1557).
  - A different depth and density sufficient to retard the infiltration rate to 2.4 x 10-5 inches per minute (1 x 10-6 cm/s) may also be used instead of the above criteria.
  - The slope of clay liners must be restricted to 3H: IV for all areas requiring soil cover; otherwise, the soil layer must be stabilized by another method so that soil slippage into the facility does not occur. Any alternative soil stabilization method must take maintenance access into consideration.
  - Where clay liners form the sides of ponds, the interior side slope should not be steeper than 3: 1, irrespective of fencing. This restriction is to ensure that anyone falling into the pond may safely climb out.
- Geomembrane liners completely block flow and are used for groundwater protection when bioretention facilities are used for filtering storm flows from pollutant hotspots. When specified by the project engineer, design requirements shall include:
  - Geomembrane liners shall be ultraviolet (UV) light resistant and have a minimum thickness of 30 mils. A thickness of 40 mils shall be used in areas of maintenance access or where heavy machinery must be operated over the membrane.
  - Geomembranes shall be bedded according to the manufacturer's recommendations.
  - Liners shall be installed so that they can be covered with 12 inches of top dressing forming the bottom and sides of the water quality facility, except for liner sand filters. Top dressing shall consist of 6 inches of crushed rock covered with 6 inches of native soil. The rock layer is to mark the location of the liner for future maintenance operations. As an alternative to crushed rock, 12 inches of native soil may be used if orange plastic “safety fencing” or another highly visible, continuous marker is embedded 6 inches above the membrane.
  - If possible, liners should be of a contrasting color so that maintenance workers are aware of any areas where a liner may have become exposed when maintaining the facility.
  - Geomembrane liners shall not be used on slopes steeper than 5H:1V to prevent the top dressing material from slipping. Textured liners may be used on slopes up to 3H:1V upon recommendation by a geotechnical engineer that the top dressing will be stable for all site conditions, including maintenance.

Plant Materials

Refer to the NDP materials Section D6-04.1.

Mulch Layer

Refer to the NDP materials Section D6-04.1.

Observation Port

An observation port in accordance with Standard Detail NDP-9 shall be installed in each rain garden or bioretention swale cell for projects required to meet runoff treatment (MR6) and/or flow control (MR7). The observation port access may be located either within the ponded area, or offset for access adjacent to the facility.

Native Soil / Subgrade

- Determine the native soil infiltration rate and correction factors to be applied (long-term design infiltration rate or design infiltration rate) in accordance with Section D6-02.2(C) and Section D4-06.7(D).
- The Clearing and Grading plans shall include measures to protect the native soil or subgrade from unnecessary compaction and clogging from sediment during construction.

iv. Sizing

Sizing Factors for rain gardens are provided in Section D6-03.3. These Sizing Factors may be used to size rain gardens to meet on-site stormwater management (MR5) when runoff treatment (MR6) and/or flow control (MR7) are not required. Rain garden Sizing Factors are also provided for runoff treatment and flow control, but those are intended for conceptual design only. The Developer is required to perform independent calculations to size rain gardens and bioretention swales to meet runoff treatment and flow control requirements per Chapter D3 of these Standards. Sizing Factors for bioretention swales are not provided.

When using an approved continuous model to size rain gardens or bioretention swales with the demonstrative approach, the assumptions listed in Table 6.6 shall be applied. Bioretention should be modeled as a layer of soil (with specified infiltration rate and porosity) with ponding, detention via a restricted underdrain (if applicable), infiltration to underlying soil and overflow. The tributary areas, cell bottom area, and ponding depth should be iteratively sized until runoff treatment and/or flow control requirements are met and the maximum surface pool drawdown time of 72 hours is satisfied. The surface pool drawdown time may be estimated as the ponding depth divided by the long-term design infiltration rate. ~~For example, a ponding depth of twelve (12) inches would require a minimum long-term design infiltration rate of 0.17 inches per hour to meet the maximum 72-hour drawdown standard.~~

For cells with longitudinal slopes greater than two (2) percent, the model must account for the effects that slope has on reducing the amount of wetted area that is available for infiltration. This may be done by adjusting the “Bottom Length” and “Effective Total Depth” inputs to the model as shown in Table 6.6, based on the number of cells, maximum ponding depth in each cell, and longitudinal bottom slope of each cell. See Figure 6.2 for a schematic illustration and Table 6.6 for additional details.

The overflow shall be sized for 100-year, 24-hour conveyance.

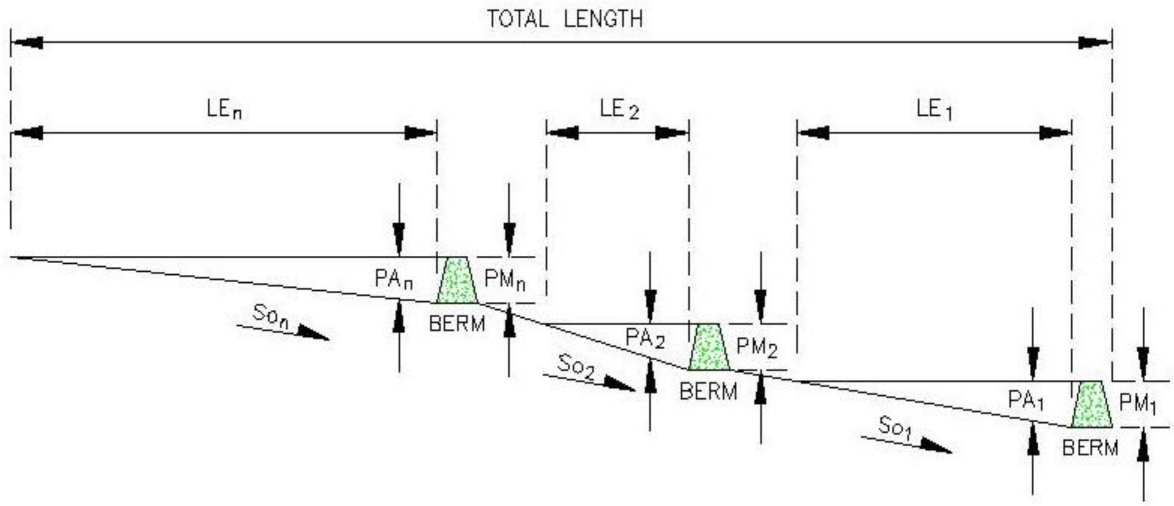

Figure 6.2. Schematic for calculating Bottom Length and Effective Total Depth for bioretention or pervious pavement on slopes where check dams (berms) are used. Refer to Table 6.6 for Rain Gardens and Bioretention Swales, and Table 6.8 for Pervious Pavement formulas.

Table 6.6. Continuous Modeling Assumptions for Rain Gardens and Bioretention Swales.

Variable	Assumption
Precipitation Series	SeaTac 50-year, hourly time series, with appropriate scaling factor based on project location
Computational Time Step	Hourly
Inflows to Facility	Surface flow and interflow from drainage area routed to facility
Precipitation and Evaporation Applied to Facility	Yes
Bottom Length	For longitudinal slopes of 2 percent or less, use actual bottom length based on design plans. For longitudinal slope greater than 2 percent, use the total effective bottom length (LE_{Total}), calculated as: $LE_{Total} = LE_1 + LE_2 + LE_n$ $= PM_1/So_1 + PM_2/So_2 + PM_n/So_n$ Where: n = number of cells LE_n = Effective bottom Length of cell n (ft) PM_n = Maximum ponding depth of cell n (ft) So_n = Bottom Slope of Cell n (ft/ft) The effective bottom length input to the model may be no greater than the actual length based on design. Figure 6.2 provides a schematic illustration of how to estimate this model input based on designs.
Bottom Width	Actual bottom width based on design plans (minimum 1 foot).
Effective Total Depth	Effective Total Depth (ETD) is the distance (in feet) between the bottom of the bioretention soil layer and the top of over-road flooding: ETD = Bioretention Soil Depth + Maximum Ponding Depth + Freeboard + Maximum Depth of Over-Road Flooding For longitudinal slopes of 2 percent or less, use the Maximum Ponding Depth based on design plans. For longitudinal slopes greater than 2 percent, use the Average Maximum Ponding $Depth_{Total}$ (PA_{Total}), calculated as follows: $PA_{Total} = 1/n \times (PA_1 + PA_2 + PA_n)$ $= 1/2n \times (PM_1 + PM_2 + PM_n)$ Where: n = Number of cells

Variable	Assumption
	PA_n = Average ponding depth of cell n (ft) PM_n = Maximum ponding depth of cell n (ft) Freeboard and Maximum Depth of Over-Road Flooding are based on designs. See discussion of the Bioretention Soil Depth input below. Figure 6.2 provides a schematic illustration of how to estimate this model input based on designs.
Bioretention Soil Infiltration Rate	For imported bioretention soil, see specification (Section D6-03.4). For compost amended native soil, rate shall be equal to the native soil design infiltration rate.
Bioretention Soil Porosity	For imported bioretention soil, porosity is 40 percent. For compost amended native soil, porosity is assumed to be 30 percent.
Bioretention Soil Depth	Minimum of 12 inches for flow control, or 18 inches for basic and enhanced water quality treatment.
Native Soil Design Infiltration Rate	Measured infiltration rate with correction factor applied, if applicable
Infiltration Across Wetted Surface Area	Yes if side slopes are 3H:1V or flatter. For steeper side slopes, only infiltration across the bottom area is modeled
Underdrain (optional)	Water stored in the bioretention soil below the underdrain may be allowed to infiltrate
Outlet Structure	Overflow elevation set at maximum ponding elevation (excluding freeboard). May be modeled as weir flow over riser edge or notch. Note that total facility depth (including freeboard) must be sufficient to allow water surface elevation to rise above the overflow elevation to provide sufficient head for discharge.

When flow control is required, either the default method or the demonstrative method can be used to calculate the amount of credit to be attributed to the rain garden or bioretention swale in sizing the downstream flow control facility, as described in Section D3-03. The default method typically results in less Flow Control Credit. The demonstrative method is described above in this section, and involves using the model developed for sizing purposes to also evaluate the amount of residual flow control needed. See Chapter D3 for guidance on hydrologic modeling for sizing flow control and runoff treatment facilities.

2. Bioretention Planter

A bioretention planter is similar to a rain garden or bioretention swale, except that it is typically designed with vertical, impervious walls and an impervious bottom to prevent infiltration or damage to nearby structures. Stormwater enters the surface via a roof downspout pipe and percolates through the bioretention soil mix layer. The treated stormwater is discharged via an underdrain pipe to a storm drainage system, approved storage facility, or dispersal area. Design options are provided in this manual for bioretention planters with and without underdrains and with and without infiltration. The bioretention planter with infiltration is called an "infiltration planter" (see Standard Detail NDP-4A); the bioretention planter without infiltration is referred to as a "flow-through planter" (see Standard Details NDP-4 and 5). Multiple smaller planters are encouraged to manage relatively small drainage areas, rather than one large planter managing larger drainage areas.

i. Applicability

- Flow-through planters may receive roof runoff from residential, commercial, and mixed-use sites.
- Infiltration planters may receive roof runoff from residential, commercial, and mixed-use sites, as well as roadway, parking lot, or other paved surfaces provided that topography allows runoff to reach facility.
- Bioretention planters can be used where space is limited.

ii. Limitations

- For infiltration planters, seasonal high groundwater must be more than 1 foot below the bottom of the facility. (Where the depth to groundwater is less than 3 feet below the bottom of the facility, the contributing impervious drainage area must be no greater than 5000 square feet.)
- Infiltration planters shall meet infiltration BMP setback requirements per D4-07.
- Planters with underdrains will not satisfy MR5 or MR7, but can be designed to satisfy MR6. See Sizing Factors (Section D6-03.3).

iii. Design Requirements

Inlet

- Inflows from pipes should be directed to the top of the facility and protected from erosion using energy dissipation (e.g., rock pad, pop-up emitter, or flow dispersion weir).

Dimensions

- Ponding depth shall be a minimum of 4 inches and a maximum of 12 inches.
- Minimum bottom width shall be 18 inches for flow-through planters.
- Minimum bottom width shall be 30 inches for infiltration planters.
- Maximum drawdown time for the ponded area shall be 72 hours when flow control is required.

Bioretention Soil Mix

- Imported bioretention soil mix must meet the materials specifications in the NDP materials section (D6-04.1) and shall have a minimum depth of 18 inches.

- If native soil meets the aggregate specification in the NDP materials Section D6-04.1, it may be amended with compost per the specification therein rather than importing materials.

Underdrain

For flow-through planters or infiltration planters in locations with lower infiltration rates, underdrain systems can be installed in the base of the facility to drain excess stormwater when the infiltration capacity of the surrounding soil is insufficient to meet minimum ponding drawdown time requirements. When specified by the designer, design requirements shall include:

- Pipe material shall be a thick-walled plastic pipe or another material type listed in D6-04.3 or a type approved by the City.
- Pipe shall have a minimum diameter of three (3) inches and a maximum diameter of eight (8) inches.
- The underdrain shall be placed in the retention zone at least 6 inches above the bottom of the retention zone, and with at least 1 foot of retention zone material above the pipe (i.e., minimum uncompacted retention zone depth of 21 inches for a 3-inch-diameter pipe and 26 inches for an 8-inch-diameter pipe)..
- Retention zone aggregates shall meet requirements per D6-04.1 and shall have a minimum uncompacted depth of one (1) foot without an underdrain, or 21 inches with an underdrain.

Plant Materials

Refer to NDP materials Section D6-04.1 for recommended bioretention plants.

Mulch Layer

Refer to NDP materials Section D6-04.1 for mulch requirements.

Observation Port

An observation port (Standard Detail NDP-9) must be installed in each bioretention planter for projects required to meet runoff treatment and/or flow control, and may be combined with the overflow cleanout.

iv. Sizing

Sizing Factors for bioretention planters are provided in Section D6-03.3. These Sizing Factors may be used size bioretention planters to meet on-site stormwater management (MR5) when runoff treatment (MR6) and/or flow control (MR7) are not required. Sizing Factors are also provided for runoff treatment and flow control, but those are intended for conceptual design only. The Developer is required to perform independent calculations to size and design bioretention planters to meet runoff treatment and flow control requirements per Chapter D3 of these Standards. Note that only infiltration planters are capable of meeting flow control requirements.

When using an approved continuous model to size bioretention planters with the demonstrative approach, the assumptions listed in Table 6.7 shall be applied. The bioretention planter should be modeled as a layer of soil (with specified infiltration rate and porosity) with ponding, detention via a restricted underdrain (if applicable), infiltration to underlying soil (if applicable), and overflow. The tributary areas, planter bottom area, and ponding depth shall be iteratively sized until runoff treatment and flow control requirements are met and the maximum surface pool drawdown time of 72 hours is satisfied. The surface pool drawdown time may be estimated as the ponding depth divided by the long-term design infiltration rate. ~~For example, a ponding depth of twelve (12) inches would require a minimum long-term design infiltration rate of 0.17 inches per hour to meet the maximum 72-hour drawdown requirement.~~

The overflow shall be sized for 100-year, 24-hour conveyance.

Table 6.7. Continuous Modeling Assumptions for Bioretention Planters.

Variable	Assumption
Precipitation Series	SeaTac 50-year, hourly time series, with appropriate scaling factor based on project location
Computational Time Step	Hourly
Inflows to Facility	Surface flow and interflow from drainage area routed to facility
Precipitation and Evaporation Applied to Facility	Yes
Bioretention Soil Infiltration Rate	For imported bioretention soil, see specification (Section D6-03.3). For compost amended native soil, rate shall be equal to the native soil design infiltration rate.
Bioretention Soil Porosity	For imported bioretention soil, porosity is 40 percent. For compost amended native soil, porosity is assumed to be 30 percent.
Bioretention Soil Depth	Minimum of 18 inches for flow control or water quality treatment
Aggregate Porosity	In-place aggregate porosity
Native Soil Design Infiltration Rate (optional)	Measured infiltration rate with correction factor applied, if applicable
Infiltration Across Wetted Surface Area	No, only infiltration across the bottom area is modeled
Underdrain (water quality treatment only)	All water which enters the facility must be routed through the underdrain in situations with no native infiltration. Water stored in the bioretention soil below the underdrain may be allowed to infiltrate in situations where native infiltration is acceptable.
Outlet Structure	Overflow elevation set at maximum ponding elevation (excluding freeboard). May be modeled as weir flow over riser edge or notch. Note that total facility depth (including freeboard) must be sufficient to allow water surface elevation to rise above the overflow elevation to provide sufficient head for discharge

When flow control is required, either the default method or the demonstrative method can be used to calculate the amount of Flow Control Credit to be attributed to the bioretention planter in order to reduce the size of the downstream flow control facility, as described in Section D3-03. The default method typically results in less credit. The demonstrative method is described above in this section, and involves using the model developed for sizing the bioretention planter to also evaluate the amount of residual flow control needed. See Chapter D3 for guidance on hydrologic modeling for sizing flow control and runoff treatment facilities.

B. Pervious Pavement

Pervious pavements are alternatives to conventional pavements (asphalt or concrete) that allow water to pass through the wearing course into a rock reservoir level, where it can infiltrate naturally into the underlying soils (see Standard Detail NDP-11-17). There are many allowed varieties of pervious pavements that fall into three primary categories:

- Asphalt
- Concrete
- Pavers

i. Applicability

- Pervious pavement can be used in areas such as parking lanes along residential streets, low-volume residential drives and access roads, driveways, sidewalks, bike lanes and other paths or trails, emergency and utility maintenance roads, and parking lots that are not High Vehicle Traffic Areas (see Section 3.3.7, Volume III, DOE Manual).
- When pervious pavement is managing its own footprint only (e.g., additional runoff not directed to it), it can be used in areas with design infiltration rates as low as 0.25~~1~~ inches per hour.
- Grass or gravel pavers can be used in recreational or open spaces that are subject to occasional vehicle traffic (e.g., maintenance vehicles or in fire lanes).
- Slopes must be less than five (5) percent for pervious asphalt, six (6) percent for pervious concrete, and ten (10) percent for pervious paver systems. Interceptor infiltration trenches or check dams must be installed for slopes greater than two (2) percent (See Standard Detail NDP-15).

ii. Limitations

- Requires special construction practices to reduce compaction and siltation of the underlying soils.
- If the pervious pavement system will be installed in an area subject to vehicle traffic, the underlying soils must be analyzed by a qualified engineer for load bearing capacity.
- Pervious pavement materials shall be designed by a qualified engineer to provide the required structural support for the intended uses. Certain manufacturers may have pre-engineered systems that do not require additional engineering.

- Pervious concrete shall only be installed by a Certified Pervious Concrete Installer (See National Ready Mix Concrete Association certification program http://www.nrmca.org/certifications/pervious).
- Additional treatment liners functionally equivalent to those in Chapter 4 of Volume V of the DOE Manual may be necessary when used for treatment in highly permeable soils with short-term infiltration rates of greater than 2.4 inches per hour to reduce the potential for groundwater contamination. These treatment liners (layers) would also be needed to satisfy MR6 when underdrains are used.
- Pervious pavement in the right-of-way requires approval. The structural capacity of pavement sections when subject to vehicular loads depends on several factors and must be designed by a licensed professional engineer.
- Susceptible to clogging if receiving runoff from off-site areas (especially where soils are exposed) and if not periodically maintained via vacuum sweeper and other recommended maintenance practices (Section D6-03.5).
- May not be used in High Vehicle Traffic Areas as defined in Section 3.3.7, Volume III of the DOE Manual.
- Must meet setback requirements per D4-07.

iii. Design Requirements

Inlet

Flow diversion and erosion control measures shall protect the pervious pavement area from sedimentation until all upstream catchment areas are thoroughly stabilized.

Pervious Wearing Course

- Materials shall meet those listed in the NDP materials section (D6-04.2).
- Positive surface drainage shall be provided to eliminate risk of ponding on pavement surface (minimum surface slope shall be 0.5 percent).
- Maximum surface slope shall not exceed five (5) percent for pervious asphalt, six (6) percent for pervious concrete, and ten (10) percent for pervious paver systems.
- For grass pavers, the grid shall be filled with sandy loam topsoil mix per Standard Detail NDP-12.
- For pervious driveways, slope surface to direct drainage away from structures or direct water away using a trench drain.

Leveling Course

- A leveling course shall be included when required by the designer or in accordance with the manufacturer's recommendations for proprietary products.

Reservoir Course

- Reservoir course aggregate depth shall be a minimum of 6 inches (placed) for pervious pavement, or 4 inches for pervious paver systems beneath the pervious

wearing course (and leveling course when used) for water storage, or a minimum of 22 inches (compacted) if an underdrain is used.
- Materials shall meet the specifications of Section D6-04.2. Thoroughly washed aggregate is recommended to limit the amount of fines in the delivered stone.
- The reservoir course shall have a minimum total void volume of 20 percent after being compacted in place.
- When the slope exceeds 2 percent, design shall include an interceptor infiltration trench or check dams to create subsurface ponding per Standard Detail NDP-15.
- The maximum ponding elevation shall be 6 inches below the top of the wearing course to prevent degradation from repeated freeze-thaw.
- Slope bottom of reservoir course away from structures.

Underdrain (Optional)

An underdrain system shall be installed in the base of the facility if necessary to accommodate water that exceeds the infiltration capacity of the underlying native soil. When included, minimum design requirements shall include:
- Underdrain shall consist of slotted, thick-walled plastic pipe or other approved underdrain pipe per the NDP materials Section D6-04.3.
- Pipe shall have a minimum diameter of 4 inches and a maximum diameter of 8 inches.
- Underdrain shall be placed in the Reservoir Course at least 6 inches above the bottom, and with at least 1 foot of Reservoir Course material above the top of the pipe (i.e., minimum Reservoir Course depth of 22 inches for a 4-inch-diameter pipe and 26 inches for an 8-inch-diameter pipe).

Geotextile (Optional)

Geotextile can be installed if necessary to prevent the migration of fines from the native soil into the reservoir course. When specified by the designer, geotextile fabric shall:

- Be in accordance with the NDP materials specifications in Section D6-04.2.
- Be placed between the reservoir course and runoff treatment layer or subgrade.
- Wrap around and over reservoir course and secure.
- Pass water at a rate greater than the infiltration rate of the existing subgrade.

Runoff Treatment Layer (Optional)

When permeable pavement is designed to provide water quality treatment, the native underlying soils must meet the *Soil Physical and Chemical Suitability for Treatment* requirements in Section 3.3.7 of Volume III of the DOE Manual. When the native soils cannot meet those requirements, a "treatment liner" shall be installed that is functionally equivalent to Section 4.4.2 of Volume V of the DOE Manual.

Native Soil / Subgrade

- The correction factor used to calculate the design infiltration rate shall consider compaction of the native soil or subgrade during construction.

- Determine the native soil infiltration rate and correction factors (long-term design infiltration rate) in accordance with Sections D6-02.2 C and D4-06.7(D).
- Clearing and Grading plans shall include instructions to protect the native soil or subgrade from unnecessary compaction and clogging from sediment during construction.

Observation Port

An observation port in accordance with Standard Details NDP-16 and NDP-17 shall be installed in the furthest downslope area for every 10,000 square feet of pervious pavement area for projects required to meet MR6 and/or 7.

Maintenance

Provide minimum 8 (eight) feet minimum width access for ongoing maintenance.

iv. Sizing

If the pervious pavement area will not receive runoff from another impervious or pervious area, it should be built according to the design criteria above to meet the minimum requirements for on-site stormwater management (MR5). Sizing Factors for pervious pavement are provided in Section D6-03.3. These Sizing Factors may be used to size pervious pavement to meet MR5 when runoff treatment and/or flow control are not also required, and when pervious pavement area will receive stormwater runoff from a different pervious or impervious area, such as a roof. Sizing Factors are also provided for runoff treatment and flow control, but those are intended for conceptual design only. The Developer is required to perform independent calculations for sizing and designing pervious pavement to meet runoff treatment and flow control requirements per Chapter D3 of these Standards.

When an approved continuous model is used to size pervious pavement with the demonstrative approach, the assumptions listed in Table 6.8 shall be applied. Pervious pavement should be modeled as an impervious area with runoff routed to a gravel-filled infiltration trench (of the same surface area). The tributary areas (including off-site tributary areas, if any), pavement area, and average water surface depth in the aggregate should be iteratively sized until runoff treatment and/or flow control requirements are met. For pervious pavement facilities with longitudinal slopes greater than two (2) percent, the model must account for the effects that slope has on reducing the amount of wetted area that is available for infiltration. This may be done by adjusting the “Gravel Trench Bottom Length” and “Effective Total Depth” inputs to the model as shown in Table 6.8, based on the number of interceptor infiltration trenches or check dams, maximum ponding depth in each cell, and longitudinal bottom slope of each cell. See Figure 6.2 for a schematic illustration and Table 6.8 for more detailed guidance.

Table 6.8. Continuous Modeling Assumptions for Pervious Pavement.

Variable	Assumption
Precipitation Series	SeaTac 50-year, hourly time series, with appropriate scaling factor based on project location
Computational Time Step	Hourly
Inflows to Facility	Model pavement area as impervious basin routed to a gravel-filled trench with infiltration to underlying soil
Precipitation Applied to Facility	No. Precipitation is applied to the contributing basin before being routing to the trench
Evaporation Applied to Facility	Yes. While evaporation is applied to the impervious basin before routing to the trench, additional evaporation occurs when water is stored in the storage reservoir
Gravel Trench Bottom Length	For longitudinal slopes up to 2 percent, use actual bottom length based on design plans. For longitudinal slopes greater than 2 percent, use the total effective bottom length (LE_{Total}), calculated as: $LE_{Total} = LE_1 + LE_2 + \ldots + LE_n$ $= PM_1/So_1 + PM_2/So_2 + \ldots + PM_n/So_n$ Where: n = Number of Cells LE_n = Effective Bottom Length of Cell n (ft) PM_n = Maximum Ponding Depth of Cell n (ft) So_n = Bottom Slope of Cell n (ft/ft) The effective bottom length input to the model may be no greater than the actual length based on design. Figure 6.2 provides a schematic illustration of how to estimate this model input based on designs.
Gravel Trench Bottom Width	Actual bottom width based on design plans.
Effective Total Depth	Effective Total Depth (ETD) is the Maximum Ponding Depth plus one foot of freeboard above the top of the riser: For longitudinal slopes less than 2 percent, evaluate the Maximum Ponding Depth based on design plans. For longitudinal slopes greater than 2 percent, use the Average Maximum Ponding $Depth_{Total}$ (PA_{Total}), calculated as follows: $PA_{Total} = 1/n \times (PA_1 + PA_2 + \ldots + PA_n)$ $= 1/2n \times (PM_1 + PM_2 + \ldots + PM_n)$ Where: n = Number of Cells

Variable	Assumption
	PA_n = Average Ponding Depth of Cell n (ft) PM_n = Maximum Ponding Depth of Cell n (ft) Figure 6.2 provides a schematic illustration of how to estimate this model input based on designs.
Reservoir Course Depth	Average maximum subsurface water ponding depth in the storage reservoir (averaged across the facility) before berm overtopping or overflow occurs.
Reservoir Course Porosity	Assume maximum 20 percent unless test is provided showing higher porosity for aggregate compacted and in place
Native Soil Design Infiltration Rate	Measured infiltration rate with correction factor applied, if applicable
Infiltration Across Wetted Surface Area	No. Only infiltration across the bottom area is modeled
Underdrain (optional)	If underdrain is placed at bottom extent of the reservoir course, all water which enters the facility must be routed through the underdrain (e.g., no infiltration). If there is no liner or impermeable layer and the underdrain is elevated within the storage reservoir, water stored in the reservoir below the underdrain is allowed to infiltrate.
Outlet Structure	Overflow elevation set at average maximum subsurface ponding depth. May be modeled as weir flow over riser edge or notch. Note that freeboard must be sufficient to allow water surface elevation to rise above the overflow elevation to provide sufficient head for discharge.

When downstream flow control is required, either the default method or the demonstrative method can be used to calculate the amount of credit to be attributed to the pervious pavement in order to reduce the size of the downstream flow control facility, as described in Section D3-03. The default method typically results in less credit. The demonstrative method is described above in this section, and involves using the model developed for sizing the pervious pavement to also evaluate the amount of residual flow control needed. See Chapter D3 for guidance on hydrologic modeling for sizing flow control and runoff treatment facilities.

C. Rain Recycling

Rain recycling consists of capturing roof runoff and storing it for either later use or slow release to the surrounding landscaping (see Standard Details NDP-18 and 19). The primary components of a rain recycling system are the collection system (downspouts), a storage tank (rain barrel or cistern), and a dispersion system (pipes, hoses, or trenches), as in Standard Details NDP-18, NDP-19 and NDP-20.

Rainwater harvest for reuse can be accomplished with either rain barrels or cisterns. Cisterns are larger than rain barrels and can hold a greater volume of rainwater, or several rain barrels can be linked together to achieve the desired storage volume for rainwater reuse on-site. Cisterns with detention can be used for on-site stormwater management (MR5) or flow control (MR7) in addition to rainwater harvest and reuse.

i. Applicability

- Storage for irrigating landscaped areas near buildings, carports, sheds, or other structures
- Optimum reduction in runoff achieved when the overflow is directed to a rain garden, bioretention swale, or other on-site stormwater management BMP
- Indoor use of recycled water is allowed per the Uniform Plumbing Code, as described in the Seattle King County Department of Public Health's "Rainwater Harvesting and Connection to Plumbing Fixtures" (January 30, 2007 or current), and requires a plumbing permit.
- Can be used in residential or non-residential applications.

ii. Limitations

- The watered landscaped area should ideally be at least one half the area of the roof being collected
- Storage tanks must drain within 72 hours after a storm event, unless sealed against entry by mosquitoes (openings must be smaller than 1/16-inch)

iii. Design Requirements

Catchment Area / Collection System

A roof catchment area collection system includes the gutters, downspouts, piping, and any other conveyance needed to route water to the rain barrel(s) or cistern. The roof catchment area must be clearly delineated on the Plans.

Leaf/Rock Screen

A filter screen or other debris barrier is required to prevent insects, leaves, and other larger debris from entering the system. A self-cleaning inlet filter is recommended.

Cistern / Rain Barrel

- All cisterns or rain barrels must be installed in accordance with manufacturer's installation instructions and the building code.
- Screen all opening locations adequately to prevent mosquitoes and other life forms from entering the system.
- Latch or lock covers to prevent wildlife and unauthorized human access into storage tanks.
- Opaque containers must be used for aboveground cisterns and rain barrels to minimize algae growth.
- Underground cisterns must be designed by an engineer.

- If an electric water pump is installed, an electrical permit is required, and a reduced pressure principle backflow assembly is required on the customer side of the water meter.
- The overflow conveyance capacity must be no less than the capacity of the inflow pipe or downspout.
- Connections to potable water systems or appliances require a reduced pressure backflow assembly and must comply with the Uniform Plumbing Code.

Low Flow Orifice for Cisterns with Detention

- The minimum diameter shall be 0.25 inches for orifices located above ground. This is the only exception to the minimum orifice size in Section D4-06.4(C), and these systems shall have screens to prevent debris from clogging the orifice. The minimum diameter shall be 0.5 inches for orifices located below ground.
- The low flow orifice invert must be at least 3 inches above the bottom of the cistern to prevent entraining sediment.

Overflow

Overflows shall be designed to convey excess flow to an additional tank, on-site stormwater management BMP, or discharge appropriately away from any structures, on-site sewage systems, wells, or steep slopes, and shall not cause erosion or flooding on-site or on downstream properties.

iv. Sizing

To receive Flow Control Credit for rain recycling with either rain barrels or cisterns, runoff reduction must be demonstrated by a water balance model indicating the amount of rooftop runoff, the amount of harvested water that will be used, and the amount of overflows from the rain recycling system. A spreadsheet-based modeling tool may be used for this purpose.

The minimum time step to be used in the water balance model shall be one (1) day so that the timing, magnitude, and duration of overflows are considered in sizing residual detention to meet flow control requirements for the site, when needed, or to size overflow conveyance systems to properly route flows away from structures. The assumptions to be used in the water balance model are summarized in Table 6.9.

Table 6.9. Spreadsheet-Based Modeling Assumptions for Rain Barrels or Cisterns with Water Reuse.

Variable	Assumption
Precipitation Series	Obtain at least the last 10 years of historical rainfall data from SeaTac or other approved station. A daily (or finer) time step must be used
Computational Time Step	Daily (or finer)
Inflows to Facility	Daily (or finer) rainfall volume assumed to equal daily (or finer) inflow to the facility. This neglects abstraction or evaporation that may occur on the roof surface.
Storage	Available storage volume in rain barrel or cistern tanks below the overflow invert elevation
Water Reuse	Daily (or finer) cumulative outflows corresponding with irrigation, outdoor cleaning, indoor plumbing, or any other water use demands
Overflow	To be solved for in the model on a daily (or finer) time step

Rain Barrel

Flow Control Credits for rain barrels are provided in Section D6-03.4.

Cisterns with Detention

Sizing Factors for cisterns are provided in Section D6-03.4 for meeting on-site stormwater management (MR5) and flow control (MR7) requirements. Sizing factors for flow control are intended for conceptual design only. The Developer is required to show independent calculations used to size and design cisterns to meet flow control requirements.

For the demonstrative approach, continuous modeling shall be used to size the cisterns. The assumptions listed in Table 6.10 shall be used. The cisterns are modeled as a flat-bottomed detention vault or tank with an outlet structure that includes a low flow orifice. Tributary areas, detention bottom area, overflow depth, and orifice configuration should be iteratively sized until flow control is met or the desired reduction in downstream conveyance and flow control facilities is achieved.

Table 6.10. Continuous Modeling Assumptions for Cisterns with Detention.

Variable	Assumption
Precipitation Series	SeaTac 50-year, hourly time series, with appropriate scaling factor based on project location
Computational Time Step	Hourly
Inflows to Facility	Surface flow and interflow from drainage area should be connected to facility
Precipitation and Evaporation Applied to Facility	No
Infiltration	No
Total Depth	The total depth is the cistern height (including freeboard) above the cistern bottom
Outlet Structure	Low flow orifice, riser height and diameter
Overflow	The top of the overflow orifice should be set a minimum of 6 inches below the top of the cistern
Low Flow Orifice	Invert of low flow orifice should be set at a minimum of 3 inches above the bottom of the cistern

D. Vegetated Roof

Vegetative roofs are gently sloped roofs covered with soil and planted with vegetation in place of conventional roofing material. These roofs may be either intensive designs with soils 6 inches or deeper, multiple uses, and more garden plant varieties or extensive designs with shallow, lightweight soils less than 6 inches in depth and more drought-tolerant groundcover plants. Green roofs can be either “single-course,” consisting of a single media designed to be freely draining and support plant growth, or “multi-course,” which includes both a growth media layer and a separate, underlying drainage layer. Commercially available modular systems consisting of prefabricated trays filled with growing media are considered multi-course systems.

i. Applicability

- Effective stormwater management strategy in high-density urban areas and/or zero lot line situations.
- Energy-conservation-conscious developments.
- Retrofitting existing roofs with excess structural capacity.

ii. Limitations

- The Developer shall demonstrate that all design components have been addressed by experienced and qualified professionals, including loading, structural, waterproofing, fire resistance, and horticultural considerations.
- Requires careful construction practices by an experienced vegetated roof contractor.

  - May require irrigation and routine maintenance.
  - May require additional insurance.
  - Maximum roof slope of 20 percent.

iii. Design Requirements

Waterproof Membrane

A waterproof membrane is required for all vegetated roof designs.

Root Barrier

- A root barrier shall be included in the vegetated roof design
- When waterproofing membrane is also to provide a root barrier function, provide supporting manufacturer documentation with submittal
- Root barrier shall not contain leachable water quality contaminants (e.g., herbicides, copper, and zinc)

Drainage Layer

- Intensive and extensive vegetated roofs shall include a drainage layer
- The aggregate for the drainage layer shall meet the following minimum requirements:
  - Minimum total pore volume of 25 percent by volume (per ASTM E2399)
  - Minimum saturated hydraulic conductivity of 425 inches per hour (per ASTM E2396-05)
  - Maximum total organic matter of one (1) percent by mass (per loss-on-ignition test)

Separation Fabric

- On all intensive and extensive vegetated roofs, separation fabric shall be installed to separate the growth media from the drainage layer, roof edges, penetrations, structures, and all surrounding areas.
- Separation fabric shall be a non-woven geotextile.
- Fabric shall have an average opening size sufficient to retain media.
- Fabric shall have permissivity sufficient to pass the anticipated peak rainfall intensity.

Growth Medium (Soil)

- The growth medium shall be a minimum of four (4) inches deep, and have the following characteristics:
  - Minimum total pore volume shall be 45 percent by volume for multi-course systems and 30 percent by volume for single-course systems (per ASTM E2399).

  - Water capacity shall be no less than 25 percent for single-course systems, 35 percent for extensive (shallow) multi-course systems, and 45 percent for intensive (deep) multi-course systems (per ASTM E2399).
  - Saturated hydraulic conductivity (permeability) shall be between 14 and 1,200 inches per hour for single-course systems and 2.8 and 28 inches per hour for multi-course systems (per ASTM E2396-05).
  - Minimum air content at maximum water capacity shall be 5 percent by volume (per ASTM E2396-05).
  - Maximum total organic matter shall be four (4) percent by mass for single-course systems, six (6) percent by mass for extensive (shallow) multi-course systems, and eight (8) percent by mass for intensive (deep) multi-course systems (per loss-on-ignition test).
- Growth media depth and characteristics must support growth for the plant species selected and shall be approved by a certified landscape architect.
- Vegetated roofs must not be subject to any use that will significantly compact the growth medium.
- Vegetated roof areas that are accessible to the public shall be protected (e.g., signs, railing, and fencing), and areas designed for foot traffic shall meet Building Code requirements.
- Mulch, mat, or other measures to control erosion of growth media shall be maintained until 90 percent vegetation foliage coverage is attained.
- To increase flow control, consider designing the growth media with a water holding capacity on the high end of the specified range and a saturated hydraulic conductivity on the low end of the specified range.

<u>Vegetation</u>

- Vegetation foliage of the selected plants shall attain 90 percent coverage of the vegetated roof surface area within 2 years or additional plantings shall be provided until this coverage requirement is met.
- Plant spacing and plant size shall be designed to achieve specified coverage by a certified landscape architect.
- Vegetation shall be suited to harsh (e.g., hot, cold, wet and windy) rooftop conditions (see plant list in NDP Materials, Section D6-04.8).
- Plants shall not require fertilizer, pesticides or herbicides after the 2-year establishment period has ended.
- The Developer shall develop and implement a Landscape Management Plan to be submitted as part of the Operations and Maintenance Manual per Chapter D2.

<u>Irrigation Plan</u>

Minimum design requirements are as follows:

- Provisions shall be made for irrigation during the first two growing seasons following installation.
- Sufficient irrigation shall be provided to achieve and maintain 90 percent plant coverage after 2 years following installation.
- Irrigation design shall be included in the Landscape Management Plan.

Drain System

Vegetated roofs shall include a drain system capable of safely collecting and conveying water to an approved discharge point.

Structural Roof Support

Structural considerations for vegetated roofs shall include roof slope, design loads (including loads due to ponding), slipping and shear considerations, wind load, snow load, seismic load, and fire resistance. All vegetated roof structural designs must be prepared or stamped by a structural engineer.

iv. Sizing

Flow Control Credits for vegetated roofs are provided in Section D6-03.4. These Flow Control Credits may be used for small sites with 10,000 square feet of contributing impervious or less. When using continuous modeling to size vegetated roofs with a demonstrative approach, the assumptions listed in Table 6.11 shall be applied. Vegetated roofs should be modeled as layers of aggregate with surface flows, interflow, and exfiltrating flow routed to an outlet.

Table 6.11. Continuous Modeling Assumptions for Vegetated Roofs.

Variable	Assumption
Precipitation Series	SeaTac 50-year, hourly time series, with appropriate scaling factor based on project location
Computational Time Step	Hourly
Inflows to Facility	None
Precipitation and Evaporation Applied to Facility	Yes
Depth of Material (inches)	Growth medium/soil depth (minimum of 4 inches). Depth of underlying aggregate drainage layer, if any, is neglected.
Vegetative Cover	Ground cover or shrubs. Shrubs are appropriate only when growth medium is at least 6 inches.
Length of Rooftop (ft)	The length of the surface flow path to the roof drain
Slope of Rooftop (ft/ft)	Flat slope should be set to a minimum slope of 0.001 V:1 H (1,000H:1V)
Discharge from Facility	Surface flow, interflow and exfiltrated flow (groundwater) routed to point of compliance

E. Reverse Slope Sidewalk

Reverse slope sidewalks are standard concrete or asphalt pavement sidewalks which are sloped to drain away from the road and onto adjacent vegetated areas (see Standard Details NDP-21 and TE-11).

i. Applicability

- Public transportation projects with frontage on parks, open space, or vegetated areas.
- Public or private walks with adjacent vegetated areas.

ii. Limitations

- Critical Area restrictions may apply.
- Public transportation projects must have sufficient right-of-way, easement, or adjacent city-owned property to accommodate the full required width of the vegetated area.
- Private projects may require agreement from the adjacent property owner to allow unconcentrated sheetflow runoff from the surface of the reverse slope sidewalk (only) to flow onto the vegetated area, if applicable.

iii. Design Requirements

- The maximum width of the reverse slope sidewalk shall be 6 feet.
- The cross slope of the reverse slope sidewalk shall be 2 percent.
- The maximum longitudinal slope of the reverse slope sidewalk shall be 10 percent.
- Runoff from the reverse slope sidewalk must sheetflow to an adjacent downslope vegetated surface that is at least 10 feet wide and not directly connected into the storm drainage system.
- Vegetated area must be native soil or meet guidelines in BMP T5.13 of the DOE Manual Volume 5, Section 5.3.1.
- Vegetated area shall have a maximum slope of 8 percent (perpendicular to the alignment of the reverse slope sidewalk, see Standard Detail NDP-21).
- The shoulder on the downslope side of the reverse slope sidewalk shall be no greater than 1 foot wide.
- Reverse slope sidewalks shall be designed in accordance with the above requirements and standard sidewalk design requirements (see Standard Detail TE-11).

iv. Sizing

When flow control is required, the assumptions listed in Table 6.12 can be used to calculate the amount of credit to be attributed to the reverse slope sidewalk in sizing the downstream flow control facility. See Chapter D3 for guidance on hydrologic modeling for sizing flow control and runoff treatment facilities.

Table 6.12. Continuous Modeling Assumptions for Reverse Slope Sidewalks.

Variable	Assumption
Precipitation Series	SeaTac 50-year, hourly time series, with appropriate scaling factor based on project location
Computational Time Step	Hourly
Land Use Input for Reverse Slope Sidewalk	Landscaped area on underlying soil with flat or moderate slope, based on site conditions

F. Minimal Excavation Foundation Systems

Minimal excavation foundation systems are defined as foundations that minimize disturbance to the natural soil profile within the footprint of the structure. This preserves most of the hydrologic properties of the native soil. Minimal excavation foundation systems are generally a combination of driven piles and a connection component at, or above, grade. The piles allow the foundation system to reach or engage deep load-bearing soils without having to dig out and disrupt upper soil layers, which infiltrate, store and filter stormwater flows. Pin foundations are an example of a minimal excavation foundation system.

i. Applicability

- Pier and perimeter wall configurations for residential or commercial structures up to three stories high.
- Elevated paths and foot-bridges in environmentally sensitive areas.
- Can be installed on Hydrologic Soil Group A/B (outwash) and C/D (till) soils provided that the material is penetrable and will support the intended type of piles.
- Wall configurations are typically used on sites with slopes up to 10 percent, and pier configurations are typically used on sites with slopes up to 30 percent.

v. Limitations

- Prior to design, the site soils must be reviewed and described by a licensed geotechnical engineer, unless exempt by the City's Plan Review Department.
- The structure shall be designed by a Washington State licensed architect or engineer specifying lateral load connections to the foundation system. Certain manufacturers may have pre-engineered systems that do not require additional engineering for smaller projects, such as decks, walkways, and exterior stairways.
- Design calculations, a lateral load analysis and foundation specifications shall be submitted by the Developer with the building permit application.

- During construction, heavy equipment cannot be used within or immediately surrounding the building. Terracing of the foundation may be accomplished by tracked, blading equipment not exceeding 650 psf.
- Construction must be in compliance with the selected product listing.

vi. Design Requirements

- On relatively flat sites (i.e. less than 5 percent slope), grading shall be limited to knocking down the highs and lows to provide a better working surface. The top organic duff layer shall not be removed from the site. Re-distribute the organic duff evenly over the site after grading activities are complete.
- On sloped sites (i.e. between 5 percent and 30 percent slope), the soils may be graded smooth (knocking down superficial highs and lows) at their existing slope to provide a better working surface to receive pier systems, pre-cast walls, or slope cut forms for pouring continuous walls.
- To minimize the soil disturbed on sloped sites with terraces, the width of each terrace must be limited to the width of the equipment blade.
- A free draining, compressible buffer material (pea gravel, corrugated vinyl or foam product) shall be placed on the surface soils to prepare the site for placement of pre-cast or site poured wall components. This buffer material separates the base of the grade beam from the surface of the soil to prevent compaction from expansion or frost heave, and in some cases is employed to allow the movement of the saturated flows under the beam or wall.
- Where possible, roof runoff must be infiltrated or dispersed upslope of the structure to take advantage of infiltration and subsurface storage areas that would otherwise be lost in construction and placement of conventional “dug-in” foundation systems. Passive gravity systems for dispersing roof runoff are preferred; however, active systems may be used if back-up power sources are incorporated and a consistent manageable maintenance program is ensured.
- See Section 6.5 of the LID Manual for additional design information.

vii. Sizing

- Where roof runoff is dispersed on the up gradient side of a structure in accordance with the design criteria in “Roof Downspout Dispersion” (Section D6-03.1(F)), model the tributary roof area as pasture on the native soil.
- Where terracing or “step forming” is used on a slope, the square footage of roof that can be modeled as pasture must be reduced to account for lost soils. In “step forming,” the building area is terraced in cuts of limited depth. This results in a series of level plateaus on which to erect the form boards. The following equation can be used to reduce the roof area that can be modeled as pasture:

  A1 – (dC X 0.5)/dP X A1 = A2

  Where:

A1 = roof area draining to up gradient side of structure

dC = average depth of cut into the soil profile

dP = average permeable depth of soil over the dispersion area (the A horizon plus an additional few inches of the B horizon where roots permeate into ample pore space of soil).

A2 = roof area that can be modeled as pasture on the native soil

- If roof runoff is dispersed down gradient of the structure in accordance with the design criteria and guidelines in "Roof Downspout Dispersion" (Section D6-03.1(F)), and there is at least 50 feet of vegetated flow path through native material or lawn/landscape area that meets the guidelines in "Amended Soil" (Section D6-03.1(D)), model the tributary roof areas as landscaped area.
- Runoff dispersed up gradient of a garage slab, monolithic poured patio, or driveway may not be included as applicable infiltration areas for these systems.

D6-03.3 Sizing Factors for On-site Stormwater BMPs

Sizing Factors may be used to simplify the design and review of on-site BMPs sized to meet on-site stormwater management (MR5) when runoff treatment and/or flow control are not required. When used for this purpose, these Sizing Factors can be used by the Developer without an engineer. Sizing Factors are also presented for runoff treatment and flow control to provide general guidance for conceptual design only. The Sizing Factors are presented in Table 6.13 (Section D6-03.3 C).

A. Applicability

Sizing Factors may not be used to assign partial credit for on-site facilities towards flow control or runoff treatment requirements.

Generalized assumptions were used to develop the Sizing Factors that may result in conservative sizing for some sites. Developers have the option to use the Sizing Factors provided in this section, or to follow an engineered sizing approach (Section D6-03.2) and submit an alternative facility size with supporting engineering calculations for review.

The required BMP may be sized for on-site stormwater management only when flow control and treatment are not required using the Sizing Factors provided in Table 6.13. For most BMPs, Sizing Factors are used to calculate the BMP bottom surface area, as follows:

BMP Area = Contributing Impervious Area x Sizing Factor (%)/100

Cistern and infiltration trenches represent exceptions, for which the sizing factors are used to calculate the required infiltration trench length (in feet) or cistern volume (in gallons), respectively.

Example:

To size a rain garden without an underdrain to meet Minimum Requirement 5 with six (6) inches of ponding storage depth at a site with a native soil design infiltration rate of 0.25 inches per hour, use the Sizing Factor of 8.6 percent from Table 6.13. If this rain garden were being sized to manage 10,000 square feet of impervious surface area, the required bottom footprint area would be 860 square feet. The top footprint area would depend on the total depth and side slopes of the rain garden.

In order to use these Sizing Factors, the BMP must meet all of the specific design requirements (e.g., side slopes, freeboard, soil characteristics, gravel depth) in accordance with Section D6-03.1 or D6-03.2 and the respective Standard Detail.

Developers may linearly interpolate between the design depths evaluated. However, design infiltration rates for the native soils must be rounded down to the nearest rate in Table 6.13.

B. Implementation

The following describes how the Sizing Factors are to be used to size on-site stormwater management BMPs.

i. Roof Downspout Infiltration Trench

Sizing Factors for roof infiltration trenches receiving runoff from an impervious surface are provided in Table 6.13. Factors are organized by MR and native soil type. Infiltration trenches are sized by linear feet required for a given contributing area, rather than by bottom footprint area (in square feet) required. ***To use these Sizing Factors, the roof infiltration trench must meet the general requirements outlined in the DOE Manual Volume III, Section 3.3.11.***

ii. Rain Gardens

Sizing Factors for rain gardens (with and without underdrains) receiving runoff from an impervious surface are provided in Table 6.13. Factors are organized by MR, facility ponding depth, and native soil design infiltration rate. A 6- or 12-inch facility ponding depth may be selected. The design rate for the native soils must be rounded down to the nearest design infiltration rate in Table 6.13. ***To use these Sizing Factors, the rain garden must meet the design requirements for rain gardens outlined in Section D6-03.2 plus the following specific requirements:***

- Bottom area shall be sized using the applicable sizing factor
- Bottom area shall be no more than two (2) percent slope
- When an underdrain is used, the diameter shall be eight (8) inches and the gravel backfill depth shall be a minimum of 26 inches (porosity = 0.35)
- Side slopes within ponded area shall be no steeper than 2.5H:1V
- Bioretention soil mix shall have an infiltration rate of at least 2.5 inches per hour (porosity = 0.4)
- Bioretention soil mix depth shall be a minimum of 18 inches for on-site stormwater management and runoff treatment

- Minimum ponding depth shall be set at the designated height (6 inches or 12 inches). For intermediate ponding depths (between 6 and 12 inches), a Sizing Factor may be linearly interpolated.

iii. Bioretention Planters

Sizing Factors for bioretention planters receiving runoff from an impervious surface are provided in Table 6.13. Factors are organized by MR, facility ponding depth, and native soil design infiltration rate. A 6- or 12-inch facility ponding depth may be selected. For infiltration planters, the design rate for the native soils must be rounded down to the nearest design infiltration rate in Table 6.13. Planters with underdrains can only be used to meet requirements for basic or enhanced treatment (MR6). Infiltration planters can be used to meet MR5, 6, and 7. ***To use these Sizing Factors, the bioretention planter must meet the design requirements outlined in Section 6-03.2 plus the following specific requirements:***

- The bioretention planter area shall be sized using the applicable sizing factor
- Bottom area shall be flat (0 percent slope)
- The underdrain diameter shall be 8 inches
- Vertical side slopes
- Bioretention soil mix shall have an infiltration rate of at least 2.5 inches per hour (porosity = 0.4)
- Bioretention soil mix depth shall be a minimum of 18 inches for runoff treatment
- Gravel depth shall be a minimum of 26 inches (porosity = 0.35)
- Freeboard shall be 4 inches or greater
- Minimum ponding depth shall be set at the designated height (6 inches or 12 inches). For intermediate ponding depths (between 6 and 12 inches), a Sizing Factor may be linearly interpolated.

iv. Pervious Pavement

Sizing Factors for pervious pavement receiving runoff from an impervious surface are provided in Table 6.13. Factors are organized by MR and native soil design infiltration rate. The design rate for the native soils must be rounded down to the nearest design infiltration rate in Table 6.13. ***To use these Sizing Factors, the pervious pavement must meet the design requirements for pervious pavement outlined in Section 6-03.2 plus the following specific requirements:***

- The pervious pavement area shall be sized using the applicable sizing factor.
- The longitudinal bottom slope shall be 2 percent or less.
- The maximum subsurface water ponding depth in the reservoir course before overflow shall be at least 6 inches. See Standard Detail NDP-15 for design measures to provide subsurface ponding.
- The storage reservoir shall be composed of aggregate with a minimum void volume of 20 percent.

- No underdrain or impermeable liner shall be used.

v. Rain Recycling - Cistern

Sizing Factors for cisterns receiving runoff from an impervious surface are provided in Table 6.13. Factors are organized by MR. Cistern sizing factors are presented in two ways: 1) percentage values that represent the top cross-sectional area of the storage tank as a percentage of the contributing roof area; and 2) the equivalent volume represented in terms of gallons per square feet of contributing roof area. ***To use these Sizing Factors, the cisterns must meet the design requirements for outlined in Section 6-03.2 plus the following specific requirements:***

- The low flow orifice diameter shall be 0.25 inches.
- Screening to prevent leaves and debris from clogging the orifice shall be less than 0.1 inch mesh. The inlet pipe shall have a self-cleaning filter, and if possible, the top of the cistern shall also be screened.
- The low flow orifice must be able to drain continuously from October 1 through June 30.
- Invert of overflow shall be set at the designated height (3 or 4 feet) above invert of low flow orifice. For intermediate ponding depths (between 3 and 4 feet), a Sizing Factor may be linearly interpolated.
- The cistern shall have vertical walls to the designated overflow height.

C. Sizing Factors

Table 6.13 summarizes the Sizing Factors for on-site stormwater management (MR5), and provides sizing estimates for conceptual design for runoff treatment (MR6) and flow control (MR7). The Sizing Factors represent the required BMP size (generally the bottom footprint area) as a function of MR and design configuration (e.g., ponding depth (PD) and native soil design infiltration rate (inf)).

Table 6.13. Sizing Factors for On-site BMPs.

BMP	Design Variables	On-site Sizing Factor (MR5)	Runoff Treatment Sizing Factor (MR6)	Flow Control Sizing Factor (MR7)
Roof Downspout Infiltration Trench[a]	Coarse sands and cobbles, inf>10 in/hr	20 LF/1,000 sf	N/A	20 LF/1,000 sf
	Medium sand, inf>7.5-10 in/hr	30 LF/1,000 sf	N/A	30 LF/1,000 sf
	Fine sand, loamy sand, inf>2.4-7.5 in/hr	75 LF/1,000 sf	N/A	75 LF/1,000 sf
	Sandy loam, inf>1-2.4 in/hr	125 LF/1,000 sf	N/A	125 LF/1,000 sf
	Loam, inf=0.25-1 in/hr	190 LF/1,000 sf	N/A	190 LF/1,000 sf
Rain Garden (no Underdrain)	~~PD=.5', inf=0.1 in/hr~~	~~13.2%~~	~~9.1%~~	~~33.2%~~
	PD=.5', inf=0.25 in/hr	8.6%	5.4%	21.6%
	PD=.5', inf=1 in/hr	4.0%	2.0%	10.1%
	~~PD=1', inf=0.1 in/hr~~	~~9.1%~~	~~6.8%~~	~~22.9%~~
	PD=1', inf=0.25 in/hr	6.0%	3.8%	15.0%
	PD=1', inf=1 in/hr	2.9%	1.54%	7.4%
Rain Garden with Underdrain	~~PD=.5', inf=0.1 in/hr~~	~~N/A~~	~~1.51%~~	~~Engineered Design~~
	PD=.5', inf=0.25 in/hr	N/A	1.46%	Engineered Design
	PD=.5', inf=1 in/hr	5.51%	1.3%	13.84%
	~~PD=1', inf=0.1 in/hr~~	~~N/A~~	~~1.02%~~	~~Engineered Design~~
	PD=1', inf=0.25 in/hr	N/A	0.98%	Engineered Design
	PD=1', inf=1 in/hr	5.47%	0.79%	13.76%
Bioretention Planter with Underdrain	PD=.5'	N/A	2.5%	N/A
	PD=1'	N/A	2.0%	N/A
Bioretention Planter - Infiltration	~~PD=5',inf=0.1 in/hr~~	~~11.5%~~	~~2.5%~~	~~33.4%~~
	PD=.5',inf=.25 in/hr	8.8%	2.5%	19.0%
	PD=.5',inf=1 in/hr	5.0%	2.5%	7.2%
Pervious Pavement	~~BC=.5', WC=.33 ft, inf=0.1 in/hr~~	~~41.2%~~	~~33.4%~~	~~103%~~
	BC=.5', WC=.33 ft, inf=0.25 in/hr	33.3%	19.0%	55.4%
	BC=.5', WC=.33 ft, inf =1 in/hr	33.3%	7.2%	21.8%
Rain Recycling - Cistern[b]	Depth above orifice=3.0', low flow orifice diameter=0.25"	10.4% (2.34 gal/sf)	N/A	25.9% (5.86 gal/sf)
	Depth above orifice=4.0', low flow orifice diameter=0.25"	5.96% (1.78 gal/sf)	N/A	14.9% (4.46 gal/sf)

Notes:
N/A = not applicable
PD = ponding depth
BC = base course depth
WC = wearing course depth
inf = ~~native soil~~ design infiltration rate (measured infiltration rate with appropriate correction factors applied)
gal = gallons
a – Roof infiltration trench Sizing Factors are provided as linear feet (LF) per 1,000 square foot (sf) of roof area.
b – Rain recycling – cistern Sizing Factors are also provided as gallons (gal) of storage per square foot of roof area.

D6-03.4 Flow Control Credits for On-site Stormwater Management BMPs

For on-site BMPs that are not capable of meeting flow control alone, Flow Control Credits can be used to calculate partial credit towards meeting flow control requirements to reduce the size of downstream flow control facilities. Flow Control Credits are presented in Table 6.14 (Section D6-03.4 C).

Flow Control Credit may be achieved by implementing the following on-site BMPs:

- Retaining trees
- Planting new trees
- Installing rain barrels
- Downspout or sheet flow dispersion
- Installing a vegetated roof

  The impervious area mitigated is calculated as the product of the Flow Control Credit and the quantity of the BMP.

Example:

Flow control facilities must be sized to meet on-site stormwater management (MR5) and flow control (MR7) requirements for a site with 15,000 sf of impervious area. The design plans include a 5,000 sf vegetated roof with a 4-inch-deep growing medium. The amount of impervious area mitigated is 43 percent of 5,000 sf, or 2,150 square feet. This reduces the total impervious surface area requiring mitigation from 15,000 square feet to 12,850 square feet. Additionally, ten (10) evergreen trees with canopy areas of approximately 100 square feet each are retained, so the additional impervious area mitigated is 200 square feet (20% x 100 sf x 10 evergreen trees retained). This further reduces the total impervious area requiring mitigation to 12,650 square feet. Only the unmitigated impervious area (12,650 square feet) is then included in the continuous hydrologic model to size the downstream flow control facilities (Section D3-02) for the project.

To use these Flow Control Credits, the facility must meet all specified design requirements in accordance with Sections D6-03.1 and D6-03.2 and the respective Standard Details.

A. Applicability

For BMPs that do not fully meet the flow control requirement, Flow Control Credits can be applied to reduce the size of flow control facilities. The Flow Control Credit values are based on the degree to which these facilities achieve the flow control standard per Chapter D3. These credits represent impervious area reductions applied to the amount of impervious surface area requiring flow control, or mitigation. Flow Control Credits are presented in Table 6.14 (Section D6-03.4 C).

Generalized assumptions were used to develop the Flow Control Credits that may underestimate actual flow control benefits for some sites. Developers have the option to use the Flow Control Credits provided in this section, or to follow the demonstrative approach (Section D6-03.2) and submit an alternative facility Flow Control Credit with supporting engineering calculations for review.

B. Implementation

The following describes how the Flow Control Credits are used to evaluate the amount of impervious area mitigated to meet the applicable Minimum Requirements for on-site BMPs that do not fully achieve flow control requirements.

i. Retained Trees

Retaining trees alone will not achieve flow control requirements; however, some flow control benefits are achieved with this BMP. Credits for retained trees are provided in Table 6.14 for deciduous and evergreen trees. This credit can be applied to reduce the effective impervious surface area used in downstream conveyance and flow control calculations. Since partial credit only is applied, additional flow control measures will be required. ***To use the Flow Control Credit, the retained trees must meet the following specific requirements:***

- Retained trees shall have a minimum six (6) inches diameter at a height of four (4) feet above the existing ground on the uphill side of a tree.
- The tree trunk center must be within 20 feet of new and/or replaced ground level impervious surface.
- Tree credits do not apply to trees in native vegetation areas used for flow dispersion or other Flow Control Credit.
- The total tree credit for retained trees shall not exceed 25 percent of impervious surface requiring mitigation.

ii. New Trees

Newly planted trees alone will not achieve flow control requirements; however, some flow control benefits are achieved with this BMP. Credits for new trees are provided in Table 6.14 for deciduous and evergreen trees. This credit can be applied to reduce the effective impervious surface area used in downstream conveyance and flow control calculations. Since only partial credit is applied, additional flow control measures will be required. ***To use the Flow Control Credit, the new trees must meet the following specific requirements:***

- The tree trunk center must be within 20 feet of new and/or replaced ground level impervious surface.
- Tree credits do not apply to trees in native vegetation areas used for flow dispersion or other Flow Control Credit.
- The total tree credit for newly planted trees shall not exceed 25 percent of impervious surface requiring mitigation.
- Minimum five (5) foot setback from structures.
- Minimum five (5) foot setback from underground utility lines.
- Minimum two (2) foot setback from edge of any paved surface.
- New deciduous trees shall be at least 1.5 inches in diameter measured six (6) inches above the ground. New evergreen trees shall be at least four (4) feet tall.

iii. Roof Downspout, Concentrated, or Sheet Flow Dispersion

Dispersion will not achieve flow control requirements unless it meets the requirements of Full Dispersion as outlined in Section D6-03.1; some flow control benefits are achieved with more limited dispersion BMPs. Credits for dispersion are provided in Table 6.14, or Flow Control Credits for roof downspout dispersion from Chapter 3, Volume III of the DOE Manual may be applied. This credit can be applied to reduce the effective impervious surface area used in drainage calculations. Since partial credit is applied, additional flow control measures will be required. ***To use the Flow Control Credit, roof downspout dispersion, concentrated flow dispersion or sheet flow dispersion must meet the general requirements outlined in Section D6-03.1.***

iv. Rain Recycling - Rain Barrels

Rain barrels alone will not achieve flow control requirements; however, some flow control benefits are achieved with this BMP. Credits for rain barrels are provided in Table 6.14. This credit can be applied to reduce the effective impervious surface area used in downstream conveyance and flow control calculations. Since partial credit only is applied, additional flow control measures will be required. ***To use the Flow Control Credit, the rain barrels must meet the general requirements for rain barrels outlined in Section 6-03.2. A minimum of four (4) rain barrels must be installed to receive Flow Control Credit.***

v. Vegetated Roof

Vegetated roofs alone will not achieve flow control requirements; however, some flow control benefits are achieved with this BMP. Credits for vegetated roofs are provided in Table 6.14, organized by growth medium depth. This credit can be applied to reduce the effective impervious surface area used in downstream conveyance and flow control calculations. Since partial credit only is applied, additional flow control measures will be required. ***To use the Flow Control Credit, the vegetated roof must meet the design requirements for vegetated roofs outlined in Section 6-03.2 plus the following specific requirements:***

- Roof slope shall have a pitch of up to 2-2/5”:12” (2-2/5 inch fall per foot), 5H:1V, or 20 percent.

C. Flow Control Credits

Table 6.14 summarizes the default Flow Control Credits for several on-site stormwater management BMPs. The Flow Control Credits represent the percentage or square footage of impervious area mitigated by the BMP. This mitigated impervious area can be subtracted from the amount of impervious area input to the continuous hydrologic model used to size downstream flow control facilities as described in Section D3-03. Additional default Flow Control Credits for BMPs not included herein can be found in Chapter 7 of the LID Manual.

Table 6.14. Flow Control Credits.

BMP	Design Variables	Flow Control Credit
Retained Trees[a]	Evergreen	20% canopy area (minimum 100 sf)
	Deciduous	10% canopy area (minimum 50 sf)
New Trees[a]	Evergreen	50 sf/tree
	Deciduous	20 sf/tree
Roof Downspout, Concentrated or Sheet Flow Dispersion	Dispersion to compost amended lawn or landscape in accordance with D6-03.1.	90%
Rain Recycling - Rain Barrels[b]	(4) 50-60 gallon tanks	1% /4 rain barrels
Vegetated Roof	4-inch growing medium	43%
	8-inch growing medium	50%

Notes:
sf = square feet
a – Trees must be within 20 feet of ground-level impervious surface. The total tree credit shall not exceed 25 percent of impervious surface requiring mitigation.
b – Minimum of 4 rain barrels shall be installed to receive Flow Control Credit.

D6-03.5 Maintenance

Long-term maintenance is required for all runoff control and treatment facilities. See Section D2-09 for operation and maintenance manual (O & M Manual) requirements. General maintenance shall be performed per DOE Manual Volume IV, Chapter 2, page 2-40, BMPs for Maintenance of Stormwater Drainage and Treatment Systems. In addition:

A. For each required On-site Stormwater BMP, refer to Section D6-03.1 for general maintenance guidelines. All BMPs except splash blocks, sheet flow dispersion, and concentrated flow dispersion require a maintenance log be kept on-site per D2-09.

B. For Natural Drainage Practices (D6-03.2), use the performance standards and inspection and maintenance schedules and techniques provided by the designer or manufacturer. Comply with the maintenance guidelines in Bellevue Maintenance Standards, and copy applicable maintenance procedures into the O&M Manual for each facility.

D6-04 NDP MATERIALS

D6-04.1 Bioretention

A. Bioretention Soil Mix (BSM)

For use in Rain Gardens, Bioretention Swales and Downspout Planter Boxes. Functions as a Detention/Filter layer and growth medium for plants.

BSM shall be as follows:

- Placed to a minimum depth of 18 inches with the following characteristics:
- Initial infiltration rate ≤12 inches per hour;
- Cation exchange capacity (CEC) ≥ 5 meq/100 grams of dry soil;

- Minimum 8 percent to maximum 10 percent organic matter content (by dry weight); and
- 2-5 percent fines passing the No. 200 sieve;
- Contain less than 5% clay, by volume, and
- A uniform soil mixture, free of stones, stumps, roots, or debris larger than 2 inches.

When required by the Engineer, testing shall be done by a Contractor-provided testing laboratory. The laboratory must be accredited by STA, AASHTO, ASTM, or other industry-recognized standards organization, and have current and maintained certification. The testing laboratory shall be capable of performing all tests to the standards specified, and shall provide test results with an accompanying Manufacturer's Certificate of Compliance to the Engineer. Testing laboratories include but are not limited to those listed in Section 7 in "Building Soil: Guidelines and Resources for Implementing Soil Quality and Depth BMP T5.13 in WDOE Stormwater Management Manual for Western Washington." This document may be downloaded at www.soilsforsalmon.org or www.buildingsoil.org. It is the responsibility of the contractor to verify the laboratory's accreditations are up to date.

Submittal Requirements

At least ten (10) working days prior to placement of the BSM, the Contractor shall submit to the Engineer for approval:

1. Grain size analysis results of Mineral Aggregate performed in accordance with ASTM D 422, Standard Test Method for Particle Size Analysis of Soils;
2. Quality analysis results for compost performed in accordance with STA standards, as specified in the Standard Specifications, Section 9-14.4(8);
3. Organic content test results for the mixed BSM. Organic content test shall be performed in accordance with Testing Methods for the Examination of Compost and Composting (TMECC) 05.07A, "Loss-On-Ignition Organic Matter Method";
4. Modified Proctor compaction testing for the mixed BSM, performed in accordance with ASTM D 1557, Test Method for Laboratory Compaction Characteristics of Soil Using Modified Effort;
5. A list of the equipment and a description methods used to mix the Mineral Aggregate and compost to produce the BSM;
6. Permeability or hydraulic conductivity testing of the BSM, performed in accordance with ASTM D 2434, Standard Test Method for Permeability of Granular Soils. For the landscape BSM, assume a relative compaction of 85 percent of modified maximum dry density (ASTM D 1557); and
7. The following information about the testing laboratory(ies):
    1) Name of laboratory(ies) including contact person(s),
    2) Address(es),
    3) Phone contact(s),

4) E-mail address(es);
5) Qualifications of laboratory and personnel including expiration date of current certification.

Bioretention Construction Requirements

BSM shall be protected from all sources of additional moisture at the Supplier's site, covered during transport, at the Project Site, and until incorporated into the Work. Soil placement and compaction shall not occur when the ground is frozen or excessively wet (>3% above optimum moisture content), or when weather conditions are unsuitable as determined by the Engineer.

Bioretention Soil Placement

- The Contractor shall not place bioretention soil until the Project Site draining to the bioretention area has been stabilized and authorization is given by the Engineer.
- Mixing placing BSM shall not be allowed if the area receiving BSM is wet or saturated or has been subjected to more than ½-inch of precipitation within 48-hours prior to mixing or placement. The Engineer will have final authority to determine whether wet or saturated conditions exist.
- In rain gardens and in areas to be landscaped with vegetation other than turf, place BSM loosely. Final BSM depth shall be measured and verified only after the soil has been water compacted, which requires filling the cell with water, without creating any scour or erosion, to at least 1 inches of ponding. If water compaction is not an option, final BSM depth shall be measured at X inches above the grade specified on the plans to allow for settling after the first storm. X shall be calculated by depth of BSM multiplied by 0.15 and rounded up to the nearest whole number.
- In areas to be planted with turf, place BSM in loose lifts not exceeding 12 inches. Compact BSM for turf to a relative compaction of 85 percent of modified maximum dry density (ASTM D 1557), where slopes allow, as determined by the Engineer. Where turf BSM is placed in the 2-foot road shoulder, compact to a relative compaction of 90 percent of modified maximum dry density (ASTM D 1557). Final BSM depth shall be measured and verified only after final BSM compaction.

Type 1 – Amend Existing On-site Soils

If existing soils on-site are loam, sandy loam or loamy sand texture as defined by the USDA texture triangle, Figure 3.27 in Volume III, DOE Manual, and free of debris, the BSM can be composed of native soils excavated from the site mixed with compost to meet the above specifications. On-site soil mixing shall not be allowed if soil is saturated or has been subjected to water within 48 hours.

Projects required to meet MR1-9 – After mixing, send representative samples to a lab to verify that the BSM meets the specifications listed above. Present the manufacturer's certificate of compliance to the Engineer.

Projects required to meet MR1-5 only – Use the following table to mix appropriate quantities of on-site soils with approved compost (see compost specification under

Type 3, below). Use the USDA soil textural triangle to determine site soil texture. If the on-site soils are not one of the types below, use Type 2 or Type 3 BSM, below.

Table 6.15. Bioretention Soil Mix – Quantities using on-site (native) soils

On-site Soil Type (USDA Texture Triangle)	% Coarse Sand (by volume)	% On-site Soil (by volume)	% Compost (by volume)
Loam	40	20	40
Sandy Loam	30	30	40
Loamy Sand	0	60-65	35-40

Type 2 – Import BSM

Test soil at time of delivery or mixing, or have vendor provide certification that the soil meets the above BSM specifications.

Type 3 – Import Sand-Compost and Mix

Import materials and mix on-site, or mix at supplier location, to meet the requirements listed in Type 1, above, as follows:

- 60-65% gravelly sand by volume
- 35-40% compost by volume

Gravelly Sand must meet the following gradation:

Sieve size	Percent Passing
3/8 inch	100
US No. 4	95-100
US No. 10	75-90
US No. 40	25-40
US No. 100	4-10
US No. 200	2-5

Approved gravelly sand:

Green Earth Screen Sand (Green Earth Technologies, Bellingham)
Miles Sand & Gravel Utility Sand (Miles Sand & Gravel, Roy).

Compost must meet the specifications per D6-04.1(B), below.

B. Compost and Mulch for Bioretention

Compost and Mulch are applied on top of the BSM to hold in moisture, prevent weeds, and prevent erosion. Use Compost in the bottom of the Bioretention facilities, and use wood chip or other Mulch composed of shredded or chipped hardwood or softwood on bioretention slopes.

Apply Compost or Mulch on top of the Bioretention Soil Mix layer to a maximum depth of three (3) inches thick for compost or four (4) inches thick for wood chips (thicker applications can inhibit proper oxygen and carbon dioxide cycling between the soil and atmosphere) after plants have been installed.

Compost shall meet the following:

- Fine Compost specification (Standard Specifications 9-14.4(8)), produced according to WAC 173-350-100, Solid Waste Handling Standards, Definitions, and 173-350-220, Compost Facilities, or meeting pathogen and contaminant standards in the above WAC, or having the US Composting Council's "Seal of Testing Assurance" (STA). Compost suppliers must be a participant in the STA testing program.
- The following compost mixes are approved:

  Cedar Grove compost (Maple Valley)
  GroCo, Steerco (many suppliers)

Mulch shall be free of weed seeds, soil, roots and other material that is not trunk or branch wood and bark.

Mulch shall not include grass clippings (decomposing grass clippings are a source of nitrogen and are not recommended for mulch in bioretention areas), mineral aggregate, or pure bark (bark is essentially sterile and inhibits plant establishment).

As an alternative to mulch, a dense groundcover may be used. Mulch is required in conjunction with the groundcover until groundcover is established.

C. Retention Zone Aggregate for Bioretention

Use retention zone material's pore spaces as additional storage reservoir for rain gardens with underdrains and bedding for underdrain pipe.

For retention zones with slotted underdrain pipe, use either Gravel Backfill for Drains per Standard Specifications 9-03.12(4) or Type 26 Mineral Aggregate as follows:

Type 26 Mineral Aggregate:

Sieve Size	Percent Passing
¾ inch	100
¼ inch	30-60
U.S. No. 8	0-20
U.S. No. 50	0-2
US No. 200	0-1.5

Geotextile not required.

For an underdrain with perforated PVC underdrain pipe, use the following aggregate for the retention zone:

¾-inch to 1-1/2-inch double-washed drain rock (ASTM No. 57 aggregate or equivalent).

D. Overflows for Bioretention

When specified by the Developer, an overflow device shall be provided that safely conveys overflow without causing flooding or erosion downstream.

Use the following for overflows; also see Standard Detail NDP-8 and D7-02.3 Storm Drain Pipe and Culvert Materials:

Overflow drain pipe – PVC-SDR 35 or schedule 80 PVC pipe, minimum diameter 3"

Overflow grates/screens – Atrium grate

Overflow strainer or grate - grating and frame shall be aluminum, stainless steel or plastic,[1] medium duty.

The following overflow products are approved:

Atrium Grate 3”,4”, 6” round:
NDS models 70,75, 80
Atrium grate:
ADS model 0663SDX
Neenah grate:
R-4346, R-2560-E2, R-2561, R-4351-C, R-4353
Olympic Foundry:
MH25

E. Plants for Bioretention (Rain Gardens, Bioretention Swales, Downspout Planter Boxes)

Native plants from the Pacific Northwest region shall be used whenever possible. Hardy cultivars that are not invasive and do not require chemical inputs may also be used. Plants may be chosen from lists provided in the *Rain Garden Handbook for Western Washington Homeowners* (Washington State University, 2007), the *Low Impact Development Technical Guidance Manual for Puget Sound* (Puget Sound Partnership and Washington State University, 2005 or current), both available on the web (see D1, References).

For areas within the public right-of-way, trees that are tolerant of the site conditions and approved for streetscapes may be used.

Select and place bioretention plants to match the site’s sun, moisture and soil conditions. Plants should be planted at high enough density to cover (or shade) the entire surface of the rain garden within two years of planting. As a general guideline, plant a minimum of three types of shrubs and three types of herbaceous plants in each facility to protect against facility failure due to disease or insect infestation of a single species.

All plant materials should have normal, well-developed branches and root systems, and be free from physical defects, plant diseases, and insect pests. Small plant material is recommended for best survival and lowest expense. Optimum planting time is typically fall (beginning mid October). Spring and summer planting likely will require more watering during the summer months, and winter planting is acceptable, but may result in mortalities from freezing temperatures.

Bioretention Swales may be planted with a mixture of shrubs, grasses and ground covers if the Developer can demonstrate that conveyance capacity will be maintained when the plants are mature.

[1] If aluminum, stainless steel or plastic are not available, asphalt coated galvanized materials shall be used if available. Avoid galvanized metals because they leach zinc into the environment, especially in standing water situations, and at high concentrations zinc can be toxic to aquatic life.

Plant vegetation according to the following moisture tolerance zones:

Zone 1: Generally the bottom of the facility; area of periodic or frequent standing or flowing water. Zone 1 plants will also tolerate the seasonally dry periods of summer in the Pacific Northwest without extra watering and may also be applicable in Zone 2 or 3.

Zone 2: Periodically moist or saturated during larger storms. Plants listed under Zone 2 will also be applicable in Zone 3.

Zone 3: Dry soils, infrequently subject to inundation or saturation. This area can be used to transition or blend with the existing landscape.

D6-04.2 Pervious Pavement

This work shall consist of construction of the pervious pavement section as described in this section. Three types are allowable: pervious asphalt, pervious concrete, or pervious pavers, which include grass and gravel paving systems.

A. Wearing Course

Pervious Asphalt or Pavers – for specifications and construction methods, use *Low Impact Development: Technical Guidance Manual for Puget Sound (Puget Sound Partnership*, 2005 or current version), *Permeable Interlocking Concrete Pavements'* latest edition by the Interlocking Pavement Institute, or per the designer or manufacturer.

The following pervious pavement products are approved:

Porous/Permeable/pervious pavers:

- Invisible Structures GrassPave2
- Presto Geosystems
- Uni-Eco-Stone
- Uni-Ecoloc
- Eco-Priori
- Hastings Check Block
- Grasscrete
- Turfstone
- Geoblock 5150
- Tufftrack Grassroad Pavers
- Grassy Pavers
- Invisible Structures Gravelpave2
- Turf & Gravel Pavers

Pervious Concrete – Use ACI 522.1 *Specification for Pervious Concrete Pavement* published by the American Concrete Institute, Farmington Hills, Michigan. For projects larger than 5,000 square feet, a test panel must be submitted to the inspector prior to installation.

B. Reservoir Course

The reservoir course is designed to structurally support the pervious pavement wearing course, as well as provide water storage. Depth will be dependent on meeting the minimum depth requirement for the base course (reservoir course plus the optional choker course) of 6” and the need to store stormwater to meet flow control requirements. Depth and area based on modeling results; for MR5 when flow control and/or runoff treatment do not apply, per simplified sizing tables (See D9-04).

Use 2.5 inch to 0.5 inch uniformly graded crushed (angular) thoroughly washed stone (AASHTO No. 3), 6-36” depth.

--or--

Use thoroughly washed clean Permeable Ballast meeting the requirements of Standard Specifications (2010) 9-03.9(2), or alternatively, use non-washed Permeable Ballast that has minimum void ratio of 35%.

C. Water Quality Treatment Layer

The BSM specifications in D6-04.1 meet the soil requirements for Runoff Treatment; see Section D6-01.1 for more information.

D. Leveling Course (Also called Choker Course or Filter Course)

The Leveling Course is an optional layer that lies between the pervious pavement wearing course and the reservoir course, and is considered part of the base course. It is generally one inch to two inches in depth, and is intended to provide a uniformly graded surface over which to place the wearing course, reduce rutting from delivery vehicles during pavement installation, and more evenly distribute loads to the underlying material.

Use 1.5-inch to U.S. No. 8 uniformly graded crushed (angular) thoroughly washed stone

E. Geotextile

Geotextile is optional. If specified by the engineer, use nonwoven geotextile for separation (Standard Specifications, 9-33.2(1) Table 3, separation, nonwoven).

The following geotextile products are approved:

Geotextile Nonwoven polypropylene:

Ling Industrial Fabrics, Inc model 275EX
TNS Advantaged Technologies models R060,R080
Carthage Mills models FX60HS, FX70HS, FX80HS
DuPont DeNemours model SF65
Ten Carte (Mirafi) model 600X, FW700, 1120N
Skaps Industries LLC model GT60
Propex Inc model GeoTex801

D6-04.3 Underdrain for Bioretention or Pervious Pavement

A. Underdrain Pipe

Minimum 0.5% slope. Do not wrap in filter fabric. Attach 6-inch rigid non-perforated pipe perpendicular at bottom of facility for clean-out.

Option 1: Manufactured Slotted pipe

- Allows for pressurized water cleaning and root cutting if necessary.

- Slotted subsurface drain PVC per ASTM D1785 Schedule 40 for privately owned and maintained facilities only. Use an appropriate coupling if connecting to a city-owned pipe.
- Slotted subsurface drain PVC per D7-02.3 for systems that will be owned and/or maintained by the City of Bellevue.
- 4-8" or as specified by the designer.

Option 2: Onsite Fabricated Slotted Pipe

- Allows for pressurized water cleaning and root cutting if necessary. Use solid PVC Schedule 40 for privately owned and maintained facilities only. Use an appropriate coupling if connecting to a city-owned pipe.
- Use solid PVC per D7-02.3 for systems that will be owned and/or maintained by the City of Bellevue.
- Cut slots perpendicular to the long axis of the solid PVC pipe, slots are 0.04-0.069 inches wide by 1 inch long and spaced 0.25 inches apart (spaced longitudinally). Arrange slots in four rows spaced on 45-degree centers and cover ½ the circumference of the pipe. Use filter materials with smallest aggregate larger than slot size.

Option 3: Perforated PVC, Schedule 40 or slotted HDPE pipe for privately owned and maintained systems only

- Cleaning operations may be difficult or impossible.

The following underdrains or Equal are approved:

Manufacturers:

Johnson

CertainTeed Corporation, Lodi, CA

B. Coupler

Match the coupler to fit the underdrain used. Glue or bolt the coupler to the pipes if connecting from a privately owned or maintained system to a pipe or facility owned by the City of Bellevue.

The following couplers and Equal are approved:

Fernco, Davison, MI

D6-04.4 Observation Ports for Bioretention or Pervious Pavement

A. Expandable Test Plugs

The following expandable test plugs for pipes are approved:

Cherne Gripper plugs models MC-99930, MC-99929, MC-99931, MC-99935

B. Coupler

Match the coupler to fit the PVC pipe used. Solvent glued joints are acceptable.

C. End Cap/Pipe Plug

Match the end cap and/or pipe plug to fit the PVC pipe used. Solvent glued joints are acceptable.

D. Bentonite

The manufacturer shall certify that the granular dry bentonite is suitable for sealing monitoring wells for potable water.

E. Well Screen

See manufactured slotted pipe Option 1 for Underdrain for Bioretention or Pervious Pavement or Option 3: Perforated PVC, Schedule 40 for requirements.

D6-04.5 Amended Soil

Amend soils using materials and techniques to meet BMP T5.13, Post Construction Soil Quality and Depth per the latest version of "Guidelines and Resources for implementing Soil Quality and Depth BMP T5.13" at www.soilsforsalmon.org. The "Permitted Composting Facilities in Washington that Sell Bulk Compost" and "Soil and Compost Analytical Labs Serving the Northwest" from Section Seven are approved.

D6-04.6 Roof Downspout Dispersion

A. Pop-up Drainage Emitter

The following pop-up emitters are approved:

NDS model L422G, or Equal

B. Splash Blocks
Place splash block (minimum 11 inches wide by 14 inches long) or pad of crushed rock (2 feet wide by 3 feet long by 6 inches deep) under roof downspouts to direct water to an appropriate vegetated flow path.

D6-04.7 Rain Recycling

A. Rain barrels for use for rain recycling in single family applications. 50 to 60 gallon storage capacity typical, with screened lid, overflow, and hose bib, per Standard Detail NDP-18.

The following plastic rain barrels (or Equal) are approved:

Poly material:
Chicago model 18122
Suncast model RB5010PK
Emsco model 2771-1
Mayne model 5847WH
Fiskars model 5997

D6-04.8 Vegetated Roofs

The plants listed in Table 6.16 are suitable for use on vegetated roofs. This list is provided as a convenience and is not considered complete. These and other plants may be used as recommended by a vegetated roof design professional based on site conditions.

Table 6.16. Plants for Vegetated Roofs

Scientific Name	Common Name	Plant Type
Achillea tomentosa	Woolly yarrow	Herb
*Arctostaphylos uva-ursi**	Kinnikinnick	Groundcover (woody)
Armeria maritima	Sea pink, sea thrift	Herb
Carex inops (pensylvanica)	Long-stoloned sedge	Sedge
*Eriophyllum lanatum**	Oregon sunshine	Herb
Festuca brachyphylla	Pt. Joe fescue	Grass
Festuca rubra	Red creeping fescue	Grass
Festuca idahoensis	Idaho fescue	Grass
*Gaultheria shallon**	Salal	Shrub
Phlox subulata	Creeping phlox	Herb
*Polystichum munitum**	Sword fern	Fern
*Saxifraga caespitosa**	Tufted saxifrage	Herb
Sedum album	White stonecrop	Succulent
Sedum oregonum	Oregon stonecrop	Succulent
Sedum reflexum	Spruce-leaved stonecrop	Succulent
Sedum spectabile 'Frosty Morn'	Variegated blush stonecrop	Succulent
Sedum spurium	Two-row stonecrop	Succulent
Sedum 'Vera Jameson'	Showy stonecrop	Succulent
Sisyrinchium idahoensis	Blue-eyed grass	Grass
Thymus serphyllum	Thyme	Herb (woody)
Triteleia hyacintha	Fool's onion	Herb
Allium cernuum	Nodding wild onion	Herb
Polypodium hesperidum	Western polypody	Fern
*Lupinus polyphyllus**	Blue-pod lupine	Herb
Fragaria chiloensis	Sand strawberry	Herb

*Native to the Pacific Northwest
(http://www.seattle.gov/dpd/GreenBuilding/OurProgram/Resources/TechnicalBriefs/DPDS_009485.asp).

D6-04.9 Construction Requirements

For installation instructions and limits on use of materials for Natural Drainage Practices, install per the design engineer's or manufacturer's direction, or see the LID Manual, available online per Section D1-03.

D6-04.10 Miscellaneous Products

A. Catch basins for use in residential lots.

The following plastic catch basins or Equal are approved:

9" x 9" or 12" x 12":

ADS models 0909SD2, 0909SD4, 1212SD2, 1212SD4

12", 18", 24" diameter

Hanson Type 45

12", 18" Diameter

NyloplastDrawing No. 7001-110-374

D6-05 NDP STANDARD DETAIL LIST

NDP-1	AMENDED SOILS
NDP-2	RAIN GARDEN
NDP-3	BIORETENTION SWALE
NDP-4	BIORETENTION PLANTER – FLOW-THROUGH
NDP-4A	BIORETENTION PLANTER – INFILTRATION
NDP-5	BIORETENTION PLANTER – FLOW-THROUGH WITH OVERFLOW CONNECTED TO STORM SYSTEM
NDP-6	RAIN GARDEN OVERFLOW WITH CONVEYANCE FURROW
NDP-7	RAIN GARDEN OVERFLOW WITH PIPE CULVERT
NDP-8	OVERFLOW CONFIGURATIONS FOR BIORETENTION
NDP-9	OBSERVATION PORT FOR RAIN GARDEN
NDP-10	DRAIN CURB CUT OPENING FOR BIORETENTION
NDP-11	PERVIOUS ASPHALT OR CONCRETE PAVEMENT SECTION
NDP-12	PERVIOUS PAVER SYSTEMS
NDP-13	PERVIOUS PAVEMENT SIDEWALK IN PLANTING STRIP
NDP-14	PERVIOUS PAVEMENT SIDEWALK
NDP-15	CHECK DAM AND INTERCEPTOR FOR PERVIOUS PAVEMENT ON SLOPES
NDP-16	OBSERVATION PORT FOR PERVIOUS PAVEMENT
NDP-17	OBSERVATION PORT COVERS FOR PERVIOUS PAVEMENT
NDP-18	RAIN RECYCLING SYSTEM – RAIN BARREL
NDP-19	RAIN RECYCLING SYSTEM – CISTERN
NDP-20	POP-UP DRAINAGE EMITTER
NDP-21	REVERSE SLOPE SIDEWALK