Chapter 2 Low Impact Development Best Management Practices

This Chapter presents the methods for analysis and design of on-site stormwater management Best Management Practices (BMPs). Design procedures and requirements for stormwater management BMPs meeting Minimum Requirement #7, Flow Control, are contained in Volume 3.

2.1 Application

Low impact development techniques should be used at every site when feasible. Using low impact development techniques may eliminate the need to install more costly flow control or water quality devices. When utilized in accordance with this manual, most low impact development techniques provide flow credits. Flow credits only apply to flow control thresholds. Flow credits do not apply to water quality thresholds.

2.2 Best Management Practices

The following Low Impact Development BMPs are discussed in this Chapter:

2.2.1 Site Design BMPs

- BMP L620 Preserving Natural Vegetation
- BMP L621 Better Site Design

2.2.2 Structural Low Impact Development BMPs

- BMP L630 Bioretention Areas (Rain gardens)
- BMP L631 Vegetated Rooftops
- BMP L632 Rainfall Re-use
- BMP L633 Alternate Paving Systems
- BMP L634 Minimal Excavation Foundations
- BMP L635 Reverse Slope Sidewalks

Infiltration, dispersion, soil quality and tree retention BMPs can be found in Volume 3, Volume 5 and Volume 6.

2.2.3 Site Design BMPs

2.2.3.1 BMP L620 Preserving Natural Vegetation

Purpose

Preserving natural vegetation on-site to the maximum extent practicable will minimize the impacts of development on stormwater runoff.

Applications and Limitations

On lots that are one acre or greater, preservation of 65 percent or more of the site in natural vegetation will allow the use of full dispersion techniques presented in BMP L614. Sites that can fully disperse are not required to provide runoff treatment or flow control facilities.

Design Criteria

- Situate the preserved area to maximize the preservation of wetlands, and to buffer stream corridors.
- Place the preserved area in a separate tract or protect through recorded easements for individual lots.
- If feasible, locate the preserved area downslope from the building sites, since flow control and water quality are enhanced by flow dispersion through duff, undisturbed soils, and native vegetation.
- Show the preserved area on all property maps and clearly mark the area during clearing and construction on the site.

Maintenance

- Do not remove vegetation and trees from undisturbed areas, except for approved timber harvest activities and the removal of dangerous and diseased trees.

2.2.3.2 BMP L621 Better Site Design

Purpose

Fundamental hydrological concepts and stormwater management concepts can be applied at the site design phase that are:

- More integrated with natural topography,
- Reinforce the hydrologic cycle,
- More aesthetically pleasing, and
- Often less expensive to build.

Design Criteria

Define Development Envelope and Protected Areas – The first step in site planning is to define the development envelope. This is done by identifying protected areas, setbacks, easements and other site features, and by consulting applicable local standards and requirements. Site features to be protected may include important existing trees, steep slopes, erosive soils, riparian areas, or wetlands.

By keeping the development envelope compact, environmental impacts can be minimized, construction costs can be reduced, and many of the site's most attractive landscape features can be retained. In some cases, economics or other factors may not allow avoidance of all sensitive areas. In these cases, care can be taken to mitigate the impacts of development through site work and other landscape treatments.

Minimize Directly Connected Impervious Areas

Impervious areas directly connected to the storm drain system are the greatest contributors to urban nonpoint source pollution. Minimize these directly connected impervious areas. This can be done by limiting overall impervious land coverage or by infiltrating and/or dispersing runoff from these impervious areas.

- **Maximize Permeability** - Within the development envelope, many opportunities are available to maximize the permeability of new construction. These include minimizing impervious areas, paving with permeable materials, clustering buildings, and reducing the land coverage of buildings by smaller footprints. All of these strategies make more land available for infiltration and dispersion through natural vegetation.
- **Build Narrower Streets** - More than any other single element, street design has a powerful impact on stormwater quantity and quality. In residential development, streets and other transportation-related structures typically can comprise between 60 and 70 percent of the total impervious area, and, unlike rooftops, streets are almost always directly connected to the stormwater conveyance system.
- **Maximize Choices for Mobility** - Given the costs of automobile use, both in land area consumed and pollutants generated, maximizing choices for mobility is a basic principle for environmentally responsible site design. By designing residential developments to promote alternatives to automobile use, a primary source of stormwater pollution can be mitigated.
- **Use Drainage as a Design Element** - Unlike conveyance storm drain systems that hide water beneath the surface and work independently of surface topography, a drainage system for stormwater infiltration or dispersion can work with natural land forms and land uses to become a major design element of a site plan.

2.2.4 Low Impact Development BMPS

Low impact development BMPs are structural BMPs that can be used to manage stormwater on-site. Using LID techniques can reduce surface runoff. For each category, basic design criteria is included. The design criteria components in this manual must be used in order to obtain runoff credits. Runoff credits are considered when determining project thresholds.

The guidance provided in "Low Impact Development: Technical Guidance Manual for Puget Sound", found on the Puget Sound Partnership website: www.psp.wa.gov, should also be used in design.

2.2.4.1 BMP L630 Rain Gardens

Purpose and Definition

Bioretention areas are shallow stormwater retention facilities designed to mimic forested systems by controlling stormwater through detention, infiltration, and evapotranspiration. Bioretention areas provide water quality treatment through sedimentation, filtration, adsorption, and phytoremediation. Bioretention facilities are integrated into the landscape to better mimic natural hydrologic conditions. Bioretention facilities may be used as a water quality facility or a water quality and flow control (retention) facility.

Applicability and Limitations

- Three feet of separation is required between the lowest elevation of the bioretention soil or any underlying gravel infiltration layer and the seasonal high groundwater elevation or other impermeable layer if the area tributary to the facility requires compliance with Minimum Requirement #6 or Minimum Requirement #7.
- For bioretention facilities with a contributing area less than the above thresholds, a minimum of 18 inches of separation is required between the lowest elevation of the bioretention soil or any underlying gravel infiltration layer and the seasonal high groundwater or other impermeable layer.
- For facilities with underdrains, the seasonal high groundwater elevation or other impermeable layer shall be below the lowest elevation of the bioretention area or underdrain collection system. Separation shall be such that groundwater will not migrate into the underdrain system.
- Bioretention facilities may meet the requirements for basic and enhanced treatment when soil is designed in accordance with the requirements below and at least 91% of the influent runoff volume modeled using WWHM or another approved continuous simulation model is infiltrated. Drawdown requirements must also be met as applicable, for water quality facilities see Volume 5, Section 7.3.4.

Setback and Site Constraints

Setback requirements are generally required by the City, uniform building code requirements, the Tacoma Pierce County Health Department, or other state regulations. Where a conflict between setbacks occurs, the City shall require compliance with the most stringent of the setback requirements from the various codes/regulations. The following are the minimum setbacks required per this manual:

- At least 100 feet from drinking water wells, and springs used for public water supplies. Infiltration facilities upgradient of drinking water wells and within 1, 5, and 10-year time of travel zones must comply with Health Department requirements (Washington Wellhead Protection Program, DOH, Publication #331-018).

- The City of Tacoma Public Works Department and Tacoma-Pierce County Health Department developed a guidance document that provides the circumstances and requirements for approval of infiltration facilities for managing pollution-generating stormwater runoff in the South Tacoma Groundwater Protection District. The document, "Implementation of Stormwater Infiltration for Pollution-Generating Surfaces in the South Tacoma Groundwater Protection District" is available at www.cityoftacoma.org/stormwater.
- At least 10 feet from any building structure and at least 5 feet from any other structure or property line unless approved in writing by Environmental Services.
- Rain gardens designed for infiltration shall not be built on slopes steeper than 20 percent. A geotechnical analysis and report shall be required on slopes over 15% or if located within 200 feet of the top of steep slopes (40% or greater) or a landslide hazard area. More stringent setbacks may be required based upon the Tacoma Municipal Code. Rain gardens that do not infiltrate may be allowed within the setback areas with a geotechnical analysis that indicates that the facility will have no adverse impact to the slope.
- At least 10 feet from septic tanks and septic drainfields. Additional setbacks from DOH Publication 333-117 On-Site Sewage Systems, Chapter 246-272A WAC may apply. Shall not be located upstream of residential septic systems unless topography or a hydrology analysis clearly indicates that subsurface flows will not impact the drainfield.
- Environmental Services may require additional setbacks or analysis for infiltration facilities proposed to be sited within the influence of known contaminated sites or abandoned landfills.

Design Criteria

Flow Entrance/Presetting

- Flow velocity entering the facility shall be less than 1 ft/sec for the 100-year, 24-hour storm event. If 1 ft/sec can not be obtained, a designed flow dispersion or energy dissipation device may be required depending on the type of inlet and size of facility.
- Use one of the following types of flow entrances (other alternatives may be considered on a case-by-case basis):
    - Dispersed, low velocity flow across a grade or landscape area. A minimum 2-inch grade change between the edge of the contributing area and the flow entrance is required.
    - Dispersed flow across pavement or gravel and past wheel stops for parking areas. A minimum 2-inch grade change between the edge of the contributing area and the flow entrance is required. A transition zone of 1 foot shall be provided at a 2% slope. This shall include 6-inches of subgrade material (crushed rock), modular pavement, drain rock or other material acceptable to the City.
    - Dispersed curb cuts for driveway or parking lot areas. A minimum 2-inch grade change between the edge of a contributing area and the flow entrance is required. Place rock or other erosion protection material in the channel entrance to dissipate energy. A minimum 1-foot gravel pad in the bottom of the facility shall be provided.
    - Pipe flow entrance. The inlet pipe invert elevation shall be higher than the overflow elevation. Place rock or other erosion protection material at the facility entrance to dissipate energy and/or provide flow dispersion.

- Do not place plants directly in the entrance flow path as they can restrict or concentrate flows.
- Install flow diversion and erosion control measures to protect the bioretention area from sedimentation until the upstream area is stabilized.
- If the catchment area exceeds 2,000 square feet, a presettling facility may be required.

Cell Ponding Area

- The surface pool drawdown time shall be less than 24 hours.
- The bottom of the ponding area shall be level.
- Side Slopes shall be no steeper than 3H:1V. Fencing may be required where determined applicable by Environmental Services.
- Bioretention sizing is based on bottom area. Once bottom area is determined, top area shall be based upon side slopes and total depth of facility.
- The minimum freeboard measured from the overflow elevation to the top of the facility shall be 2” for drainage areas less than 1,000 square feet and 6” for drainage areas 1,000 square feet or greater.
- If berming is used to achieve the minimum top elevation, maximum slope on berm shall be 3H:1V, and minimum top width of design berm shall be 1 foot. Soil for berming shall be imported bioretention soil or amended native soil compacted to a minimum of 90% dry density.

Overflow

- Unless designed for full infiltration of the entire runoff volume, bioretention systems must include an overflow.
- A drain pipe installed at the designed maximum ponding elevation and connected to a downstream BMP or an approved discharge point can be used as the overflow.
- Overflows shall be designed to convey the 100-year recurrence interval flow or maximum flow that can reach the facility if a flow splitter is utilized.
- Overflow channels shall be rock-lined.
- An emergency overflow pathway shall be provided for all facilities to ensure that all potential overflows are directed into the downstream conveyance system or the public right of way.
- See Volume 3, Chapter 11 for additional guidance on rock protection.

Bioretention Soil Mix

For bioretention systems to meet the requirements for basic and enhanced treatment, the following requirements must be met:

The bioretention soil mix (BSM) shall:

- Have a 60% aggregate component as represented in Table 6 - 1 below and a 40% compost component as represented in Table 6 - 2 below.

Table 6 - 1: Bioretention Soil Mix Aggregate Component Gradation

Aggregate Component (60% by Volume)	
Sieve Size	Percent Passing
3/8”	100
#4	95-100
#10	75-90
#40	25-40
#100	4-10
#200	2-5

- The compost component shall be stable, mature, and derived from organic waste materials including yard debris, wood wastes or other organic matter. Compost must meet the Washington State compost regulations in WAC 173-350, which is available at http://www.ecy.wa.gov/programs/swfa/compost and the following:
  - Have a compost component meeting the size requirements in Table 6 - 2.

Table 6 - 2: Bioretention Soil Mix Compost Component Gradation

Compost Component	
Sieve Size	Percent Passing
1”	99-100
5/8”	90-100
1/4”	40-90

  - Have a pH between 5.5 and 8.0.
  - Have a manufactured inert material (plastic, concrete, ceramics, metal, etc.) less than 1.0% by weight
  - Have a organic matter content between 45 and 65 percent dry weight bases as determined by TMECC 05.07A, “Loss-On-Ignition Organic Matter Method”.
  - Have a soluble salt content less than 6.0 mmhos/cm tested in accordance with TMECC 04.10-A, “1.5 Slurry Method, Mass Basis”.
  - Have a maturity greater than 80% in accordance with TMECC 05.05-A, “Germination and Vigor”.
  - Have a stability at 7 or below in accordance with TMECC 05-08.B, “Carbon Dioxide Evolution Rate”.
  - Contain a minimum of 65% and up to 100% by volume recycled plant waste as defined in WAC 173-350-100 as “Type 1 Feedstocks.” A maximum of 35% by volume of other approved organic waste as defined in WAC 173-350-100 as “Type III”, including post-consumer food waste but not including biosolids, may be substituted for recycled plant waste.
  - Have a carbon to nitrogen ratio of less than 25:1 as determined using TMECC 04.01 “Total Carbon” and TMECC 04.02D “Total Kjeldhal Nitrogen”. A ratio up to 35:1 can be used if all plants are native species.

The Washington State Department of Ecology keeps a list of approved composting facilities in Washington at: http://www.ecy.wa.gov/programs/swfa/compost/

- Minimum depth of bioretention soil mix must be 18 inches.
- Contact Environmental Services for assistance in verifying bioretention soil mix suitability.

Underdrain

Only install underdrains in bioretention areas if:

- Infiltration is not permitted and/or a liner is used, or
- Where infiltration rates are not adequate to meet the maximum pool drawdown time, or
- Where the facility is not utilized for infiltration.

Underdrain pipe diameter will depend on hydraulic capacity required, 6-inch minimum.

Slotting/perforations should not be less than 0.5% of drain surface unless specified otherwise by engineer.

Slots/perforations should not be smaller than the smallest aggregate of the gravel filter. AASHTO M278 pipe may be utilized.

Install hard plastic, non-corrugated, non-perforated cleanouts every 100 feet and at the end of each pipe for maintenance access.

Underdrains shall be designed with a 1 foot width of gravel filter media on either side of the underdrain pipe. A minimum of 6 inches of underdrain media shall be below the pipe and 12 inches of media shall be placed above the pipe. Use care when placing filter media atop underdrain to avoid crushing the pipe section.

For slotted pipe, filter media shall be ¾” clean aggregate (Type 26 is acceptable). For perforated pipe, filter media shall be ¾” to 1 ½ clean washed rock (Type 57 is acceptable). All filter media shall be double washed to ensure removal of fines.

Underdrains connected directly to a storm drainage structure must be non-perforated for at least 2 feet from the structure interface.

NOTE: Facilities with underdrains will not qualify for flow credits.

Soils Report

For facilities that infiltrate and do not have an underdrain, a soils report, prepared by a soils professional, shall be required in accordance with Volume 3, Section 2.2.8 for flow control or Volume 5, Section 5.4 for water quality.

Planting

- Plants must be tolerant of summer drought, ponding fluctuations, and saturated soil conditions.
- Consider rooting depth when choosing plants. Roots must not damage underground infrastructure.
- Locate slotted and perforated pipe at least 5 feet from tree roots and side sewer pipes.
- Consider adjacent plant communities and avoid potential invasive species.
- Consider aesthetics, rain gardens should blend into surrounding landscapes.

- The “Low Impact Development: Technical Guidance Manual for Puget Sound” is a good tool for selecting proper bioretention plants.
- Submit a planting plan showing the type, location and size of each plant.
- Irrigation may be required until plants are fully established and in the summer months.

Mulch Layer

Bioretention facilities should be designed with a mulch layer. Properly selected mulch material reduces weed establishment, regulates soil temperatures and moisture, and adds organic matter to soil.

- Mulch should 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, mineral aggregate or pure bark.
- Mulch shall be:
  - Compost in the bottom of the facilities, depth 3 inches
  - Wood chip mulch composed of shredded or chipped hardwood or softwood on side slopes, depth 4 inches.
- A dense groundcover can be used as an alternative to mulch although mulch shall be required until the dense groundcover is established.

Modeling and Sizing

Rain gardens may be utilized as a flow control facility, as a water quality facility, or as a combined water quality and flow control facility.

Table 6 - 3 provides sizing for on-site stormwater management. Table 6 - 3 provides the square footage of the bottom of the rain garden per 1000 square feet of impervious area.

This method of sizing can be used for rain gardens receiving runoff from pollution generating surfaces if the facility does not have to be sized to meet Minimum Requirement #6, Water Quality.

Table 6 - 3: Sizing Table for Rain Gardens

Native Soil Type	Rain Garden Bottom Area (square feet)
Coarse sands and cobbles	50
Medium sands	50
Fine sands,loamy sands	50
Sandy loam	50
Loam	150

For facilities sized to meet Minimum Requirement #6, Water Quality:

Use WWHM and model the facility as an infiltration facility with appropriate stage-storage and overflow/outflow rates. Alternatively, use the bioretention swale element available in some versions of WWHM. The tributary area, cell bottom area, and ponding depth should be iteratively sized until 91% of the runoff file volume is infiltrated. The remaining 9% of the runoff volume may be discharged through the overflow untreated or the facility may be sized to treat 100% of the runoff volume. The surface pool drawdown time shall be 24 hours or less. Size the facility using the lowest of the following:

- The infiltration rate of the underlying soil with no correction factor applied (estimated using either method 1 or 3 as described in Volume 5, Chapter 7), or
- The infiltration rate of the bioretention soil mix as given in Table 6 - 4.

For facilities sized to meet Minimum Requirement #7, Flow Control:

Use WWHM and model the facility as an infiltration facility or bioretention swale with appropriate stage-storage and overflow/outflow rates. The tributary area, cell bottom area, and ponding depth should be iteratively sized until the duration curves and/or peak volumes meet the flow control requirements. The surface pool drawdown time shall be 24 hours or less. Size the facility using the lowest of the following:

- The infiltration rate of the underlying soil with no correction factor applied (estimated using either method 1 or 3 as described in Volume 3, Section 6.5), or
- The infiltration rate of the bioretention soil mix as given in Table 6 - 4.

Table 6 - 4: Modeling Assumptions for Rain Gardens

Variable	Assumptions
Computational Time Step	15 minutes
Inflows to Facility	Surface flow and interflow from drainage area routed to facility
Precipitation and Evaporation applied to Facility	Yes
Bioretention Soil Infiltration Rates	For sites that have a contributing area of less than 5,000 square feet of pollution-generating surfaces, less than 10,000 square feet of impervious area, and less than 3/4 acre of landscaped area, the bioretention soil infiltration rate including the factor of safety shall be 3 inches per hour. For sites above these thresholds, the bioretention soil infiltration rate including the factor of safety shall be 1.5 inches per hour.
Bioretention Soil Porosity	40%
Bioretention Soil Depths	Minimum of 18 inches
Native Soil Infiltration Rate	Measured infiltration rate with applicable safety factors. See Volume 3 for more information on infiltration rate determination.
Infiltration Across Wetted Surface Area	Only if sides slopes are 3:1 or flatter
Overflow	Overflow elevation set at maximum ponding elevation (excluding freeboard). May be modeled as weir flow over riser edge or riser notch.

Rain garden infiltration rates shall be determined as outlined in this manual based on facility function.

General Construction Criteria

- Do not install or excavate during soil saturation periods.
- Excavation and soil placement should be done from a backhoe operating adjacent to the facility – no heavy equipment should be operated in the facility if possible.

- If equipment must be operated within the facility, use lightweight, low ground pressure equipment and scarify the base to reduce compaction upon completion.
- Do not use fully excavated bioretention facilities for erosion and sedimentation control during construction;
  - Consider partial excavation of bioretention cells prior to construction (to within 12 inches above finished bottom grade) for use as temporary stormwater detention.
- Clogged soil and silt shall be removed during excavation to finished bottom grade prior to installing bioretention cell profile.
- Scarify sides and bottom to roughen where heavy equipment may have compacted soil.
- Ensure the bioretention facility is protected from erosion and sedimentation until all contributory areas are fully stabilized.
- If sedimentation occurs within the bioretention facility, excavate the area a minimum of 12 inches below final grade to remove sediment.

Maintenance Criteria

- Make provision for regular and perpetual maintenance of the bioretention facility.
- Include access for operation and maintenance in system design.
- Refer to the Bioretention Maintenance Standards included in Volume 1 Appendix D.

2.2.4.2 BMP L631 Vegetated Rooftops (Green Roofs)

Purpose and Definition

A vegetated rooftop, also known as a green roof, is a rooftop that is partially or completely covered with vegetation and a growing medium planted over a waterproofing membrane. The green roof will also contain a root repelling membrane and drainage system.

Applications and Limitations

Vegetated rooftops offer a practical method of managing runoff in densely developed urban neighborhoods and can be engineered to achieve specific stormwater runoff control objectives.

Design Guidelines

- Soil or growth media must have a high field capacity.
- Soil or growth media must have a saturated hydraulic conductivity of ≥1 inch/hour.
- Drainage layer must allow free drainage under the soil/growth media.
- Vegetative cover must be both drought and wet tolerant.
- There must be a waterproof membrane between the drain layer and the structural roof support.
- The maximum slope shall be 20%.
- The roof support structure shall be analyzed by a structural engineer to address the weight of the green roof, including any potential ponded water.
- An overflow system shall be included in design to safely convey the 100-year peak flow from the roof.
- The system shall include a way to drain the roof for maintenance purposes.

Flow Credits for Vegetated Roofs

Where vegetated roofs are used, the impervious areas may be modeled based on the thickness of the soil media:

- For roofs with 3-8” of soil/growing media, model the roof as 50% till landscaped and 50% impervious.
- For roofs with ≥8” of soil/growing media, model the roof as 50% till pasture and 50% impervious.

Maintenance Criteria

Per Minimum Requirement #10, an operation and maintenance manual shall be prepared for all stormwater management facilities. See Volume 1, Appendix D, Maintenance Checklist #26 for specific maintenance requirements for vegetated roofs. Maintenance shall be a basic consideration in design and cost-determination of the stormwater management facility.

Any standing water removed during the maintenance operation must be disposed ofin a City-approved manner. See the dewatering requirements in Volume 4 of this manual. Pretreatment may be necessary. Solids must be disposed of in accordance with state and local waste regulations.

Resource Material

Miller, C. and Grantley Pyke. Methodology for the Design of Vegetated Roof Covers, Proceedings of the 1999 International Water Resources Engineering Conference, Seattle, Washington.

2.2.4.3 BMP L632 Rainfall Re-use Systems

Purpose and Definition

Rainfall re-use systems are designed to collect stormwater runoff from non-pollution generating surfaces and make use of the collected water. Rainfall re-use systems are also known as rainwater harvesting systems and rainfall catchment systems.

Applications and Limitations

Approval of the water re-use system requires approval of the appropriate state and local agencies as required for any water right.

Design Guidelines

- If a rainwater re-use system holds more than 6 inches depth of water, it should not be accessible except for maintenance purposes.
- Design and maintain the system to minimize clogging by leaves and other debris.

Flow Credits for Rainfall Re-use Systems

The drainage area to the rainfall re-use system does not need to be entered into the runoff model when:

- 100% of the annual average runoff volume (using WWHM) is re-used, or
- Interior uses have a monthly water balance that demonstrates adequate capacity for each month and re-use of all stored water annually.

Maintenance Criteria

Per Minimum Requirement #10, an operation and maintenance manual shall be prepared for all stormwater management facilities. See Volume 1, Appendix D, Maintenance Checklist #24 for specific maintenance requirements for cisterns. Maintenance shall be a basic consideration in design and cost-determination of the stormwater management facility.

Any standing water removed during the maintenance operation must be disposed ofin a City-approved manner. See the dewatering requirements in Volume 4 of this manual. Pretreatment may be necessary. Solids must be disposed of in accordance with state and local waste regulations.

2.2.4.4 BMP L633 Permeable Paving Surfaces

Purpose and Definition

Alternate paving surfaces include porous asphalt pavement, porous concrete, grid and lattice rigid plastic or paving blocks where the holes are filled with soil, sand, or gravel; and cast-in-place paver systems. Porous surfaces are designed to accommodate pedestrian, bicycle, and auto traffic while allowing infiltration and storage of stormwater.

Alternate paving systems may be designed with an underdrain to collect stormwater or without an underdrain as an infiltration facility.

Applications and Limitations

- Alternate paving systems can generally be used where traditional paving surfaces are used.
- Infiltration through pervious pavement surfaces shall not be allowed with land uses that generate heavy pollutant loads. The potential sediment loading for each application should be considered when determining if the application of alternate surfaces is appropriate.
- No point discharges may be directed to porous surfaces.
- Sheet flow runoff may be directed onto a porous surface provided that the length of sheet flow across the paved section is no more than twice the length of sheet flow across the porous pavement section, and provided it is not a source of increased contamination.
- Three feet of separation is required between the lowest elevation of the pavement base material and the seasonal high groundwater elevation or other impermeable layer if the area tributary to the facility requires compliance with Minimum Requirement #6 or Minimum Requirement #7.
- For facilities with contributing areas less than the above thresholds, a minimum of 18 inches of separation is required between the lowest elevation of the base layer and the seasonal high groundwater or other impervious layer.
- For facilities with underdrains, the seasonal high groundwater elevation or other impermeable layer shall be below the lowest elevation of the base material or underdrain collection system. Separation shall be such that groundwater will not migrate into the underdrain system.

Design Criteria

- Unless approved in writing by Environmental Services, maximum slopes for alternative paving surfaces are:
  - 5% for porous asphalt
  - 6% for porous concrete
  - 10% for interlocking pavers
  - 5-6% grid and lattice systems
- For areas with slopes over 2%, check dams may be required.
- Follow manufacturer’s recommendations for design, installation, and maintenance.
- Subgrade infiltration rates less than 2.4 inches/hour and a cation exchange capacity of 5 milliequivalents CEC/100 grams dry soil (or greater) will provide water quality treatment.

- Typical cross-sections of porous paving systems consist of:
  - A top layer with either porous asphalt, porous concrete, concrete block pavers, or a plastic grid paver filled with sand topsoil or gravel.
  - An aggregate subbase with larger rock at the bottom and smaller rock directly under the top surface.
  - For open-celled paving grids and blocks, a leveling course consisting of finer aggregate.
  - A geotextile fabric
- Both gravel and soil with vegetation can be used to fill the opening in paver and rigid grid systems. Manufacturer recommendations should be followed to apply the appropriate material.
- Porous systems that use pavers shall be confined with a rigid edge system to prevent gradual movement of the paving stones.
- When pervious pavement is adjacent to standard pavement, a geomembrane liner is recommended, and may be required to protect the standard pavement subbase.
- Subgrade layer:
  - Compact the subgrade to the minimum necessary for structural stability. Do not allow heavy compaction. The subgrade should not be subject to truck traffic.
  - Use on soil types A through C.
  - Subgrade may need to be scarified prior to installation.
- Geotextile
  - Use geotextile between subgrade and base material to keep soil out of base layer.
  - The geotextile must pass water at a greater rate than the subgrade soils.
- Separation or Bottom Filter Layer (optional but recommended)
  - A layer of sand or crushed stone graded flat is recommended to promote infiltration across the surface, stabilize the base layer, protect the underlying soil from compaction, and serve as a transition between the base course and the underlying geotextile.
- Base Material

  Material must be free draining. See Chapter 6 of the “Low Impact Development: Technical Guidance Manual for Puget Sound” for more detailed information.
- Wearing Layer
  - A minimum infiltration rate of 10 inches/hour is required though higher infiltration rates are desirable.
  - For *porous asphalt*, products must have adequate void space, commonly 12-20%.
  - For *porous concrete*, products must have adequate void space, commonly 15-21%.
  - For *grid/lattice systems* filled with gravel, sand, or a soil of finer particles with or without grass, fill must be at least 2”. Fill should be underlain with 6” or more of sand or gravel to provide an adequate base. Locate fill at or slightly below the top elevation

the top elevation of the grid/lattice structure. Modular grid openings must be at least 40% of the total surface area.

  - For *paving blocks*, fill spaces between blocks with 6" of free draining sand or aggregate material. Provide a minimum of 12% free draining surface area.

- Drainage Conveyance
  - Design roads with adequate drainage conveyance facilities if the road surface was impermeable.
  - Design drainage flow paths to safely move water away from the road prism and into the roadside drainage facility for roads with base courses that extend below the surrounding grade.
- Acceptance Test
  - Test all permeable surfaces by throwing a bucket of water on the surface. If anything runs off the surface or puddles, additional testing is necessary prior to accepting the construction.
  - As directed by Environmental Services, test with a 6" ring infiltrometer or sprinkle infiltrometer. Wet the road surface continuously for 10 minutes. Test to determine compliance with 10 inches/hour minimum infiltration rate.
  - For facilities designed to infiltrate, the bucket test shall be completed annually.
  - Test documentation shall be retained with maintenance records.

Maintenance

- Follow manufacturer's suggestions for maintenance.
- Inspect project upon completion to correct accumulation of fine material. Conduct periodic visual inspections to determine if surfaces are clogged.
- Sweep non-planted surfaces with a high-efficiency sweeper twice per year, one in autumn and one in early spring. Sweeping frequency can be reduced if infiltration rate testing indicates that a rate of 10 inches/hour or greater is being maintained.
- Maintenance records shall be retained and provided to the City upon request.

Flow Credits for Alternate Paving Systems

Flow credits for alternate paving systems are based on the base material and type of alternate surface. The following lists the possible credits that can be achieved by using alternative paving systems:

- For porous asphalt or concrete systems used as public road or public parking lot configurations where base material is laid above surrounding grade:
    - Without an underdrain, model the surface as grass over underlying soil type.
    - With an underdrain either at or below the bottom of the base layer or elevated within the base course, model the surface as impervious.
- For porous asphalt or concrete systems used as public road or public parking lot configurations where base material is laid partially or completely below surrounding grade:
    - Without an underdrain, model the surface as grass over underlying soil type or impervious surface routed to an infiltration.
    - With an underdrain at or below bottom of base layer or elevated within the base course, model the surface as impervious.
- For porous asphalt or concrete systems used at private facilities such as driveways, parking lots, walks and patios where the base material is laid below ground:
    - Without an underdrain, model the surface as 50% grass on underlying soil and 50% impervious.
    - With a pipe underdrain, model the surface as impervious.
- For grid/lattice systems and paving blocks used as public road or public parking lot where base material is laid above the surrounding grade:
    - Without an underdrain, model grid/lattice systems as grass on underlying soil and model paving blocks as 50% grass on underlying soil with 50% impervious.
    - With an underdrain, model the surface as impervious.
- For grid/lattice systems and paving blocks used as public road or public parking lot where base material is laid partially or completely below surround ground:
    - Without an underdrain, model grid/lattice systems as grass on underlying soil and model paving blocks as 50% grass with 50% impervious or model both grid/lattice systems and paving blocks as impervious surfaces routed to an infiltration basin.
    - With an underdrain, at or below bottom of the base layer, model the surface as impervious.
- With an underdrain elevated within the base course, model the surface as impervious routed to an infiltration basin.
- For grid/lattice systems and paving blocks used at private facilities (driveways, parking lots, walks, patios, etc.) where base material is laid partially or completely below surrounding ground:
    - Without an underdrain, model the surface as 50% grass and 50% impervious.
    - With an underdrain, model the surface as impervious.

2.2.4.5 BMP L634 Minimal Excavation Foundations

Purpose and Definition

Minimal excavation foundation systems are those techniques 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. Pin foundations are an example of a minimal excavation foundation.

Applications Limitations

- Suitable for pier and perimeter wall configurations for residential or commercial structures up to three stories high.
- Useful for elevated paths and foot-bridges in environmentally sensitive areas.
- Heavy equipment cannot be used within or immediately surrounding the building. Terracing of the foundation area may be accomplished by tracked, blading equipment not exceeding 650 psf.

Design Criteria

See Chapter 6 of “Low Impact Development: Technical Guidance Manual for Puget Sound” for design information.

Flow Credits for Minimal Excavation Foundation Systems

- Where roof runoff is dispersed on the up gradient side of a structure in accordance with the design criteria in “Downspout Dispersion”, model the tributary roof area as pasture on the native soil.
- Where “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.

  $$A_1 - \frac{dC(0.5)}{dP} \times A_1 = A_2$$

  Where:

  A_1 = roof area draining to up gradient side of structure

  dC = depth of cuts into the soil profile

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

  A_2 = 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 “Downspout Dispersion”, and there is at least 50 feet of vegetated flow path through native material or lawn/landscape area that meets the guidelines in BMP L613 of Volume 5, Chapter 5, model the tributary roof areas as landscaped area.

2.2.4.6 BMP L635 Reverse Slope Sidewalks

Definition and Purpose

Reverse slope sidewalks are sloped to drain away from the road and onto adjacent vegetated areas.

Design Criteria for Reverse Slope Sidewalks

- There must be ≥10 feet of vegetated surface downslope that is not directly connected into the storm drainage system.
- Vegetated area receiving flow from sidewalk must be native soil or meet the guidelines in BMP L613: Post-Construction Soil Quality and Depth.
- Provide a vegetated buffer width of 10 feet of vegetation for up to 20 feet of width of paved or impervious surface. Add an additional 5 feet of width for each additional 20 feet of width or fraction thereof.

Flow Credits for Reverse Slope Sidewalks

- Model the sidewalk area as landscaped area over the underlying soil type.