Pierce County
Draft Stormwater Management and Site Development Manual

Volume VI
Low Impact Development

Prepared by:
Pierce County Surface Water Management

Ordinance No. 2008–59S
August 2008
Effective Date: March 1, 2009

♻ *printed on recycled paper*

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

Table of Contents

Tables

Figures

Chapter 1 - Introduction

Low impact development (LID) is a term generally used to describe a land use development strategy that emphasizes protection and use of onsite natural features integrated with engineered, small-scale hydrologic controls at the parcel and subdivision scale to manage stormwater and more closely mimic predevelopment watershed hydrologic functions. LID techniques are increasingly being looked to as an alternative to traditional, structural stormwater management solutions. In addition, individual LID best management practices (BMPs) as outlined in this volume can play an integral role in meeting the minimum requirements applicable to any stormwater design, even if the overall project is not entirely an LID project. In order to be considered a full/comprehensive LID development project, the project must adhere to all of the requirements of this volume.

1.1 Volume Intent

The purpose of this volume is twofold. First, this volume provides a mechanism to utilize an alternative method of stormwater management referred to as low impacts development (LID). LID strategies meet multiple objectives such as open space, critical area, and habitat protection while still meeting the standards and requirements set forth under the county’s National Pollutant Discharge Elimination System (NPDES) permit and growth management act (GMA) density requirements. Second, this volume presents design requirements for several LID BMPs that can potentially be used for any stormwater design – LID or traditional.

This volume outlines both the performance goal and objectives, and prescriptive standards necessary to evaluate the application of LID methods as an effective stormwater management tools, both as a comprehensive design approach as well as through a la carte BMP selection.

1.2 Applicability

The primary focus for application of LID approaches is new development (residential, commercial, and industrial) that occurs within urban growth management areas. However, this methodology can also be applied to development within the rural setting and in redevelopment of highly urbanized areas.

At the time of adoption of this volume, the LID approaches and BMPs outlined herein are encouraged for all private development. Pierce County is in the process of developing public road standards for LID, however until those guidelines are finalized, LID approaches in the right-of-way require prior approval by the county engineer.

Though encouraged, the use of the LID design approach or individual LID BMPs in this volume shall be considered voluntary by the applicant, unless it is mandated through a county planning process or other implementing ordinances or regulations.

Low impact development can be applied to a variety of zoning and physical land classifications to protect water resources, and specifically should be considered for the following:

- Sites located in a pothole subbasin (i.e., draining to a closed depression)
- Sites that contain or are located adjacent to wetlands, riparian areas (such as rivers, streams, creeks, or swales), fish or wildlife habitat areas, tidal marshes, estuaries, or Puget Sound marine shorelines or the subbasins tributary to these areas if changes in the land use will result in any negative impacts caused by the increase in volume or rate of surface water leaving or arriving to these areas
- Sites that are underlain by a critical aquifer recharge area
- Sites located within a designated open space area
- Subbasins where preservation of trees is recommended by a basin or community plan.

1.3 Administration

1.3.1 Compliance with the Provisions of this Volume

The application of the comprehensive LID design approach is designed to reduce total and effective impervious areas to less than 10 percent, retain or restore native soils and vegetation (a target of 65 percent for residential and 25 percent for commercial developments), and reduce the overall development footprint. Among other benefits, this approach may result in the significant reduction or elimination of traditional stormwater collection, storage, and treatment system requirements outlined in Volumes I, III, and V of this manual. All other provisions contained in this volume shall apply to a comprehensive LID proposal unless specifically specified otherwise in this volume.

A successful comprehensive LID design approach will use a combination of the prescriptive standards set forth in Chapter 2 to achieve the performance goal and objectives outlined in Section 1.4. Some prescriptive standards may be identified as mandatory or minimum requirements (noted with a “shall” or other affirmative directive statement) and are therefore required to be integrated into the final design.

Where LID is required by a community plan or other requirement, it will be at the discretion of the county review staff to determine whether the performance goal and objectives have been adequately achieved through the LID design. Whether LID is voluntary or required, the applicant is required to meet, at a minimum, the requirements set forth in Volumes I through V of this manual.

1.3.2 Submittal Requirements

LID design proposals shall comply with the submittal requirements outlined in Volume I, Chapter 3 of this manual. In addition, an application for a short plat, preliminary plat, large lot, or land use which has proposed an LID design shall also include a site inventory (see section 2.2.1), preliminary road and stormwater design calculations to assure that the design of stormwater treatment for the site has been adequately considered during the lot and open space layout process. Finally, LID design proposals must also meet any applicable maintenance, management, or ownership submittal requirements outlined in Section 4.2.

1.3.3 Deviations

LID projects that require a deviation from existing county codes shall utilize a planned development district (PDD). However, any proposed deviations from the road standard requirements outlined in Title 17B Pierce County Code (PCC) – Road and Bridge Standards, must meet the minimum road standards as set forth in Section 2.4. Roadway section details for private roads will not require a deviation to Title 17B PCC.

1.4 Performance Goal and Objectives

This section outlines the performance goal and objectives that govern the review of any proposed comprehensive LID design approach. These may also apply to a la carte application of LID BMPs, but are specifically intended to guide projects implementing a comprehensive LID site design approach.

The goal of low impact development is to manage stormwater generated from new development and redevelopment so there will be no negative impacts to adjacent and/or downstream property owners, and no degradation to groundwater or surface waters (such as but not limited to streams, ravines, wetlands, potholes, and rivers).

The LID site design goal shall be achieved through adherence to the following objectives:

- Minimize the impacts of increased stormwater runoff from new impervious surfaces and land cover conversions by maintaining peak flow frequencies and durations of the site's undisturbed hydrologic condition. In the Puget Sound lowlands, the historic hydrologic condition is near zero overland flow runoff and this objective, in concert with other objectives, is meant to closely achieve that condition. To provide a quantifiable and measurable standard for flow control on LID projects, Minimum Requirement #7 outlined in Volume I must be adhered to in addition to meeting the other objectives listed below.

- Retain or restore 65 percent of the residential site's native soils and vegetation (25 percent for commercial) and set aside these areas into permanent open space areas such as within a natural resource protection area, a conservation easement, or designated tract for the stormwater drainage system. Where 65 percent (25 percent for commercial) is not achieved, the applicant will demonstrate that the mandatory use of other LID techniques, as outlined in the standards contained in Chapter 2, have been met.

- Limit the effective impervious area of the site to no more than 10 percent. However, it should be demonstrated through the site layout and combined use of LID BMPs that every attempt was made to achieve near zero effective impervious area within the site.

- Retain and incorporate natural site features that promote infiltration of stormwater on a developed site.

- Utilize LID BMPs as outlined in Chapter 3 and minimize the use of traditional conveyance and pond technologies to manage stormwater quality and quantity.

- Manage stormwater as close to the origin as possible.

Chapter 2 - Low Impact Development Strategies and Applications

2.1 Introduction

Low impact development design concepts include a variety of strategies and techniques to address the negative impacts associated with stormwater runoff. The following sections provide an overview of each LID strategy and, where appropriate, establish targets or prescriptive standards for achieving the LID site design performance goal and objectives set forth in Section 1.4. It is important to note that LID design is an iterative process, which encourages ingenuity in the site layout and use of LID techniques to tailor a design to each individual site.

2.2 Conduct a Site Analysis Prior to Designing an LID Project

The site analysis is a method of evaluating the topography, soils, vegetation, and water features to determine how the site currently processes stormwater. This evaluation provides information essential for developing strategies to configure lots, determine where best to locate natural resource protection areas, and align road networks in a way that retains and restores natural hydrologic function. See also Volume I, Section 1.4.

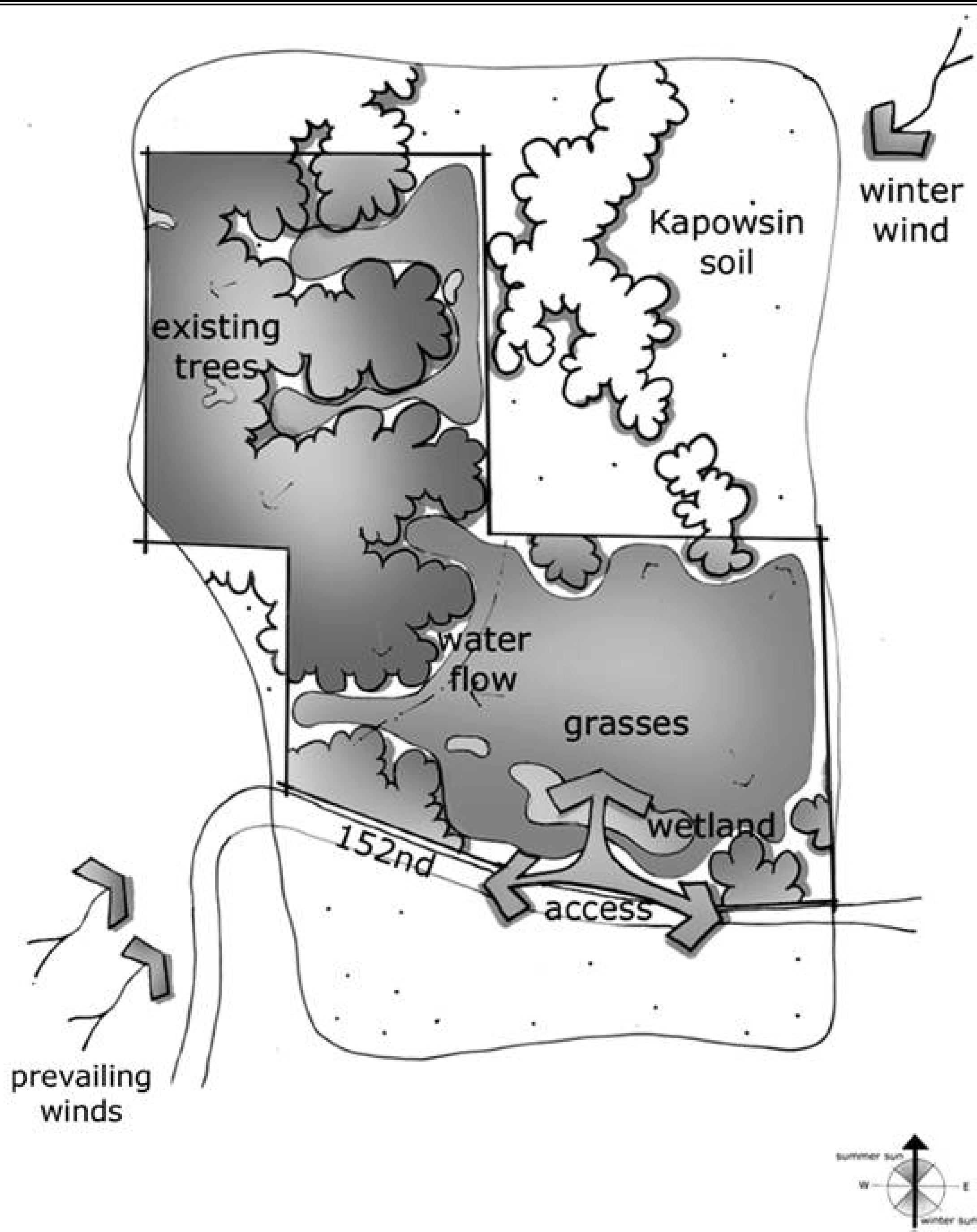
2.2.1 Site Inventory Process

A site inventory is a required component of an LID design and shall be submitted with the application for the project. Environmental features shall be inventoried on the proposed development site prior to the site planning process. In addition, important site characteristics on adjacent properties shall be assessed to identify how the project will impact or be influenced by the surrounding area. The functions of these environmental features shall be assessed for performance at both the site scale and at the watershed scale to determine potential impacts (see Figure 2.1).

An inventory of the environmental features will be used to produce an LID site plan that identifies natural resource protection areas (e.g., riparian areas, wetlands, steep slopes, and other critical areas; significant wildlife habitat areas and their associated buffers; tree conservation areas; and permeable soils offering the best available infiltration potential) as well as areas to direct development.

At a minimum, the following process for identifying natural resource protection areas shall be applied:

- Identify critical areas and associated buffers as set forth in Title 18E PCC – Critical Areas.



Not to Scale

Figure 2.1. Site Inventory.

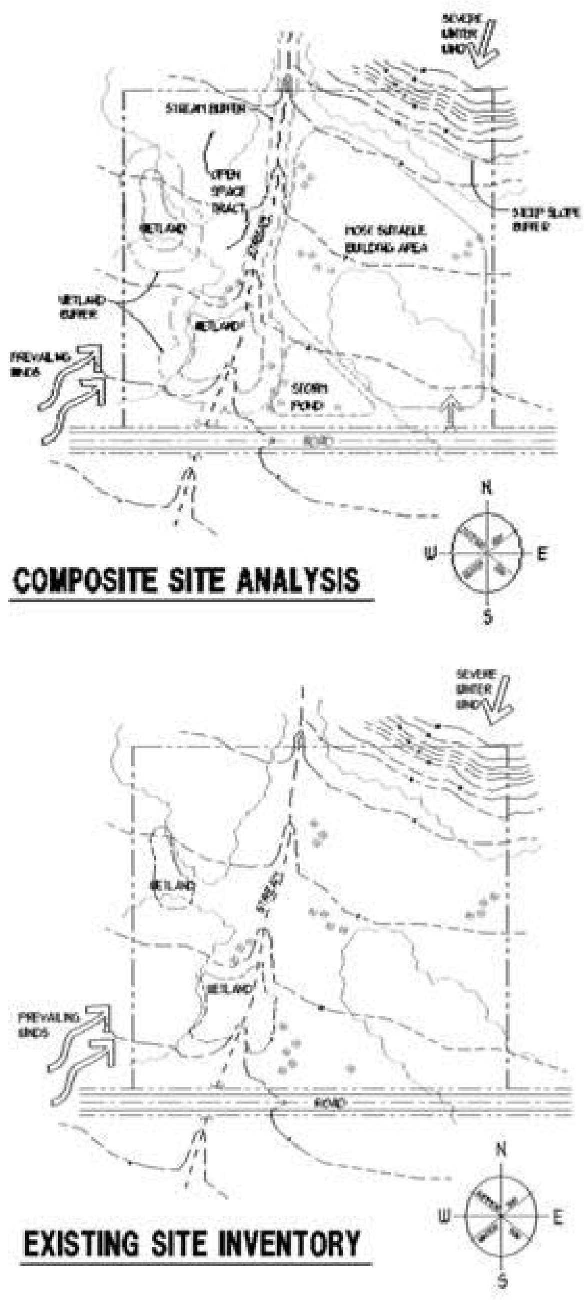
- Identify any tree conservation areas as set forth in Title 18H PCC – Forest Practices and Tree Conservation Regulations. This should include the tree species, seral stage, diameter breast height, canopy cover, and condition of groundcover and shrub layer.
- Identify underlying soils on the site utilizing soil pits and soil grain analysis to assess infiltration capability on site. (Note: frequency and distribution of soil pits shall be adequate to direct placement of the roads and structures away from soils that can most effectively infiltrate stormwater.)
- Identify topographic features that may act as natural stormwater storage/conveyance and underlying soils that provide opportunities for storage and partial infiltration.
- Identify potential wildlife movement corridors.

2.2.2 Site Design Process

The initial inventory process outlined in Section 2.2 will provide the baseline information necessary for the site design. Development areas shall be located outside of the natural resource protection areas (identified in Section 2.2.1) and within designated buildable areas to minimize soil and vegetation disturbance and take advantage of a site’s natural ability to store and infiltrate stormwater (see Figure 2.2). Guidelines for the LID site design process include:

- To the maximum extent practicable, retain 65 percent of the site in vegetated open space or natural resource protection areas preferably in contiguous blocks or linear corridors where feasible, for the protection of the best stormwater management features identified in the site analysis process. The open space layout should be situated in a location that will have the most success at providing a buffer next to impervious surfaces.

  Residential developments must retain a minimum of 50 percent of the site and commercial developments must maintain a minimum of 25 percent of the site as vegetated open space. See Section 2.3 for related requirements, and Chapter 3 for BMPs required to mitigate for the reduction in vegetated open space.
- Limit effective impervious areas to less than 10 percent for both residential and commercial developments. See Section 2.3 for related requirements. Techniques to reduce the amount of effective impervious areas via roads, walkways, and roofs are provided in Section 2.4. Additional mitigation BMPs are provided in Chapter 3.

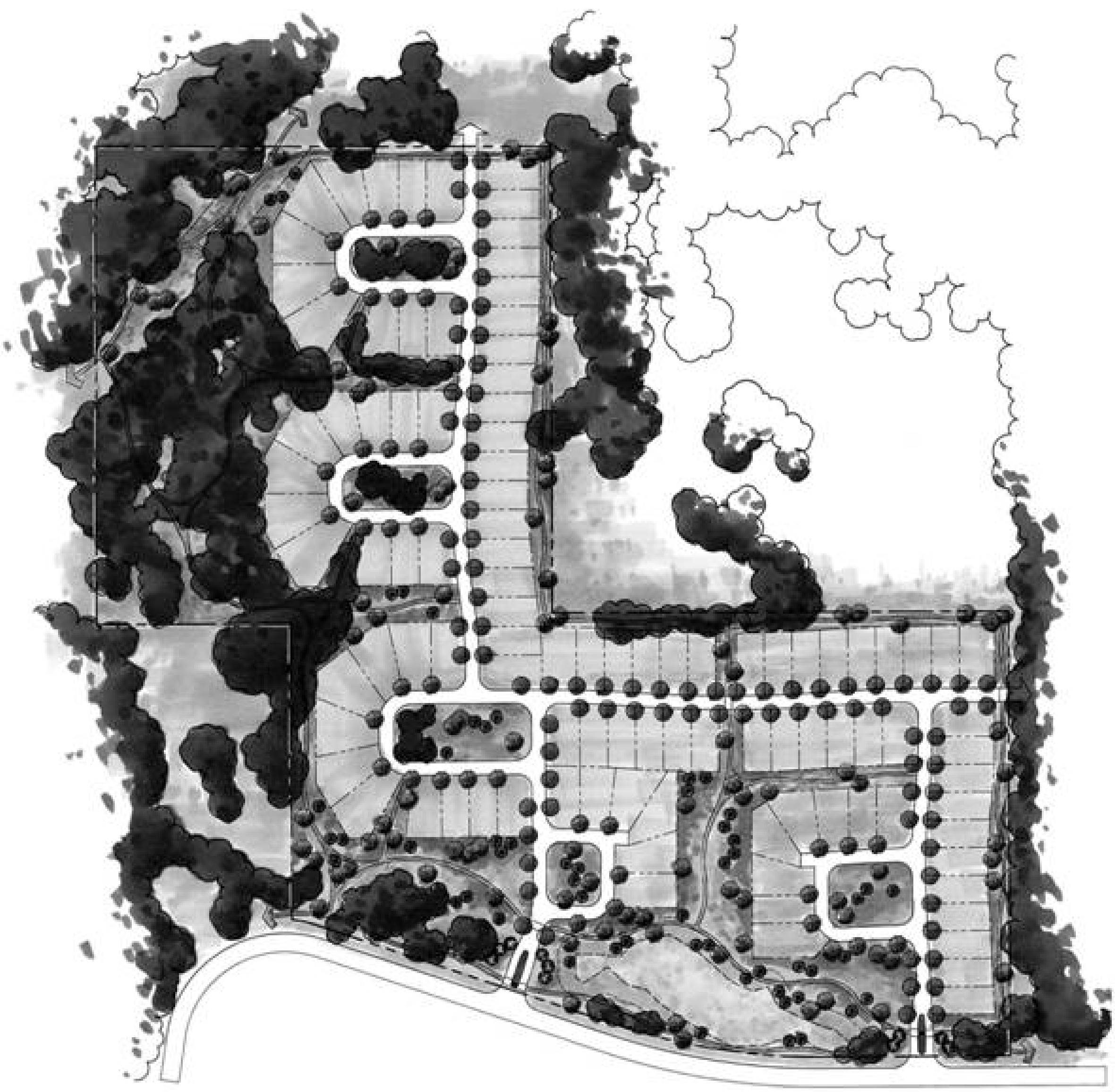


Not to Scale

Figure 2.2. Composite Site Inventory.

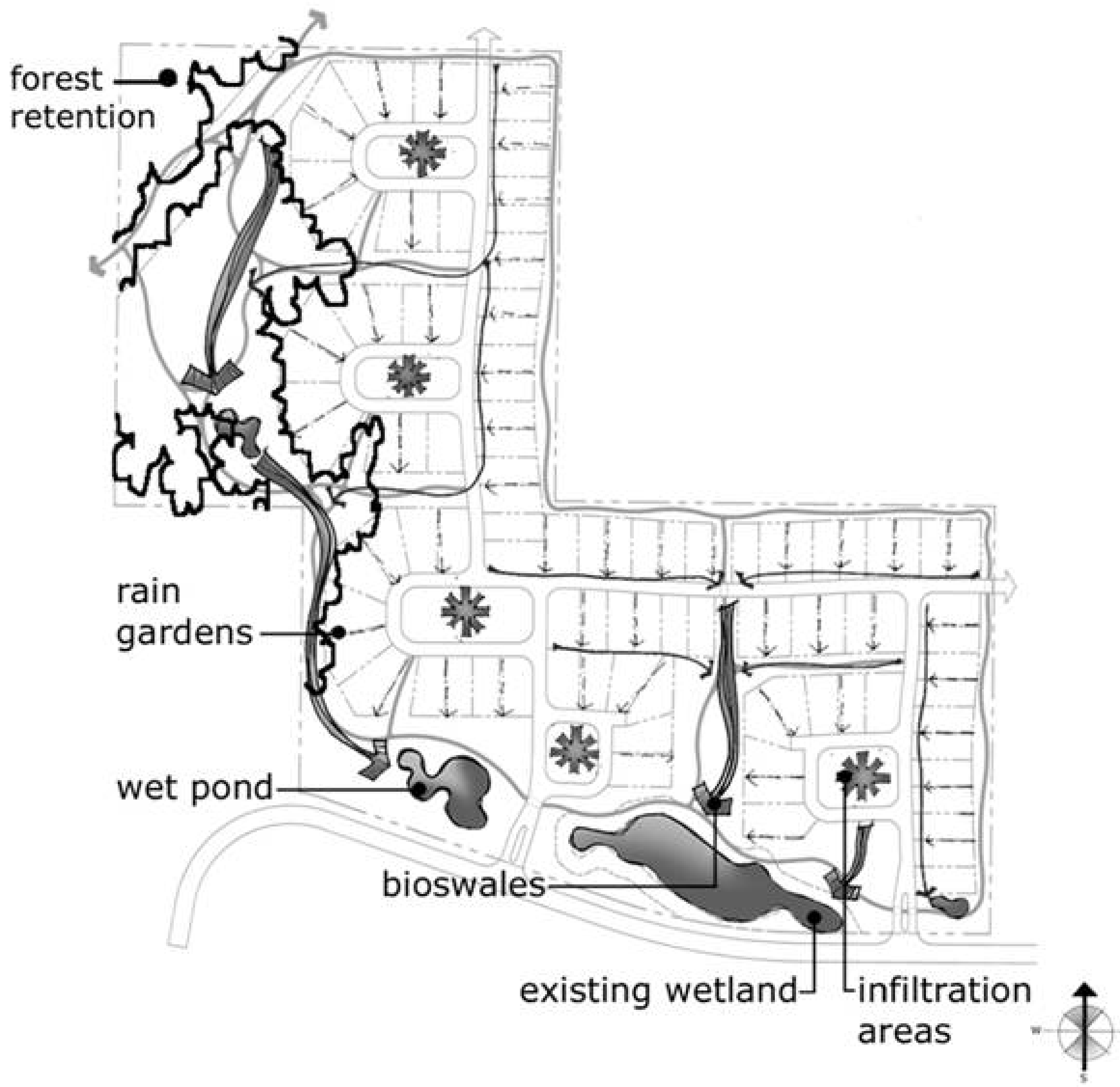
- Orient residential lots to minimize site disturbance; maximize the benefits of minimal excavation foundation systems; facilitate sheet flow into natural resource protection areas and bioretention facilities; and promote community aesthetics, livability, and privacy.
- Eliminate stream crossings with roads and conveyance systems whenever possible.
- Minimize impervious surfaces by reducing building footprints, road length and width, parking areas, and driveways.
- Eliminate effective impervious areas by directing stormwater from impervious areas in swales or as low velocity (less than 1 foot per second) sheet flow to adjacent undisturbed open space areas or bioretention areas.
- Integrate small, dispersed bioretention areas to capture, store, and infiltrate stormwater on site.
- Maintain predevelopment flow path lengths in natural drainage patterns whenever possible.
- Layout roads, lots, and other proposed site features to follow topographic contours to minimize soil and vegetation disturbance and loss of topsoil or organic duff layer.
- Utilize pervious paving surfaces such as porous pavement and pavers for roads, driveways, parking lots, or other types of drivable or walkable coverage.
- Direct rooftop runoff to infiltration areas, full dispersion systems, or to cisterns for non-potable reuse, or utilize vegetated roof systems to evaporate and transpire stormwater.
- Limit development within natural resource protection areas to:
    - Passive, confined recreation (i.e., walking and biking trails) constructed from pervious surfaces.
    - Platforms for viewing streams, lakes, and wetlands constructed with techniques to minimize disturbance to soils and vegetation.
    - Small dispersed bioretention and other LID stormwater dispersion areas, except these shall not be located in riparian areas or wetlands and their associated buffers.

(See Figures 2.3, 2.4, and 2.5.)



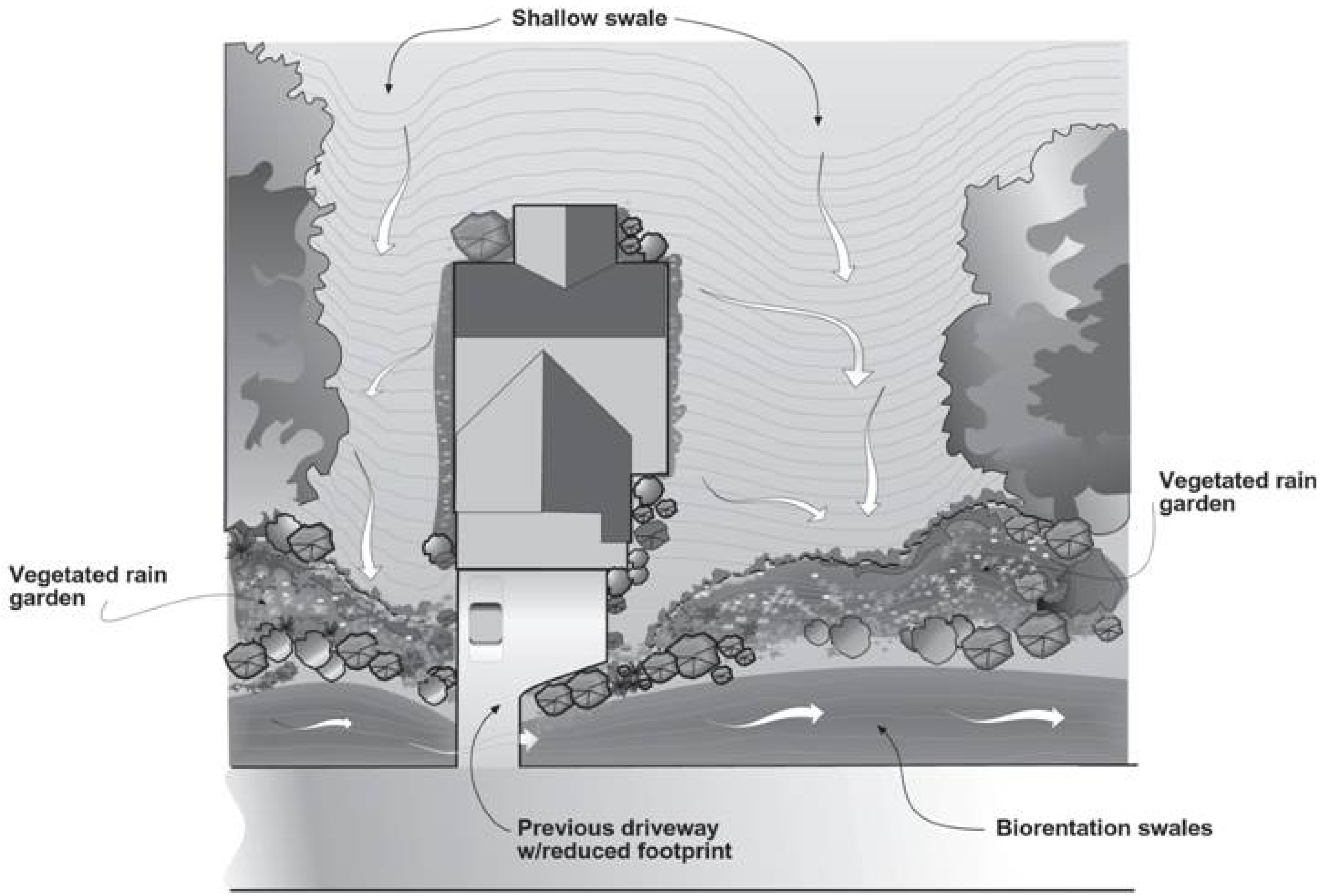
Not to Scale

Figure 2.3. LID Subdivision Design.



Not to Scale

Figure 2.4. LID Storm Drainage Concept.



Not to Scale

Figure 2.5. LID Large Lot Design.

2.3 Retain Native Vegetation, and Provide Reforestation Where Necessary

The following sections outline specific strategies to support the comprehensive LID design approach. Strategies discussed include:

- Vegetation retention
- Reforestation
- Minimizing impacts during site clearing and grading.

2.3.1 Vegetation Retention

The primary goal is to retain large, connected tracts of native vegetation areas, either through a cluster design or on individual lots, to maintain the natural hydrologic function and provide infiltration areas for overland flows generated in developed portions of the site. Tree areas not directly adjacent to structures (or located where they may potentially impact a structure) should be protected or restored to follow natural successional patterns and develop diverse multilayer canopy structure, snags, large woody debris, understory vegetation, and forest duff. In addition to meeting the primary objective of stormwater management, these large, connected tracts of native vegetation can be used to meet secondary objectives such as the creation of open space corridors and critical area and habitat protection.

Applicability – Native Vegetation Retention Standards

Assessment of natural resources outlined in Section 2.2.1 will identify critical areas and native soils and vegetation offering the best available stormwater benefit. Retaining 65 percent native vegetation is the objective; however, it is recognized that achieving this percentage may be difficult given each site's unique characteristics while trying to obtain urban level densities. In these cases, the combined use of other LID strategies will help determine the exact amount of vegetation retention necessary to maintain a site's natural hydrologic cycle.

The following standards shall be applied in designated urban areas (i.e., within the county's urban growth management area [UGA]), when retention of 65 percent native vegetation cannot be achieved:

- Residential LID projects shall retain a minimum of 50 percent native soil/vegetation protection areas and provide the following additional BMPs (as well as other LID BMPs described in Chapter 3, as specified by the county):
    - Soil amendments shall be applied to all areas which are being set aside as non-buildable areas (open space or natural resource protection areas) and are in need of rehabilitation because of

past land use disturbances such as clearing and intrusion of invasive species. The purpose is to enhance and accelerate the rehabilitation of the soil structure. The application will be non-destructive to the existing vegetation that is retained by taking care to taper depths of soil amendment near the surface roots. The depth of soil amendment will be the preapproved recommended rates for lawn areas as specified in Section 3.14, Option 1 – Amend Existing Soils in Place. However, removal of surface woody debris and rocks larger than 1-inch diameter is not required.

  - Natural resource protection areas shall be reforested to meet the minimum requirements as set forth in Title 18H PCC.

  - Trees shall be replanted throughout the buildable areas of the site. The number of trees will be two per lot spaced adjacent to the public right-of-way near the lot. The requirement for street tree plantings, outlined in Title 17B PCC – Manual on Design Guidelines and Specifications for Road and Bridge Construction in Pierce County, shall be adhered to.

- Commercial and industrial LID projects shall retain a minimum of 25 percent native soil/vegetation protection areas and provide the following additional BMPs:

  - Utilize shared parking (refer to definition in Section 2.4.2), multi-storied parking, or parking facilities located under the structure

  - Any outdoor parking areas shall be designed with bioretention facilities that are interspersed throughout the parking lot area to receive stormwater runoff from the impervious surfaces.

Design Criteria

Calculation of the Total Native Vegetation Area Required

The total area required to be retained or restored to meet the standards set in the second bullet under Section 1.4 Performance Goal and Objectives, shall be calculated by multiplying gross site acreage (excluding large water bodies) by the required protection percentage. The county will determine, on a case-by-case basis, whether a given large water body shall be included in the calculation.

Calculation of the Total Native Vegetation Retention Achieved

Calculation of native vegetation retention achieved shall exclude water bodies (such as large lakes) and include areas part of a common conservation easement (such as parks, stormwater, open space, wetland buffers, or critical area tracts) or areas incorporated into the individual lot design where conservation easements are placed on that portion of the lot. The county will determine, on a case-by-case basis, whether a given large water body shall be included in the calculation. However, proposed residential subdivisions and PDDs shall locate a minimum of 75 percent of the required native vegetation within areas of land separate from residential lots, such as those listed above. When lots or building sites are located contiguous to protective tracts the preferred location of the native vegetation areas is the area adjacent to these tracts.

Native vegetation areas shall, at a minimum, meet the required tree unit densities set forth in Title 18H PCC – Forest Practices and Tree Conservation. Where invasive species are present on the site they shall be removed.

Vegetation Protection During the Construction Phase

The following steps must be taken to protect vegetation during construction:

- Map natural resource protection areas on all plans and delineate these areas on the site with silt, construction, or other appropriate fencing to protect soils and vegetation from construction damage.

- Meet and walk property with equipment operators to clarify construction boundaries and limits of disturbance.

- Protect drainage areas during construction. If an area has any type of channel/drainage swale that provides a hydrologic connection to vegetation protection area(s), then the channel must also be protected throughout the construction phase by fencing and use of erosion control measures to prevent untreated runoff from the construction site to flow into the channel.

- Install signs and fences to identify and protect natural resource protection areas.

- Protect trees and tree root systems utilizing the following methods:

    - Reduce soil compaction during the construction phase by protecting critical tree root zones that usually extend beyond the trees canopy or drip line. The critical tree root zone should be factored using the tree's diameter breast height (6-inch diameter breast height = 8-foot radius; 10-inch diameter breast height = 10-foot radius, 30-inch diameter breast height = 45-foot radius) (see Figure 2.6).

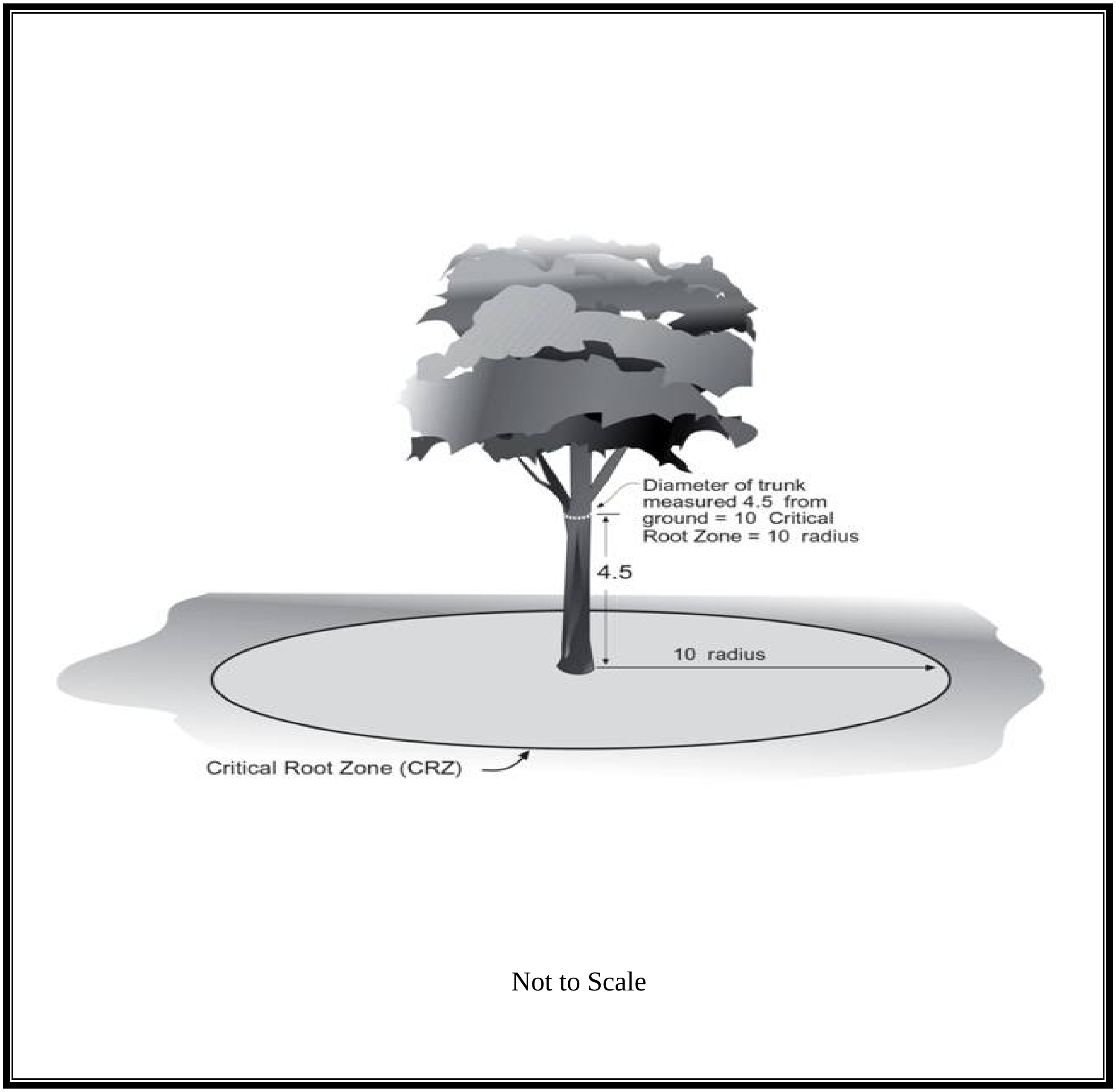


Figure 2.6. Critical Root Zone (CRZ).

- Prohibit any excavation within the critical tree root zone.
- Prohibit the stockpiling or disposal of excavated or construction materials in the vegetation retention areas to prevent contaminants from damaging vegetation and soils.
- Avoid excavation or changing the grade near trees that have been designated for protection. If the grade level around a tree is to be raised, a dry rock wall or rock well shall be constructed around the tree. The diameter of this wall or well should be at least equal to the diameter of the tree canopy plus 5 feet.
- Restrict trenching in critical tree root zone areas.
- Prevent wounds to tree trunks and limbs during the construction phase.
- Prohibit the installation of any impervious surfaces in critical root zone areas. Where road or sidewalk surfaces are needed under a tree canopy, unmortared porous pavers or flagstone (rather than concrete or asphalt) or bridging techniques should be used (see Figure 2.7).
- Prep tree conservation areas to better withstand the stresses of the construction phase by fertilizing, pruning, and mulching around them well in advance of construction activities.

Vegetation Protection Postconstruction

The following steps must be taken to protect vegetation after construction:

- Mechanisms shall be put in place to assure long-term protection of vegetation retention areas. Mechanisms to protect conservation areas include setting aside conservation areas into separate tracts, permanent easements, homeowner covenants, maintenance agreements, and education (see Sections 4.2.1 through 4.2.3 for specifics on these topics).
- Permanent signs shall be installed indicating that removal of trees or vegetation is prohibited within the native vegetation retention areas (see Figure 2.8).
- Permanent fencing is required around the limits of the vegetation retention areas. The type, size, and location of the fencing shall be approved by county review staff and should be made of materials that blend in with the natural surroundings (e.g., wood split-rail, pinned if necessary) and located in such a manner as to not impede the movement of wildlife within the vegetation retention areas.

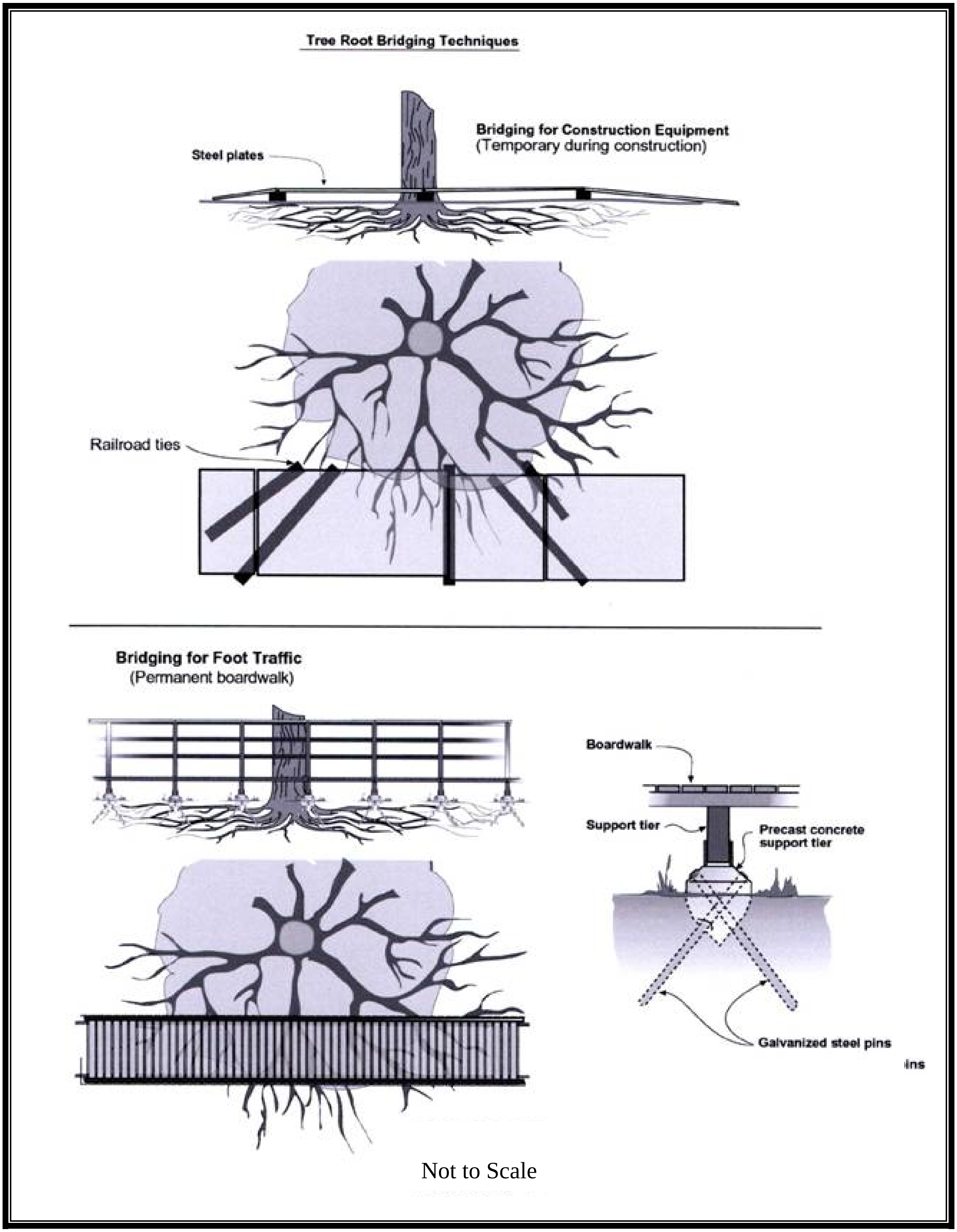
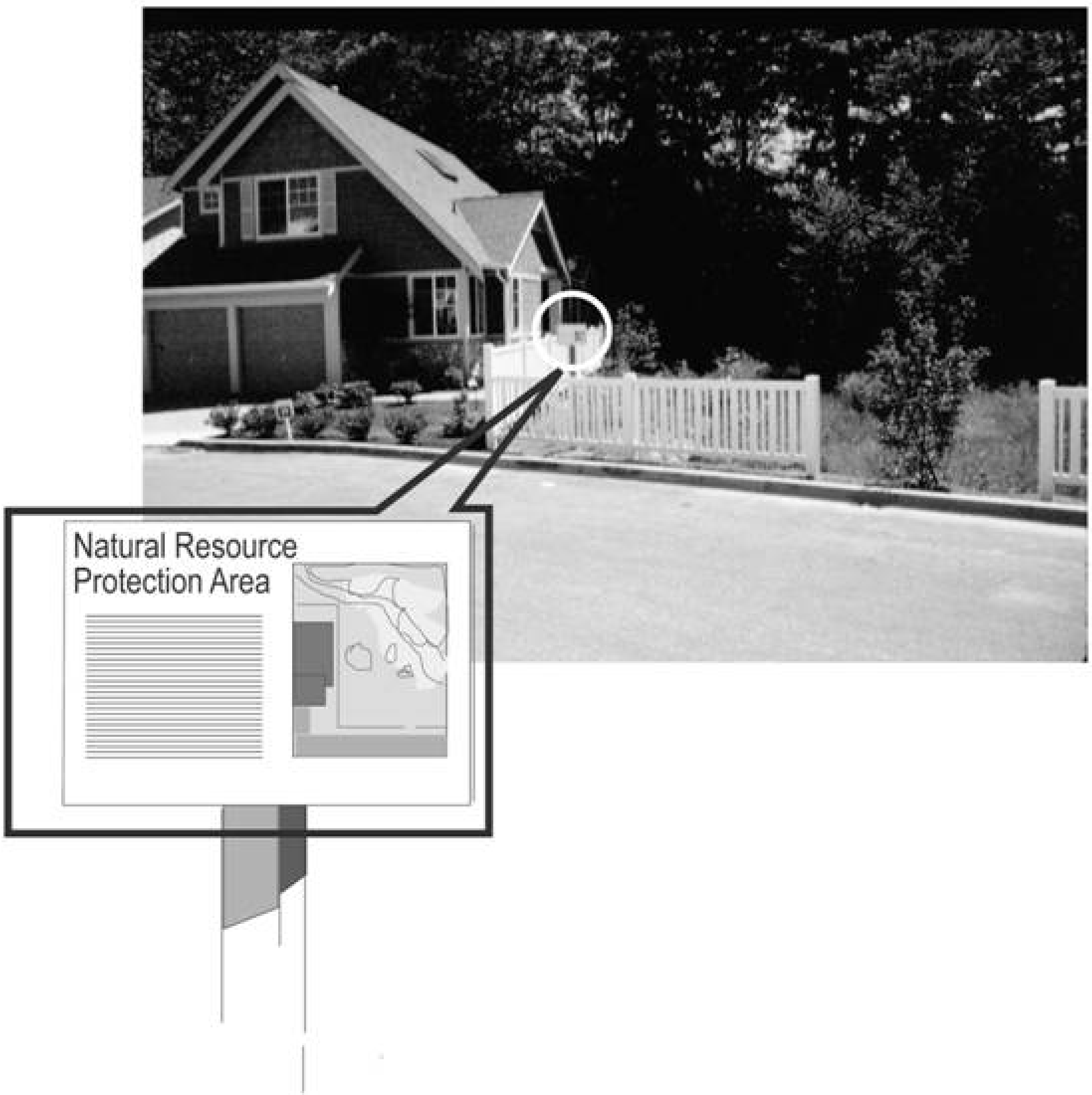


Figure 2.7. Root Bridge.



Not to Scale

Figure 2.8. Fencing and Signage for Sensitive Areas.

2.3.2 Reforestation

Restoring Native Vegetation

Natural resource protection areas that have been disturbed may need to be (or may be required to be) replanted with native trees and vegetation in order to achieve the full hydrologic benefits of a native, forested site. Vegetation restoration/planting methods shall conform to published standards as appropriate to the type of natural resource protection area. The following guidance documents are provided as an example:

- Restoring the Watershed A Citizen's Guide to Riparian Restoration in Western Washington, Washington State Department of Fish and Wildlife, 1995
- Streamside Planting Guide for Western Washington, Cowlitz County Soil and Water Conservation District
- Plant It Right: Restoring Our Streams, WSU Cooperative Extension, 2002
- Integrated Streambank Protection Guidelines, Washington State Department of Fish and Wildlife, 2000
- Surface Water and Groundwater on Coastal Bluffs: A Guide for Puget Sound Property Owners, Washington State Department of Ecology, Shorelands and Coastal Zone Management Program Publication No. 95-107, 1995
- Vegetation Management: A Guide for Puget Sound Bluff Property Owners, Washington State Department of Ecology, Shorelands and Coastal Zone Management Program Publication No. 93-31, 1993.

In those situations where it is not feasible to retain existing trees of sufficient size and quantity to achieve the required amount of tree cover, additional tree cover shall be provided through supplemental tree plantings. Additionally, on those sites where tree cover does not exist due to previous removal, tree cover shall be reestablished (reforestation). The following standards shall be utilized:

- At a minimum, the applicant shall comply with the provisions for tree replacement as set forth in Title 18H PCC – Forest Practices and Tree Conservation.
- Tree conservation areas not adjacent to or potentially impacting structures should be protected or restored to follow natural successional patterns and develop diverse multilayer canopy

structure, snags, large woody debris, understory vegetation, and forest duff.

- Trees selected for replacement purposes must be free from injury, pests, diseases, and nutritional disorders. Trees must be fully branched and have a healthy root system. Coniferous and broad leaf evergreen trees shall be no less than 3 feet in height at time of planting. Deciduous trees shall be a minimum of 5 feet in height or have a minimum caliper size of 1 inch at time of planting.

- Avoid the use of a single species of tree for replacement purposes. No individual species of replacement tree should exceed 50 percent of the total nor should any individual species be less than 10 percent of the total.

- Maintenance shall include intensive site preparation, including weed control and soil amendment. Ongoing maintenance shall include weeding and watering for a minimum of 3 years from installation so as to achieve a minimum 80 percent survival of all planted vegetation. If during the 3-year period survival of planted vegetation falls below 80 percent, additional vegetation shall be installed as necessary to achieve the required survival percentage. Additionally, the likely cause of the high rate of plant mortality shall be determined and corrective actions shall be taken as needed to ensure plant survival. If it is determined that the original plant choices are not well suited to site conditions, these plants shall be replaced with plant species that are better suited to the site.

- Title 18H.40.130 Appendix F PCC contains recommended tree species to be used. Developments shall use native trees for replacement purposes in areas that are separate from either residential lots or storm drainage areas adjacent to roadway or parking lots (i.e., locate native trees within natural resource protection areas). The native tree species selected shall be based on the underlying soils and the historic, native indigenous plant community type for the site.

2.3.3 Minimize Impacts During Site Clearing and Grading Activities

Prepare a Detailed Soils Analysis

A detailed soils analysis that identifies soil types and associated infiltration capabilities shall be conducted prior to any clearing and grading activities on the site (see Section 2.2.1 for specifics on inventory and assessment of soils).

Minimize Clearing and Grading

Grading should be kept to a minimum by incorporating natural topographic depressions into the development and limiting the amount of cut and fill on those portions of the site with permeable soils. At a minimum, the following standards shall be utilized:

- Any portion of the site with permeable soils should be closely considered for preservation to promote infiltration of stormwater runoff
- Areas of rich topsoil should either be left in place or, if excavated in construction areas, utilized elsewhere on the site to amend areas with sparse or nutrient deficient topsoil
- Direct runoff to areas of permeable soils or natural depression areas to promote infiltration
- Distances for overland flow must be kept short to promote sheet flow and minimize concentration of runoff
- Grading shall not increase steep, continuous slopes
- Limit clearing to road, utility, building pad, lawn areas, and the minimum amount of extra land necessary to maneuver machinery (e.g., a 10-foot perimeter around a building). All other land outside these areas shall be protected with construction fencing to prevent intrusion and compaction by construction equipment or other types of vehicles.

Erosion Control Techniques

In addition to the erosion and sediment control requirements specified in Volume I, Minimum Requirement #2 (and detailed in Volume II – Construction Stormwater Pollution Prevention), the following standards shall be utilized on LID sites:

- Limit secondary excavations and heavy equipment use by shaping final lot grades and topographic features at the site development stage.
- Utilize effective revegetation methods to reduce erosion including:
    - Establish vegetation quickly, particularly during the seasons that have the heaviest rainfall
    - Use native plant species adapted to the local environment
    - Plant during seasons that provide best opportunity for survival of vegetation (usually late fall, winter, or early spring months)

  - Control excess surface water runoff to prevent erosion
  - Utilize proper seedbed preparation
  - Fertilize and mulch to protect germinating plants
  - Protect areas designated for revegetation from soils compaction by restricting heavy equipment
  - Provide proper soil amendments where necessary (refer to Section 3.14).

- Protect native topsoil during the construction phase. Native topsoil has a high organic content and native seed sources, which are excellent for reestablishing permanent vegetation:
  - Topsoil or other material must not be relocated to critical areas where they can cover critical root zones, suffocate vegetation, and erode into adjacent streams
  - To prevent erosion, small stockpiles may be covered with weed barrier material that sheds moisture yet allows air transmission. Large stockpiles may need to be seeded and/or mulched.
- Minimize the amount and time that graded areas are left exposed by completing construction and erosion control in one section of the site before beginning operation on the next.
- Limit clearing and grading during heavy rainfall seasons. Construction activities shall begin during the season of lowest precipitation and end when conditions are favorable for the establishment of vegetation.
- Reduce the number and width of construction access roads. These access roads should be located in areas where future roads and utility corridors will be placed.
- Stockpile materials in areas designated for clearing and grading (such as parking areas and future roadways).
- Perform preconstruction, routine, and postconstruction inspections:
  - Conduct a preconstruction inspection to determine that adequate barriers have been placed around vegetation retention areas and structural controls are implemented properly
  - Routine inspections should be conducted to verify that structural controls are being maintained and operating effectively throughout construction

- Conduct a final inspection to verify that revegetation areas are stabilized and that stormwater management systems are in place and functioning properly.

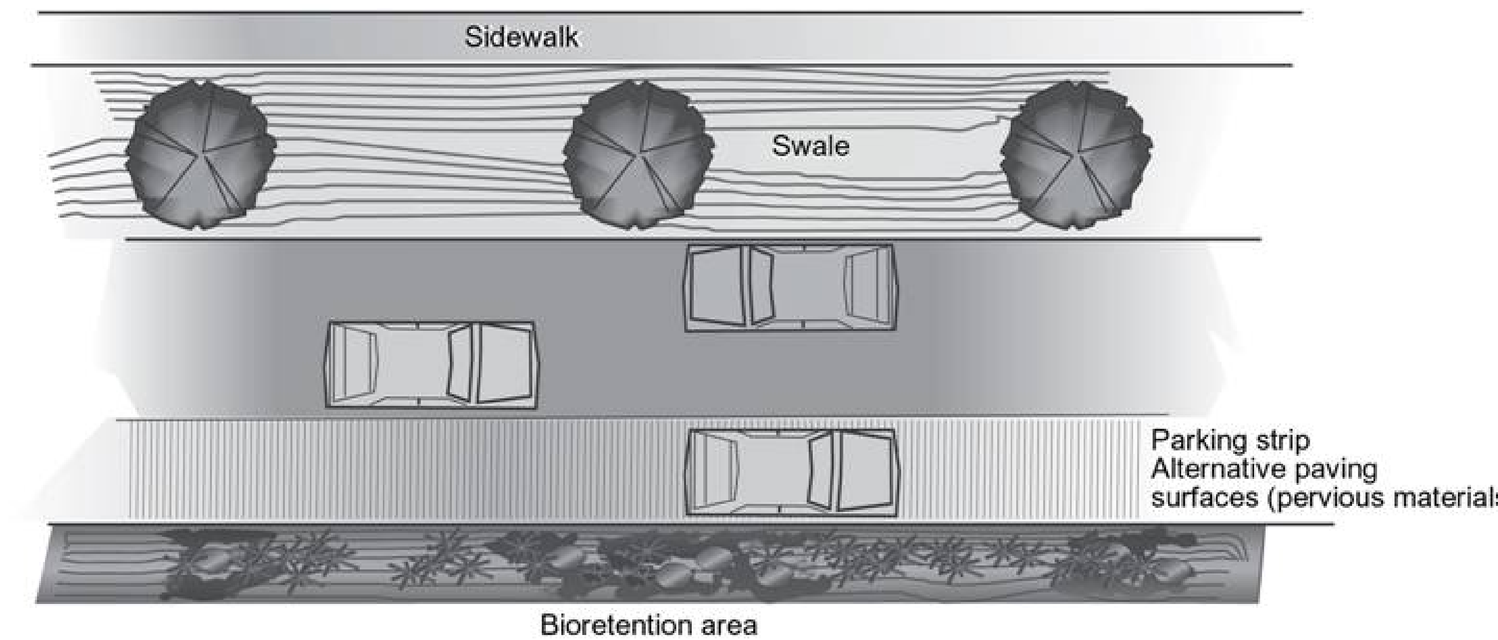
2.4 Reduce Effective Impervious Areas Associated with Roads, Shared Accesses, Alleys, Sidewalks, Driveways, and Parking Areas

Roads, shared accesses, alleys, sidewalks, driveways, and parking areas create a substantial portion of total urban impervious area and usually have highly efficient drainage systems. Reducing the amount of effective impervious area associated with roads, shared accesses, alleys, sidewalks, driveways, and parking areas is a key concept of LID site designs. The following sections contain strategies for reducing the impacts of impervious surfaces associated with transportation related networks, including roadways, parking lots, alleys, and driveways.

2.4.1 Road Design

Road design refers to the layout of the roadway system within a development. The objective for the street system design is to reduce the amount of effective impervious area associated with the road network. This may be achieved by examining alternative street layouts and determining the best option for increasing the number of homes per unit length of road. Strategies for reducing the amount of effective impervious area associated with the road network include:

- Design road layout to follow the existing topographic contours to minimize cuts and fills. This is also beneficial for creating vegetated open channels along the road that have gentle slopes.
- Design the road layout to avoid crossing natural resource protection areas.
- Natural resource protection areas or bioretention areas should be located down-gradient of roads, alleys, or other impervious surfaces when feasible.
- Roads should be designed to service clusters of development located within the buildable portions of the site (i.e., cluster housing) and avoid entering into the natural resource protection areas, thereby reducing the overall length of the roadway network and minimizing the disruption of sheet flow within these areas.
- An example road design using LID features is shown in Figure 2.9.



Not to Scale

Figure 2.9. Road Design.

Road Layout

One type of road layout cannot be used in all situations, so it is advantageous for a designer to explore different strategies and decide which ones will work best for the existing site. At a minimum, the following types of layouts should be considered:

- Grid layouts – Grid patterns provide multiple access routes to each parcel and may include alleyways between blocks with garages located at the back of the house. However, it should be noted that the use of alleys may increase the total road network and associated impervious surface unless pervious pavements are utilized.
- Cul-de-sacs – In those instances where cul-de-sacs are used, techniques should be used to reduce or disconnect the impervious area. This can be accomplished by increasing the diameter of the cul-de-sac, but including a pervious or bioretention landscaped area in the center where stormwater can be directed. See Figures 2.10 and 2.11 for example schematics.

Road Cross Sections

The objective of modifying road cross sections is to reduce the roadway width to the minimum amount of impervious surface necessary, while still accommodating emergency vehicle access, and utilizing pervious pavements where most applicable. Note: Existing applicable road standards still apply except as modified below:

- Example LID road sections are provided in Figures 2.12 through 2.14. They incorporate a narrower paved section of roadway, use of alternative paving surfaces, and promotion of sheet flow into vegetated open channels. An example of an LID road layout using a standard road section is shown in Figure 2.12.
- Paving surfaces for LID road designs may utilize alternative paving surfaces, as outlined in Section 3.16. However, use of porous surfaces within the traveled lane areas is not allowed without prior county approval. Porous paving surfaces adjacent to the traveled lane (e.g., in pull out parking, shoulders, or for sidewalks) is allowed provided the subgrade of the traveled lane will not become saturated by infiltrating runoff through the porous surfaces.
- Cement/concrete pavement strips (2-foot-wide strips of concrete that act as a transition between the traveled lane and non-rigid porous pavement surfaces adjacent to the traveled way) may be utilized to delineate the traveled lane areas. These delineator strips shall be at least 6 inches thick with expansion joints every 10 feet.

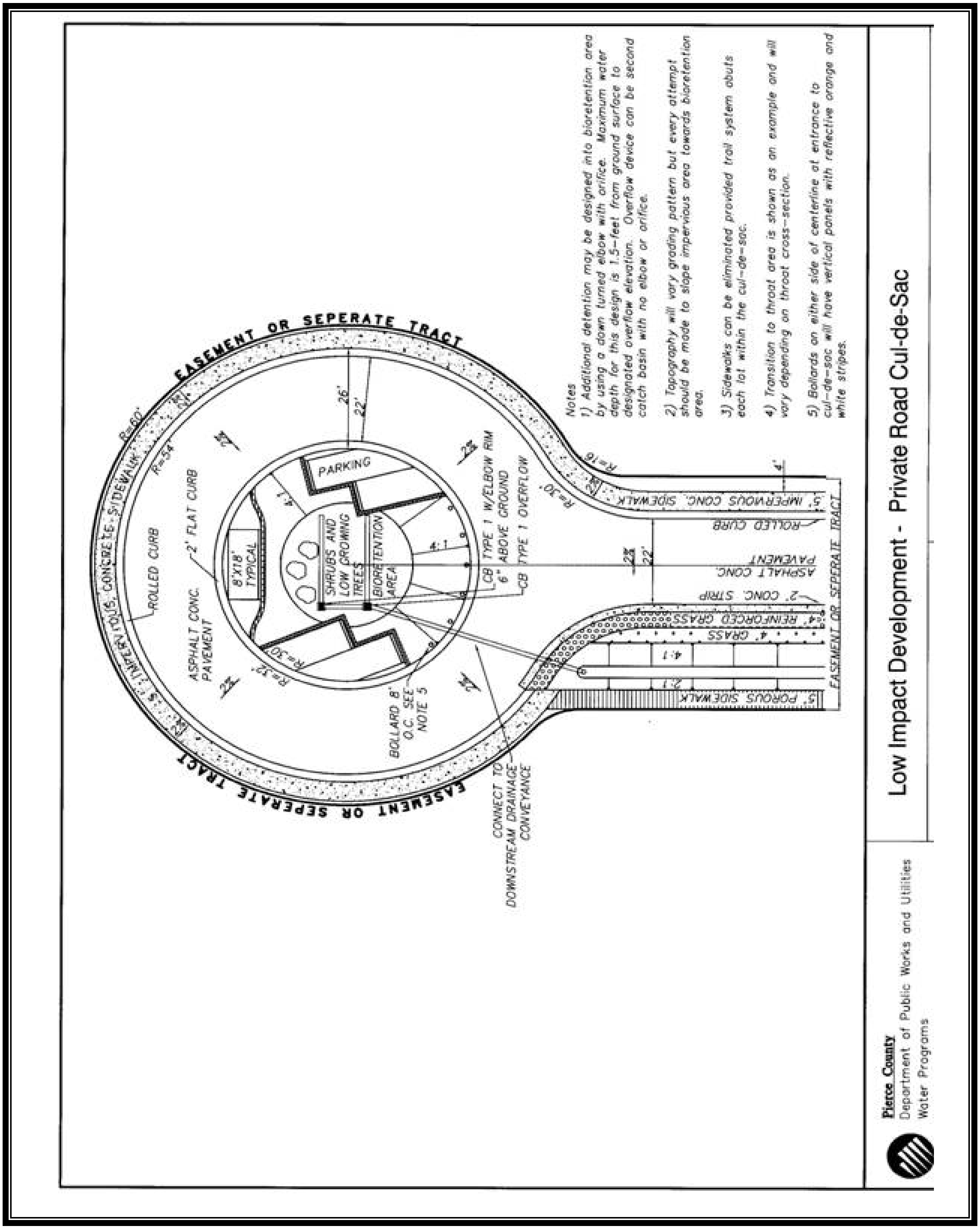


Figure 2.10. Local Road Cul-de-Sac Design with Bioretention.

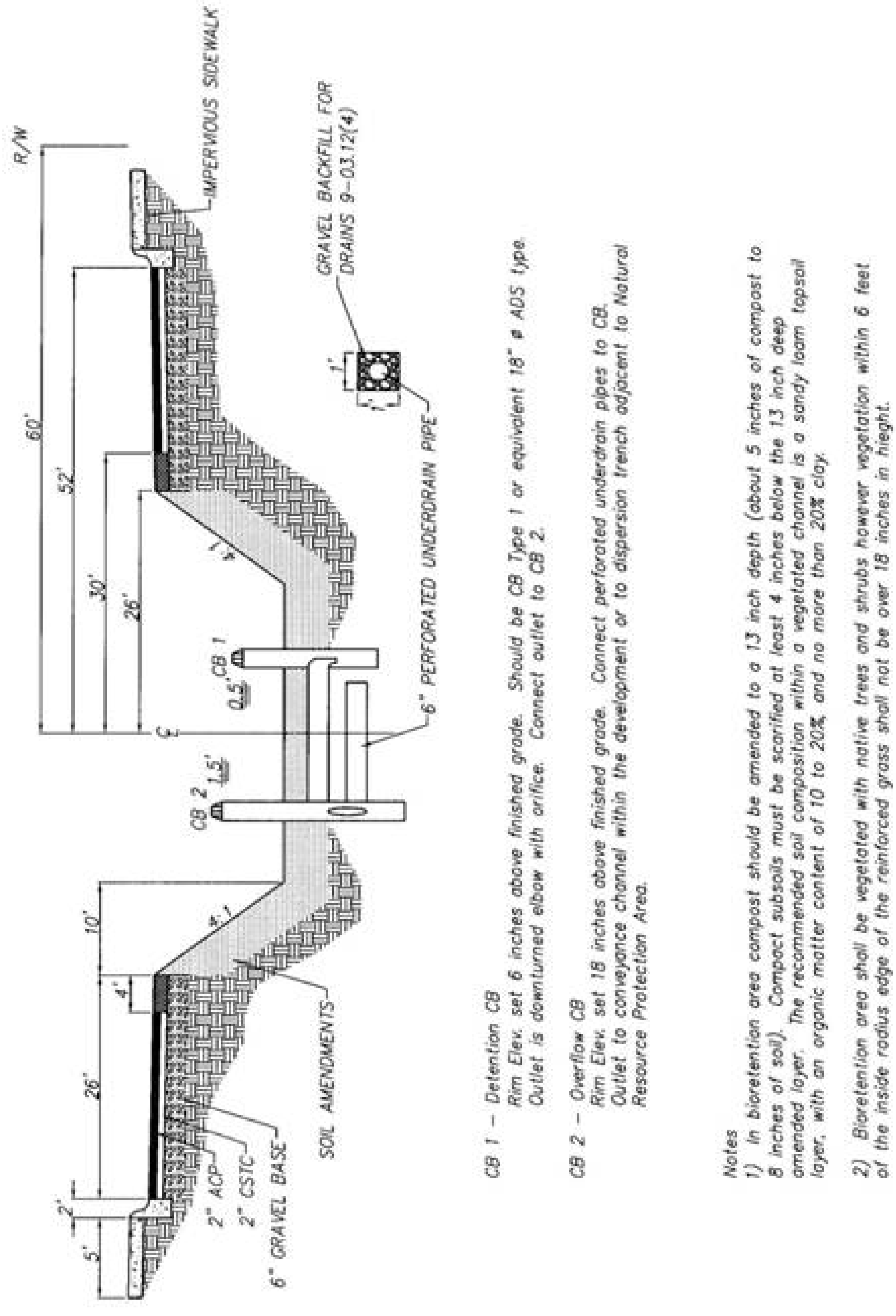


Figure 2.11. Cul-de-Sac Bioretention Detail.

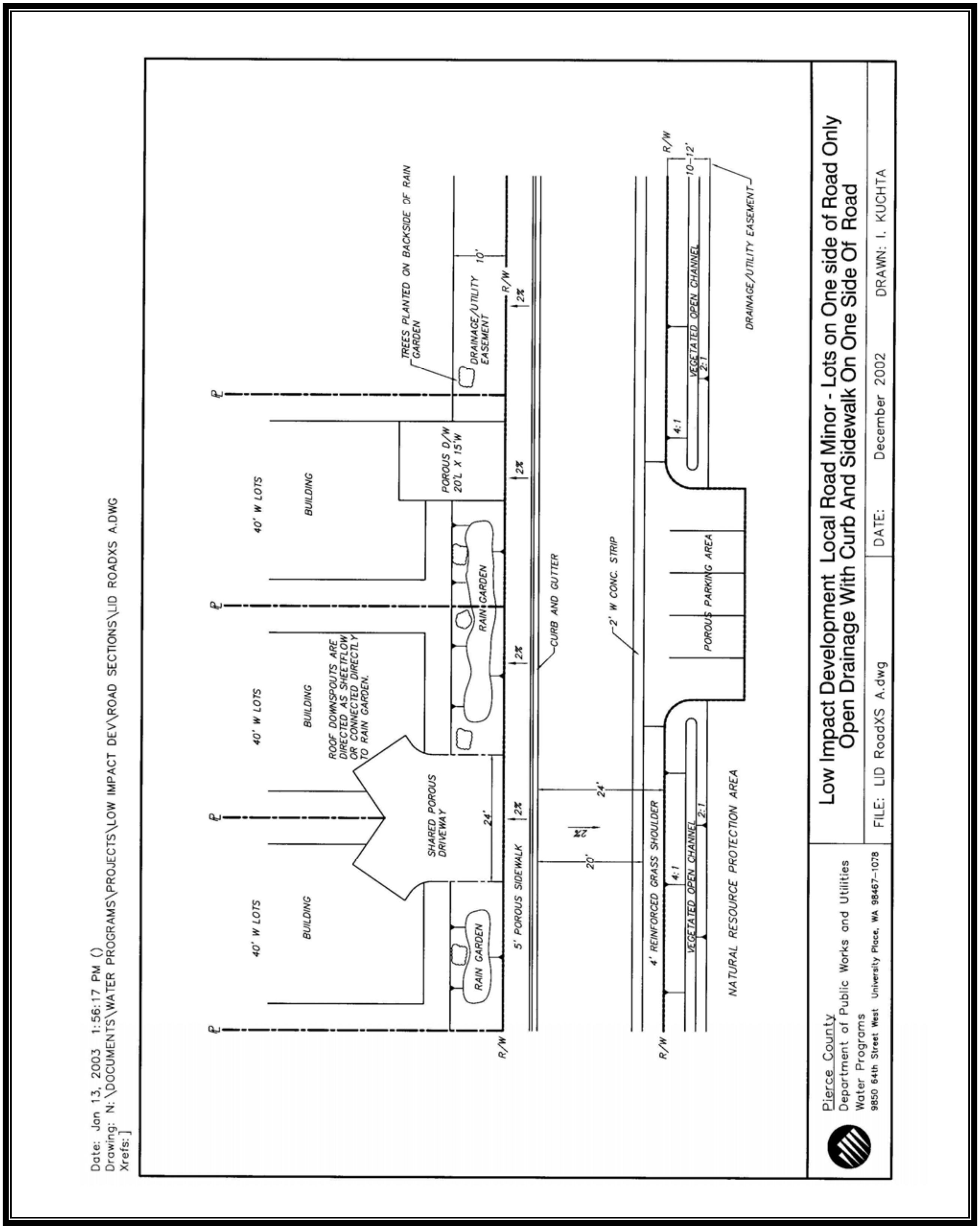


Figure 2.12. Local Road Minor – Lots on One Side of Road Only.

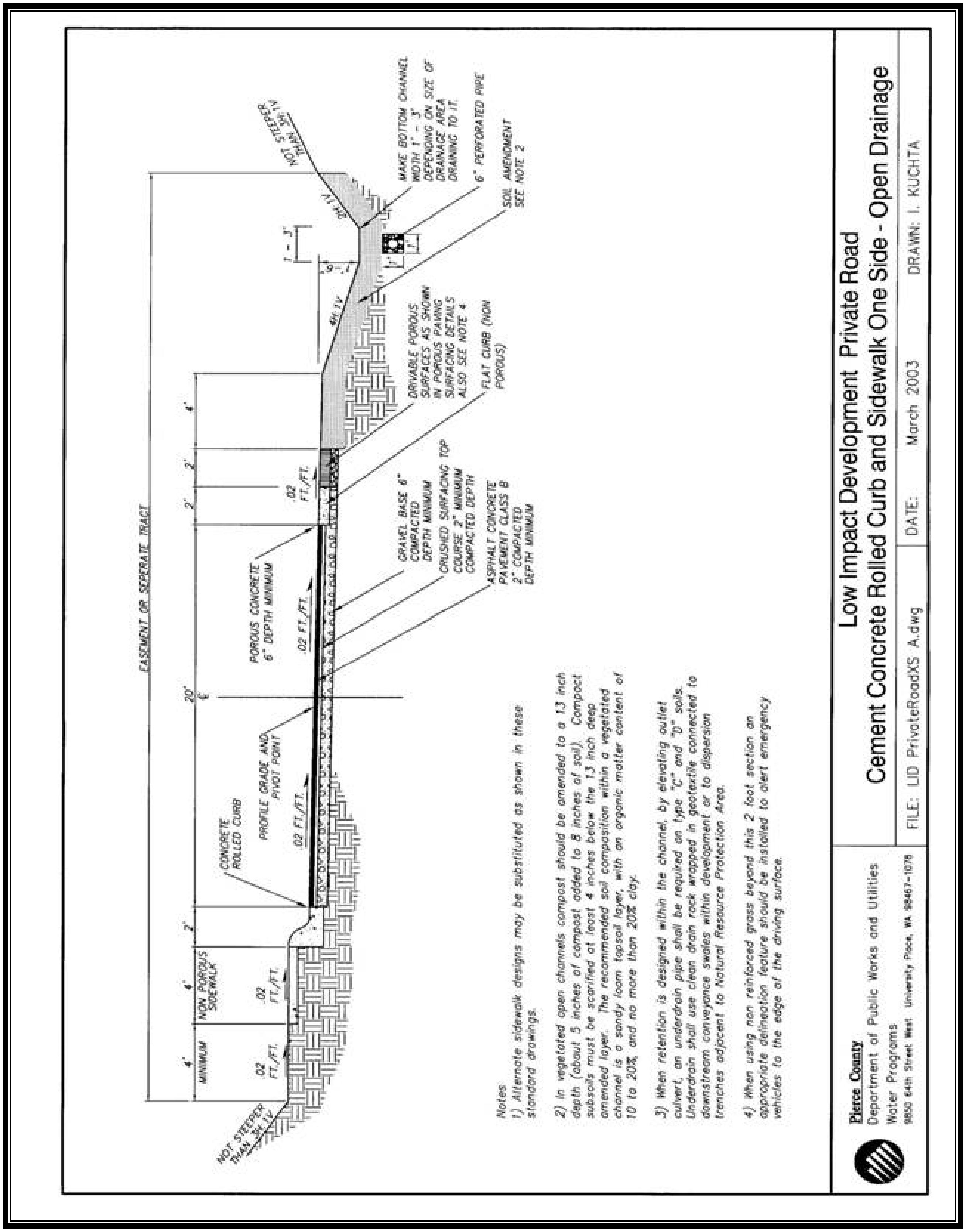


Figure 2.13. Local Road Minor – Curb One Side – Open Drainage.

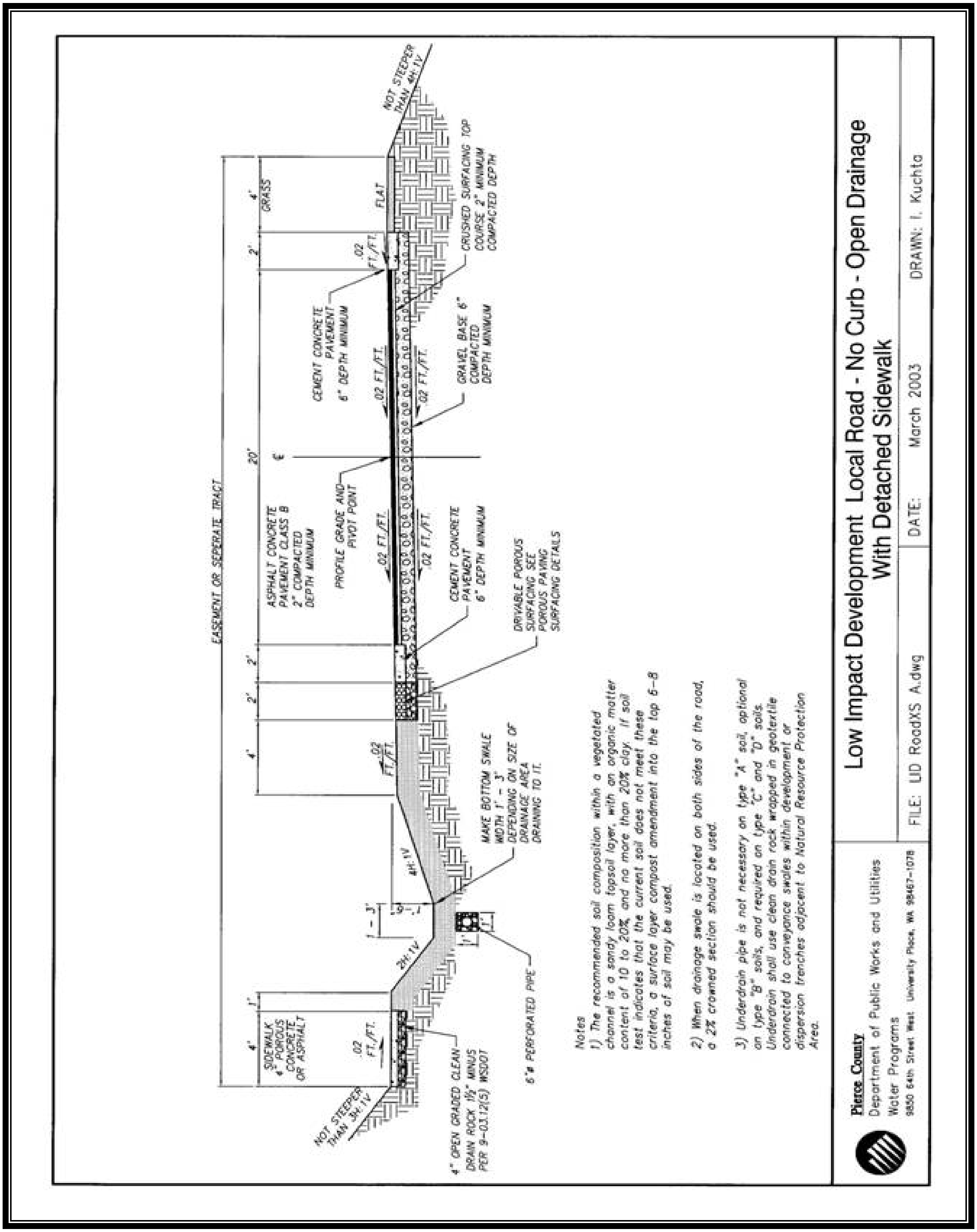


Figure 2.14. Local Road Minor – Open Drainage with Porous Shoulder and Detached Sidewalk.

- Lane widths for local road minor and local road cul-de-sacs within a development shall be a minimum of 10 feet for each traveled way, with a minimum drivable surface width of 24 feet provided within the roadway section. Alternative paving surfaces may be used to provide the additional 2 feet in width to achieve the 24-foot minimum.

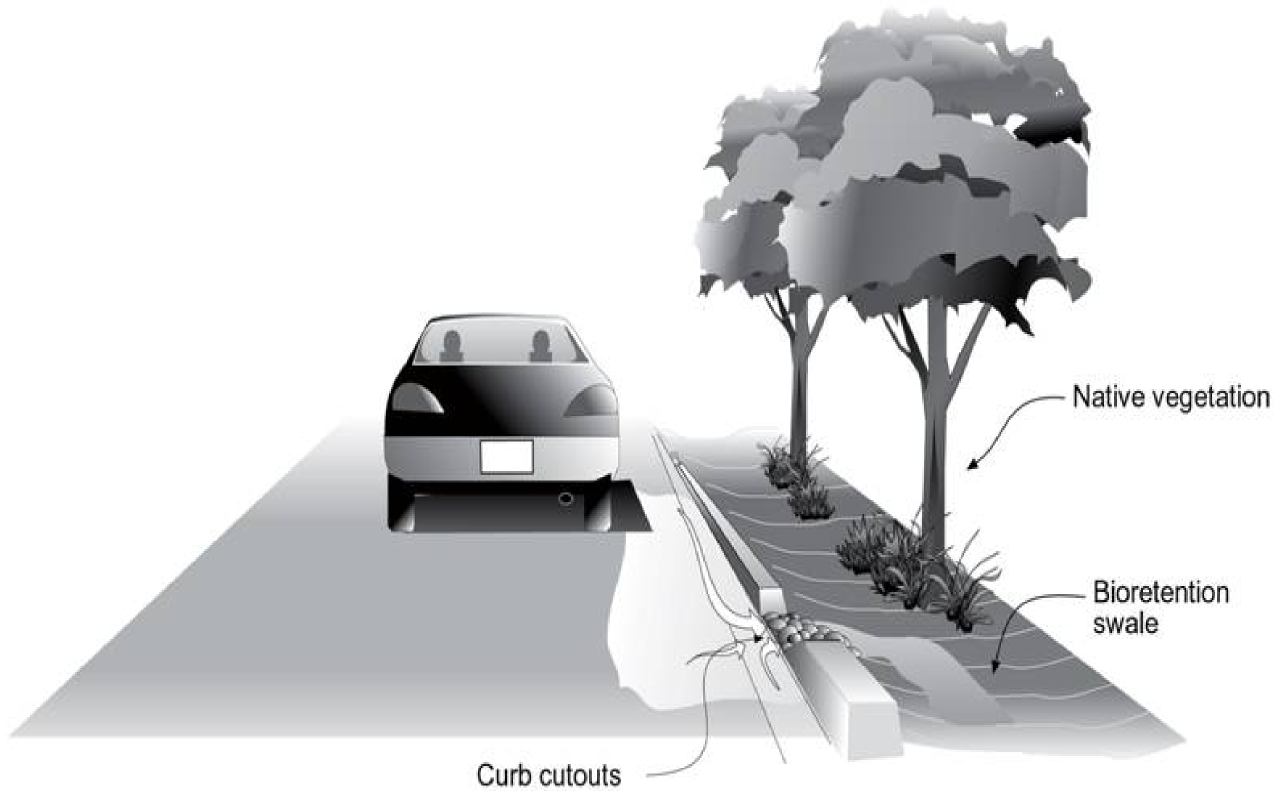
- Curbs and gutters are highly discouraged for use as stormwater collection systems in conjunction with catch basins and pipes. Where there is a legitimate need for constructing a curb and gutter system, Section 2.4.5 provides guidance for designing curb and gutter alternatives. The following general requirements apply to curb and gutter applications in road designs for LID projects:

    - Curbs are allowed when the sidewalk is adjacent and connected to the traveled way provided they are used only on one side of the road and the road cross slope is away from the curb or if curb cuts are utilized, as shown in Figure 2.15, and drain to a vegetated open channel or bioretention area behind the curb.

    - Curbs and gutters shall not be required on both sides of the road within LID developments.

- Sidewalks and trails should be disconnected from the traveled way portion of the road, to the greatest extent possible. Although sidewalks are not required on both sides of the roadway, every lot shall have pedestrian access to an abutting trail or to a sidewalk located on at least one side of the road. Sidewalks may be separated from the roadway by placement of a vegetated open channel or bioretention area between the sidewalk and the roadway.

- Sidewalks and trails may be constructed of porous materials provided the runoff through the material will not be directed towards the subgrade of the traveled lane portion of a roadway. Porous materials for sidewalks and trails which abut lots, in lieu of a roadside sidewalk, shall be Americans with Disabilities Act (ADA) compliant. Porous asphalt and porous concrete will be considered ADA compliant in regards to surface texture. An example sidewalk design is provided in Figure 2.16.



Not to Scale

Figure 2.15. Curb and Gutter Cutouts.

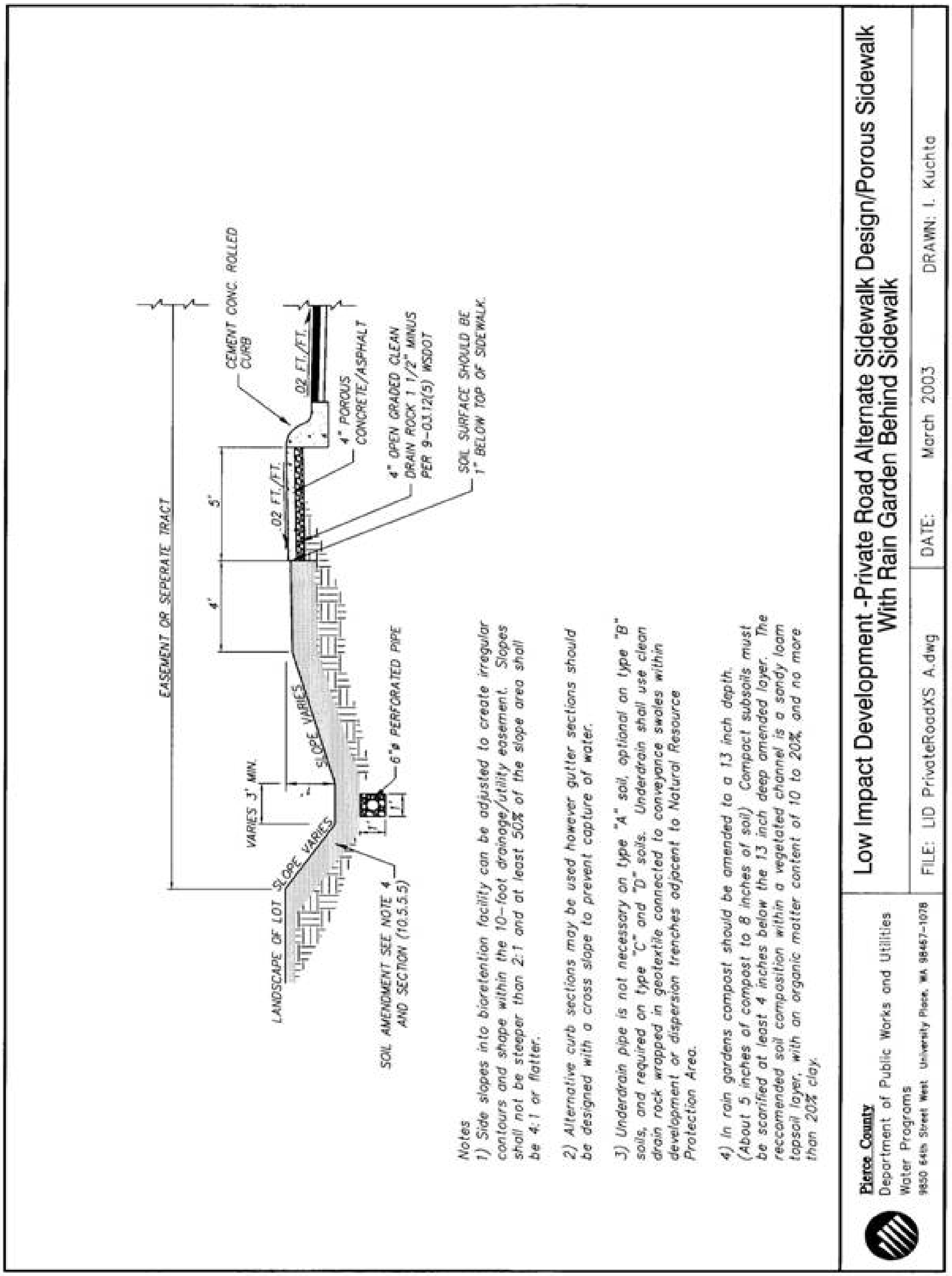


Figure 2.16. Alternate Sidewalk Design with Rain Garden Behind Porous Sidewalk.

- The use of additional pullout parking spaces is required with LID road designs to compensate for narrower road widths which restrict roadside parking. An example design is provided in Figure 2.17. Parking stalls must be provided at a rate of one-third of a stall for each house that has a two-car driveway and one-half of a stall for each house that has a one-car driveway. These rates may be increased as determined by the department when road designs other than the adopted standard LID road cross-sections are requested by deviation.

- On street parking stalls must be located within 150 feet of each lot being served.

- Signage that prohibits on-street parking shall be required for roads that provide less than 24 feet of drivable surface.

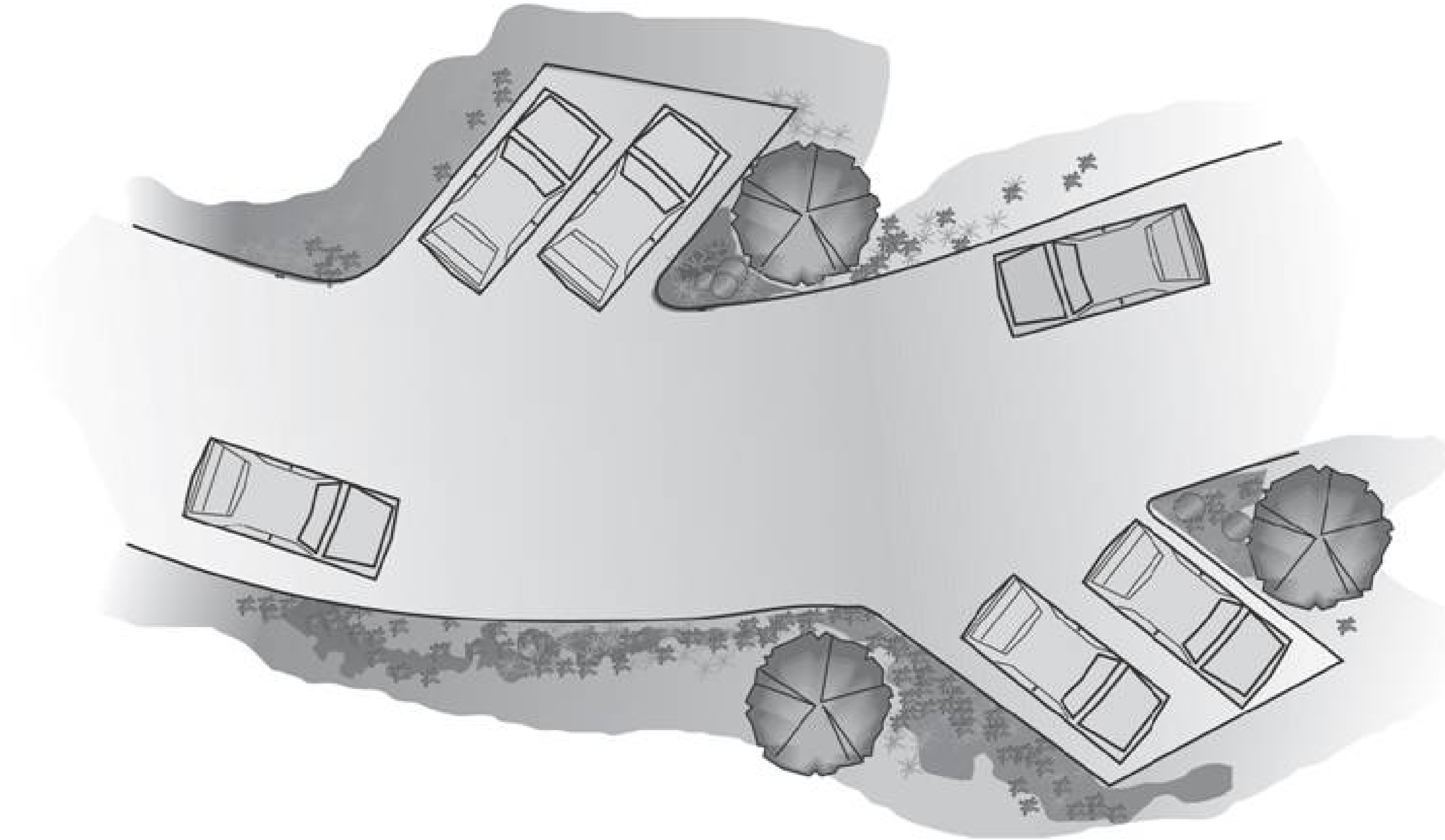


Figure 2.17. Alternative Parking.

2.4.2 Parking Lots

The objective of alternative parking lot designs is to eliminate excessive impervious areas dedicated to parking and/or reduce the effective impervious area of parking areas, while still providing adequate parking for various land use classifications.

Parking Lot Requirements

- Utilize the minimum off-street parking requirements outlined in Title 18A.35.040 PCC for non-residential uses. The total amount of parking spaces may exceed the minimums outlined in Title 18A.35.040 PCC. However, any parking lot space above the required minimum amount shall be constructed of pervious materials or accommodated in a multi-storied or underground parking structure.

- The designer should incorporate alternative paving surfaces as discussed in Section 3.16 into the parking lot to promote infiltration of the runoff without the need for conventional catch basins and pipe systems.

- Bioretention areas can be used in concert with alternative paving surfaces to maximize the attenuation of runoff. Spacing and layout of the bioretention area should be designed so runoff is maintained as sheet flow from the driving surfaces into the bioretention area. The travel path of sheet flow across a parking lot to a bioretention area should be limited to cross only one driving lane and across one set of parking stalls before arriving at the side slopes of the bioretention area.

- Dedicate at least 30 percent of the parking spaces to compact vehicle parking.

Shared Parking

The total amount of impervious area can be reduced by utilizing shared parking. This strategy is appropriate for land uses with non-competing hours of operation, such as a church and a school or office. For proposals with shared parking, the following requirements must be met:

- The peak parking demand for the two uses must occur at different times of the day or week

- Properties must be in close proximity to each other

- Each establishment must have long term, consistent parking needs

- Property owners must enter into a legally binding agreement that outlines the terms of shared parking arrangements, which shall be approved by the county.

2.4.3 Alleys

Alleyways with garages located at the rear of lots provide more visually appealing streetscapes, effectively taking vehicle access emphasis from the front of homes. However, the use of alleys may increase the overall amount of impervious surface on the site. The following standards apply to alleys:

- Alleys may not be used in-lieu of roads due to access needs of emergency vehicles
- Construct alleys with pervious materials
- Alleys should be constructed without curb, gutter, or sidewalks
- Alleys should be designed to direct sheet flow to vegetated stormwater facilities
- Alleys shall be limited to a maximum of 16 feet in width for two-way traffic and 12 feet for one-way traffic.

2.4.4 Driveways

Driveways are typically constructed with impervious surfaces and as such should be considered in the total stormwater runoff reduction strategy. The following are methods to reduce the amount of impervious surface associated with driveways:

- Driveways serving up to two single family residences shall be limited to a maximum of 18 feet in width or 24 feet for a three car garage bay. However, when 18 feet of width is exceeded, driveways shall be constructed with a pervious material. Driveways serving as shared access facilities shall follow the widths outlined in Title 17B PCC – Manual on Design Guidelines and Specifications for Road and Bridge Construction in Pierce County.
- Driveway length should be reduced as much as possible. This may be achieved by locating the house closer to the road or by using alley access directly into a garage. However, driveway length shall be designed to accommodate the entire length of an average sized passenger vehicle (e.g., SUVs, pick-up trucks, sedans, vans) for parking. A minimum length of 22 feet must be provided as

measured from the face of the garage to the back of the sidewalk, back of the concrete curb (no sidewalk), or back of the roadway vegetated open channel and/or bioretention area.

- When possible, design clusters of homes to utilize shared driveways. On lots that accommodate multiple family dwellings, such as townhouses, the courtyard between garages and the stem of the driveway can be shared space. A shared driveway shall serve no more than four dwelling units unless a greater number of units are considered acceptable to the county. The length of the shared driveway shall be a maximum of 50 feet.

- Driveways should be constructed using pervious materials and graded in such a manner to prevent stormwater runoff from saturating the subgrade of the traveled lane portion of the roadway. Surface and subsurface (e.g., discharge from the pervious material) stormwater runoff should drain to vegetated infiltration areas such as soil amended lawns, vegetated open channels, or bioretention areas.

- Runoff from driveways constructed of impervious surfaces shall be directed to vegetated infiltration areas such as soil amended lawns, or bioretention areas.

2.4.5 Curb and Gutter Alternatives

Because of the effect they have on concentrating runoff flows, the use of curb and gutter systems is highly discouraged. The discussion below is intended to give guidance for appropriate LID methods of designing curb and gutter alternatives in situations where there is a legitimate need for constructing a curb and gutter system.

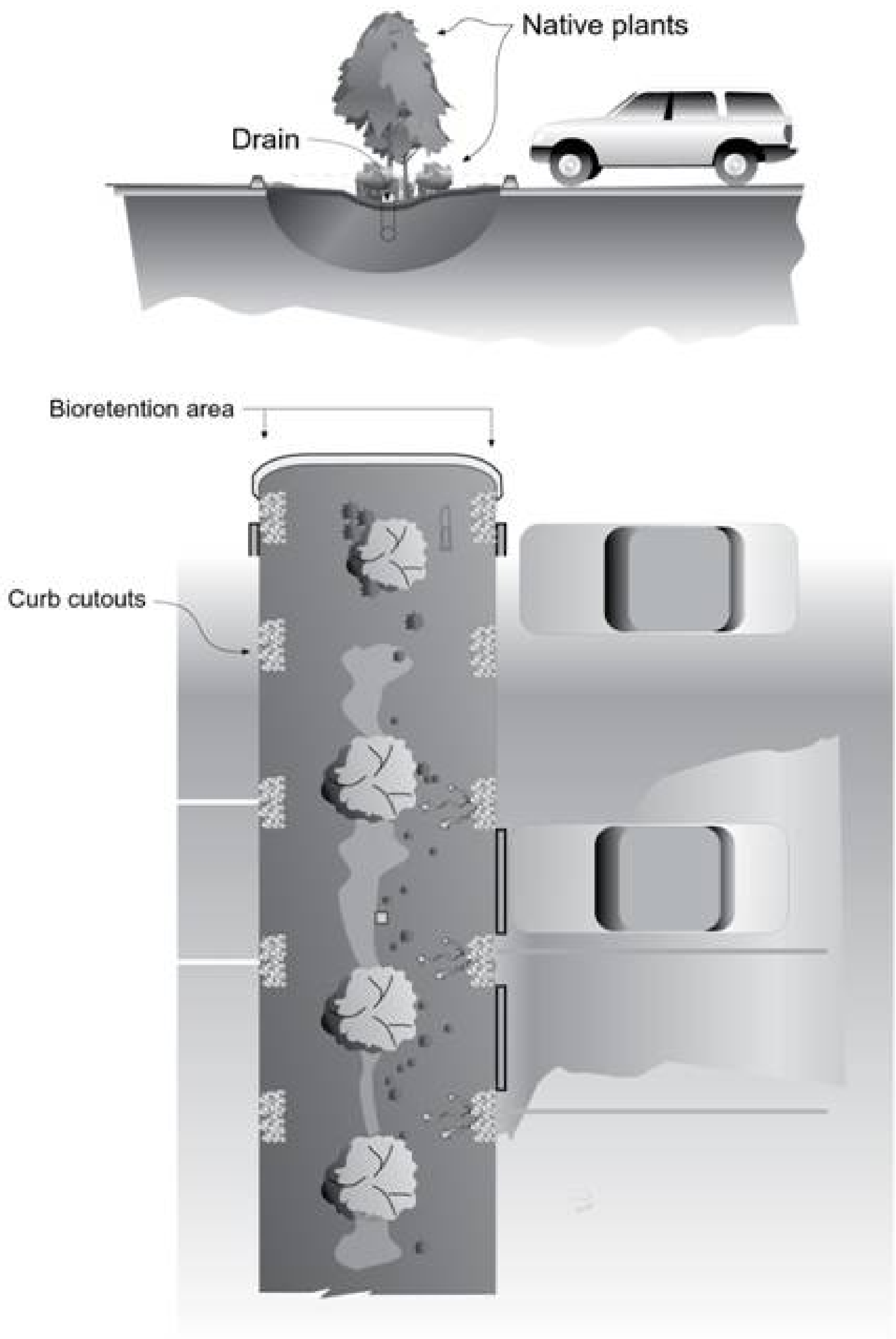
Applicability

- Legitimate needs where use of curb and gutter may be considered are; incorporation of or tie into a road with a functional classification of Collector or Secondary Arterial, or in an ultra urban setting. Local feeder roads in LID developments should not be designed with curb and gutter systems.

- Where specific community design standards require the use of curb and gutters in all or part of the road network, alternative designs (discussed below) must be considered that will still meet the functional requirements.

Design Criteria

- Where curb and gutters are required in a community to provide a means of separation between the pedestrians and the motorized traffic, an alternative design using placement of a vegetated channel between the sidewalk and the roadway should be considered. In addition, a visual barrier consisting of a 2-foot wide concrete strip along the edge of the pavement at the same surface elevation of the pavement shall be constructed. This concrete strip gives drivers a visual cue of the edge of the driving surface and can help protect the vegetated channel from tire ruts.
- Another alternative is to provide cuts in the curb at 10 to 15 foot spacing to allow runoff to enter adjacent vegetated systems or other LID BMPs. See Volume III, Section 4.9 for additional flow spreading options.
- Parking lots that incorporate bioretention into the landscaped portions of the parking lot should use concrete curb blocks as wheel stops to protect the bioretention area from traffic intrusion while also allowing the parking lot runoff to flow somewhat unobstructed to the bioretention system. Figure 2.18 provides an example schematic with LID features incorporated into the parking lot design.



Not to Scale

Figure 2.18. Direct Parking Lot Runoff to Bioretention Areas.

Chapter 3 - Low Impact Development Best Management Practices

Low impact development BMPs focus on infiltrating, dispersing, evaporating, in some cases reusing, and as a last resort, detaining and discharging stormwater. In contrast to conventional BMPs that typically collect and convey runoff to one location on the site, LID applications treat stormwater in small-scale, dispersed facilities located as close to the source of the runoff as possible. Due to the many different factors affecting both stormwater quantity and quality, there is no one technique that will work in all situations.

This section presents the list of individual LID BMPs that shall be considered either to meet applicable flow control and/or water quality minimum requirements, or to support a comprehensive LID site design approach, or both.

3.1 Applicability

The BMPs listed in this section are intended to mitigate the impacts associated with surface water runoff generated from roads, driveways, rooftops, and other forms of impervious surfaces. The following sections provide criteria and outline the order of preference for choosing LID BMPs when designing a project to meet the objectives outlined in Section 1.4. Specifically, to 1) "minimize the impacts of increased stormwater runoff from new impervious surfaces and land cover conversions by maintaining peak flow frequencies and durations of the site's predeveloped hydrologic condition," and 2) "achieve near zero effective impervious area within the site." In addition, the LID BMPs outlined in this section shall be used to help meet applicable flow control and/or water quality treatment requirements specified in Volume I.

3.2 General Design Guidelines

Knowing how the site processed stormwater historically is important in determining appropriate BMPs. The site analysis provides information on how the site and the surrounding areas process stormwater, both currently and historically before any land use changes had altered those processes. This information should aid the designer in determining the best site layout and in deciding what appropriate BMPs will either maintain or restore this natural predeveloped stormwater process. Use the following items from the site analysis to determine appropriate site layouts and LID BMPs:

- Location and quantity of offsite drainage entering and onsite drainage leaving the site, if any, and the location

- Slopes throughout the site
- Locations of existing mature vegetation (trees and shrubs) that retain intact upper soil profiles for stormwater processing
- Small depressions on site that retain stormwater runoff
- Depths and conditions of upper soil profile (the A and B horizons) along with the identification of the lower soils.

3.3 Order of Preference for LID BMP Selection

The following is the required order of preference for LID BMP selection for managing stormwater runoff from roads, driveways, buildings, and other impervious surfaces within the designated buildable portions of the site. It is assumed that BMP selection occurs after all efforts to reduce impervious surfaces and other hydrologic modifications have been utilized:

- Infiltrate where Type A and B soils exist that readily infiltrate (coarse sands and cobbles to medium sands). The surface water infiltration shall be dispersed throughout the site and not in one "end of the pipe" system. Surface infiltration systems in the form of bioretention areas (rain gardens) or vegetated channels designed for infiltration are preferred over subsurface systems (e.g., vaults) because of ease of maintenance. These BMPs require soil amendments for maximum soil absorption, porosity, and plant growth.
- Where full infiltration is not feasible, such as where less permeable Type C and D soils exists, bioretention areas (rain gardens) or vegetated channels designed with surface detention shall be the second preference.
- Where adequate flow paths are available, dispersion techniques for roof runoff (outlined in Section 3.11) shall be allowed after utilization of bioretention.
- Dispersion of road runoff may be allowed and even preferred when sheet flow can be maintained and directed into adjacent vegetated areas and/or natural resource protection areas with adequate flow path lengths to absorb the flow (see the dispersion specifications in Sections 3.12 and 3.13 for additional requirements).
- Pervious pavements outside the traveled lane, within driveways, and within parking stalls shall be utilized to the greatest extent possible to attenuate flows and recharge groundwater.

Where none of the above listed methods are feasible the designer may utilize more conventional collection, conveyance, and detention methods. When using this type of system every effort shall be made to promote groundwater recharge and reduction of runoff volumes by constructing conveyance in vegetated open channels (see Section 3.15) and limiting the size of the drainage area serviced by the detention facility.

It will be at the discretion of the Pierce County review staff to determine whether the designer has made every effort to reasonably utilize the LID BMPs in their order of preference before selecting a less preferred BMP.

Example:

A site with moderate slopes of 2 to 5 percent is underlain with a nearly impermeable cemented till soil (Type C or D) but has an upper soil horizon consisting of 2 to 5 feet of organic topsoil material. The site receives no offsite runoff but there are very loosely defined trough areas on the downhill side of the property that appear to convey excess surface runoff offsite during extreme storm events.

Infiltration through the cemented till never occurred except for in small amounts, so the focus should be to preserve the upper soil horizon to allow continued retention and allow uninterrupted pathways for stormwater movement as interflow through the upper soil horizon. With the addition of the impervious areas on the site, the remaining exposed soil will be required to process more stormwater than prior to development, so additional detention will be needed using bioretention areas and vegetated channels. The downhill side of the property should be retained as a natural resource protection area and restored with trees and shrubs if necessary to enhance natural evaporation/transpiration processes. Stormwater conveyed to this area through overflow channels from bioretention areas should be dispersed before entering the protection area.

3.4 Specialized BMP Selection

Certain BMPs are somewhat specialized such as roof gardens and stormwater runoff reuse systems. These BMPs are probably most applicable in highly urban environments or commercial centers where larger buildings or multi-story parking facilities encompass nearly all the area. Design requirements for these BMPs are also included below, but the application of these BMPs will be on a case-by-case basis.

3.5 Maintenance Criteria

Adequate operation and maintenance (O&M) must be provided for in the design, installation, and operation of all LID BMPs. See Minimum

Requirement #10 in Volume I; Volume I, Section 3.3.4; and Volume I, Appendix I-B for additional information on maintenance requirements. In addition, maintenance considerations and requirements specific to LID site designs are outlined in Section 4.2.

3.6 Preservation of Upper Soil Structure (Native Topsoil)

Preservation of the existing upper soil horizon is of primary importance to the success of LID developments maintaining natural stormwater processes on the site.

3.6.1 Applicability

- On sites that are underlain by cemented till layers, which are nearly impermeable, the upper soil horizon (native topsoil) processes the majority of stormwater on the site. Therefore, it is necessary to ensure that the existing depth of the upper soil horizon is either left in place or removed and replaced during the grading process. For soils removed and replaced on site, the soil amendment requirements outlined in Section 3.14 must also be met.

- On sites which are underlain by outwash soils the existing topsoil is not usually as deep but is still necessary for preservation to provide water quality treatment of runoff before infiltration into the outwash soils.

3.6.2 Soil Structure Design Criteria

- In buildable areas where minimal excavation foundation systems may be applied, existing top soils shall be left in place to the greatest extent feasible and shaped or feathered only with tracked grading equipment not exceeding 650 pounds per square foot machine loads. Where some re-grading is required, re-compaction of placed materials, which may include topsoils free of vegetated matter, shall be limited to the minimum densities required by the foundation system engineering.

- In buildable areas of the site, where conventional grading is required, the areas requiring cuts shall have the upper native topsoil removed and stockpiled for replacement to areas of the development utilized for LID stormwater management (yards, bioretention areas, interflow pathways, vegetated channels, or degraded natural resource protection areas).

- The depth of upper native topsoil required to be stockpiled and replaced shall be the entire depth of the native topsoil horizon up to a required maximum 3 feet.

- Over-excavation of cut sections shall be necessary if the cut is in a location that will be utilized for LID stormwater management. Cut to a depth that will allow replacement of stockpiled native topsoil to the entire depth that was on the site postdevelopment up to a required maximum of 3 feet.

- Cut sections where native topsoil replacement is required shall require ripping of any cemented till layers to a depth of 6 inches. Subsequently the replacement of stockpiled topsoil shall be thoroughly mixed into the ripped till to provide a gradual transition between the cemented till layer and the topsoil.

- Stockpiled topsoil shall be replaced in lifts no greater than 1 foot deep and compacted by rolling to a density that matches existing conditions.

- For any soils removed and replaced on site as described above, the soil amendment requirements outlined in Section 3.14 must also be met.

3.7 Rooftop Runoff and Minimal Excavation Foundation Systems

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.

3.7.1 Applicability

- Downspout infiltration systems shall be used where outwash type soils (i.e., those meeting U.S. Department of Agriculture (USDA) soil texture classes ranging from coarse sand and cobbles to medium sand, Hydrologic Soil Group Classification A or B) exist on the lot. Infiltration systems should also be considered for other soil types with the exception of silty clay loam, clay loam, clay, or any other soil having a percolation rate slower than 1 inch/hour. Where soils with slower percolation rates exist, bioretention or dispersion techniques may be considered.

- As an alternative to the above infiltration systems, minimal excavation foundation systems may be considered to provide partial rooftop runoff infiltration on sites with less permeable soils.

Where minimal excavation foundation systems are used and designed as outlined below, the portion of the rooftop area above minimal excavation foundation systems may be modeled as pasture rather than as impervious surface.

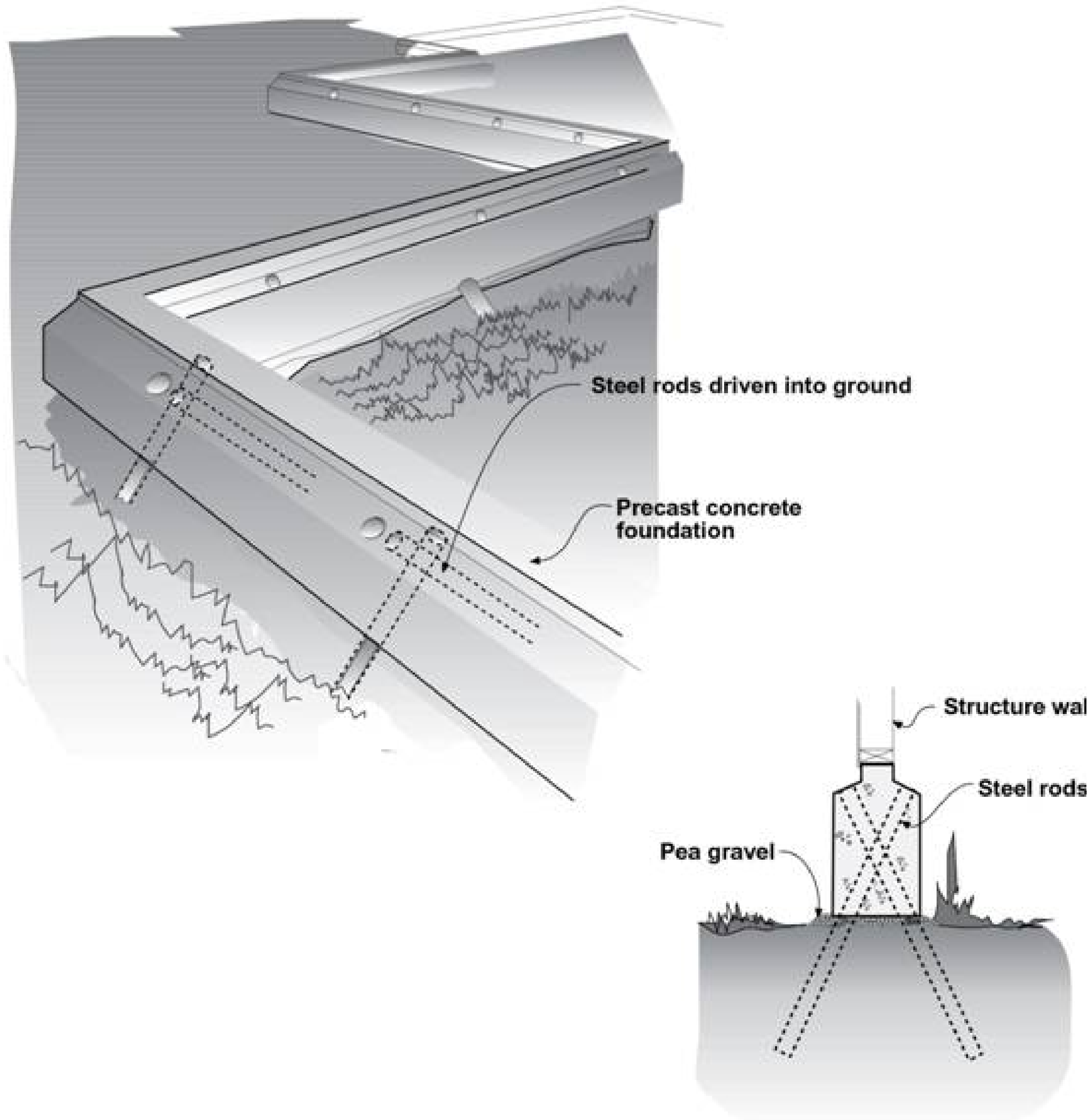
3.7.2 Design Criteria

- Minimal excavation foundation systems utilize a pin anchoring system (see Figure 3.1) or a piling/pier foundation which secures the foundation without complete removal and compaction of the surface soil beneath the house. This allows the interflow pathways of runoff under the building structure to be maintained.

- The contributing downspout areas shall be dispersed in accordance with Section 3.11. The length of vegetated flow path and setbacks required in Section 3.11 are not applicable when using minimal excavation foundation systems.

- To maximize the benefit of minimal excavation foundation systems, the roof runoff shall be dispersed upgradient of the structure. Passive systems are preferred, but active systems (pump mechanism) may be employed if they utilize back-up power sources and can be demonstrated to be consistently or easily maintained. Runoff dispersed upgradient of a garage slab, monolithic poured patio, or driveway may not be included as applicable infiltration areas for these systems.

- Where runoff cannot be dispersed upgradient of the structure, the contributing downspout areas must be dispersed in accordance with the full requirements of Section 3.11, including the flow path and vegetated cover requirements. If the design requirements of Section 3.11 are met, the tributary roof areas may be modeled as pasture area.



Not to Scale

Figure 3.1. Pin Foundation.

3.8 Bioretention Facilities or Rain Gardens

Bioretention areas and rain gardens are shallow stormwater retention systems that are designed to mimic forested systems by controlling stormwater through detention, infiltration, and evapotranspiration. Bioretention areas and rain gardens also provide water quality treatment through sedimentation, filtration, adsorption, and phytoremediation. In contrast to traditional stormwater pond designs, these facilities are typically smaller-scale and are integrated into the landscape to better mimic natural hydrologic systems. In the context of this volume, the term "rain garden" refers to an on-lot facility that receives only runoff from that lot. "Bioretention" refers to a slightly larger scale facility which receives runoff from a combination of the development's impervious and pervious areas.

Figure 3.2 provides an example illustration of a bioretention system.

3.8.1 Applicability

- Rain gardens may be utilized as on-lot retention facilities, even in areas where underlying soils may not be conducive to rapid infiltration (such as an underlying glacial till), but where the area does have a surface soil cover that allows the migration of stormwater through the upper soil horizon as interflow.

- Rain gardens should be used to receive rooftop runoff in areas where infiltration facilities are not feasible and in preference to dispersing runoff, and may be integrated into the landscaped areas of the lot.

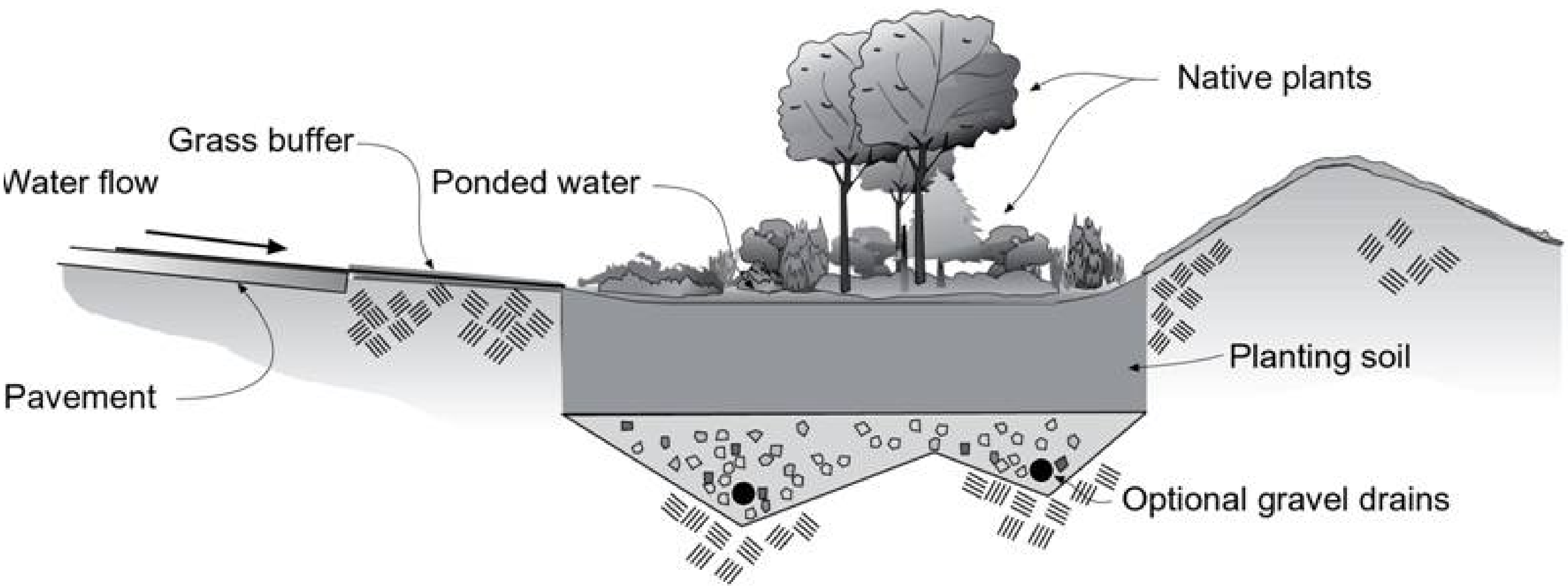
- Bioretention facilities and rain gardens are particularly effective where soils provide high infiltration rates.

- A minimum of 3 feet of clearance is necessary between the lowest elevation of the bioretention soil, or any underlying gravel layer, and the seasonal high groundwater elevation or other impermeable layer if the area tributary to the facility meets or exceeds any of the following limitations:

  - 5,000 square feet of pollution-generating impervious surface (PGIS)

  - 10,000 square feet of impervious area

  - Three-fourths of an acre of lawn and landscape.



Not to Scale

Figure 3.2. Bioretention Area.

- For bioretention systems and rain gardens with a contributing area less than the above thresholds, a minimum of 1 foot of clearance from seasonal high groundwater or other impermeable layer is acceptable.

- Bioretention facilities are applicable in parking lots as concaved landscaped areas (i.e., situated lower than the height of the parking lot surface so that stormwater runoff is directed as sheet flow into the bioretention area.). This application, in concert with porous surfaces in the parking lot, can greatly attenuate stormwater runoff.

- Bioretention and rain garden facilities may meet the requirements for basic and enhanced treatment (see Volumes I and V) when the bioretention soil is designed in accordance with the treatment soil requirements outlined in the design criteria below, and it is shown that at least 91 percent of the influent runoff file produced using a continuous simulation model is infiltrated. Applicable drawdown requirements must also be met (i.e., draining within 24 hours).

3.8.2 Bioretention Facility Design Criteria

The following provides a description, recommendations, and requirements for the components of bioretention and rain garden facilities. 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. Submittal for facility review must include documentation of the following elements, discussed in detail below:

- Flow entrance / presettling
    - Cell ponding area
    - Soils
    - Underdrain (if included)
    - Overflow
    - Plant material
    - Mulch layer
    - Modeling and sizing procedure.

Setbacks and Site Constraints

- Bioretention facilities and rain gardens rely on water movement through the surface soils as infiltration and interflow to underlying soils. Therefore, it is important to always consider the pathway of interflow and assure that the pathway is maintained in an unobstructed and uncompacted state. This is true during the construction phase as well as postconstruction.

- Minimizing compaction of the base and sidewalls of the bioretention or rain garden area is critical. Excavation, soil placement, or soil amendment shall not be allowed during wet or saturated conditions. Excavation should be performed by machinery operating adjacent to the facility and no heavy equipment with narrow tracks, narrow tires, or large lugged, high pressure tires should be allowed on the bottom of the facility. If machinery must operate in the facility for excavation, light weight, low ground-contact pressure equipment should be used and the base shall be scarified at completion to refracture soil to a minimum of 12 inches.

- All bioretention facilities and rain gardens shall be a minimum of 10 feet away from any structure or property line.

- Bioretention facilities and rain gardens shall be set back at least 50 feet from top of slopes steeper than 20 percent and greater than 10 feet high. A geotechnical analysis and report must be prepared addressing the potential impact of the facility on the slope. The geotechnical report may recommend a reduced setback, but in no case shall the setback be less than the vertical height of the slope.

- Bioretention facilities and rain gardens are prohibited within 300 feet of an active landslide hazard area (as defined by Pierce County Development Regulations Title 18E.80 PCC) unless the slope stability impacts of such systems have been analyzed and mitigated by a geotechnical professional, and appropriate analysis indicates that the impacts are negligible.

- In the event that the downstream pathway of infiltration and interflow can’t be maintained, and/or the infiltration capacity is insufficient to handle the contributing area flows (e.g., a facility enclosed in a loop roadway system or a landscape island within a parking lot), an underdrain system can be incorporated into the facility. The underdrain system can then be conveyed to a nearby vegetated channel, another stormwater facility, or dispersed into a natural protection area. Facilities with underdrains may not use the modeling credits outlined in this section. See the underdrain section below for additional information.

Flow Entrance/Presettling

The design of flow entrance to a bioretention or rain garden facility will depend upon topography, flow velocities, flow volume, and site constraints. Flows entering a facility should be less than 1 foot per second to minimize erosion potential. Vegetated buffer strips are the preferred entrance type because they slow incoming flows and provide initial settling of particulates.

Four primary types of flow entrances can be used for bioretention/rain gardens:

- Dispersed, low velocity flow across a grass or landscape area – this is the preferred method of delivering flows to the facility and can provide initial settling of particulates
- Dispersed flow across pavement or gravel and past wheel stops for parking areas
- Drainage curb cuts for driveway or parking lot areas – curb cuts shall include rock or other erosion protection material in the channel entrance to dissipate energy
- Pipe flow entrance – piped entrances shall include rock or other erosion protection material in the facility entrance to dissipate energy and/or provide flow dispersion.

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

Minimum requirements associated with the flow entrance/presettling design include the following:

- If concentrated flows are entering the facility, engineered flow dissipation (e.g., rock pad or flow dispersion weir) must be incorporated.
- A minimum 1-inch grade change between the edge of a contributing impervious surface and the vegetated flow entrance is required.
- Until the upstream catchment area is thoroughly stabilized, flow diversion and erosion control measures must be installed to protect the bioretention area from sedimentation.
- If the catchment area exceeds 2,000 square feet, a pre-settling facility (e.g., filter strip, pre-settling basin, or vault) may be required. Dispersed flow should not be concentrated for pre-settling purposes.

Cell Ponding Area

The ponding area provides surface storage for storm flows, particulate settling, and the first stages of pollutant treatment within the facility.

Ponding depth and draw-down rate requirements are to provide surface storage, adequate infiltration capability, and soil moisture conditions that allow for a range of appropriate plant species. Soils must be allowed to dry out periodically in order to 1) restore hydraulic capacity of system, 2) maintain infiltration rates, 3) maintain adequate soil oxygen levels for healthy soil biota and vegetation, 4) provide proper soil conditions for biodegradation and retention of pollutants, and 5) prevent conditions supportive of mosquito breeding.

Minimum requirements associated with the facility ponding area design include the following:

- The ponding depth shall be a maximum of 6 inches (see alternative design under the overflow section below)
- The surface pool drawdown time shall be a maximum of 24 hours
- The maximum planted side slope shall be 4H:1V
- The bottom width shall be no less than 2 feet
- The minimum freeboard measured from the invert of the overflow pipe or earthen channel to facility overtopping elevation shall be 2 inches for drainage areas less than 1,000 square feet and 6 inches for drainage areas 1,000 square feet of greater
- If berming is used to achieve the minimum top elevation needed to meet ponding depth and freeboard needs, maximum slope on berm shall be 4H:1V, and minimum top width of design berm shall be 1 foot. Soil used for berming shall be imported bioretention soil or amended native soil and compacted to a minimum of 90 percent dry density.

Overflow

Unless designed for full infiltration of the entire continuous model runoff file, bioretention and rain garden facilities must include an overflow. Facility overflow can be provided by a drain pipe installed at the designed maximum ponding elevation (6 inches) and connected to a downstream BMP or an approved discharge point.

Overflows shall be designed to convey the 100-year recurrence interval flow. This assumes the facility will be full due to plugged orifices or high inflows. The design must provide controlled discharge directly into the downstream conveyance system or another acceptable discharge point.

It is possible to design additional detention storage above the 6-inch design water surface (to a maximum of 30 inches total) by including an orifice control system within the overflow structure to help attenuate the flows. For example, a Type 1 Catch Basin with removable down-turned elbow (using properly designed orifices) could be used. This would allow the bioretention facility to dewater in a reasonable timeframe (less than 24-hours). If using this design, the plant selection must clearly reflect the additional proposed storage depth. This potential modified design is allowed only for bioretention systems, not for rain gardens on individual lots. Care must be taken to still blend these larger and deeper facilities in with the surrounding landscape. Vertical walls are not allowed.

Soils

Bioretention facilities may meet the requirements for basic and enhanced treatment, but are not subject to the same soil infiltration treatment requirements for basins, trenches, and swales discussed in Volume V (i.e., soil suitability criteria #1 and soil suitability criteria #2). For flows requiring basic or enhanced treatment, the following soil design requirements apply:

- The bioretention soil mix must meet the requirements of Section 3.14 of this volume.
- Minimum depth of treatment soil must be 18 inches.
- Soil depths of 24 inches and greater should be considered to provide improved removal of nutrients as needed, including phosphorus. Metals uptake has been shown to be greater at 22 inches than 10 inches (with no additional improvement in deeper soils); however most significant metal uptake occurs in the mulch layer that can retain a large portion of the total metals loads (PSAT 2005).
- A soils report, prepared and stamped by a geotechnical professional, shall be required that addresses the following for each bioretention or rain garden facility:
    - A minimum of one soil log or test pit is required at each facility location.
    - The soil log shall extend a minimum of 4 feet below the bottom of the subgrade (which is the lowest point of excavation where soil is to be amended).
    - The soil log shall describe the USDA textural class of the soil horizon(s) through the depth of the log and note any evidence of high groundwater level, such as mottling.

- As noted above in the applicability section, for most facilities the bottom of the subgrade must be at least 3 feet above the seasonal high groundwater level or other impermeable layer. A minimum of 1 foot of clearance may be acceptable if the contributing area is below the thresholds specified previously.

- A primary pathway for stormwater discharge from a bioretention facility with less permeable (Type C) soils can be through interflow in the upper soil structure. The soil investigation should include a detailed description of the condition of the upper soil structure, including the pathway the discharged stormwater will take.

- The report shall include recommendations on the degree of soil amendment (see Section 3.14) necessary to reestablish an upper soil profile similar to an undisturbed forested condition that will allow interflow through the upper soil structure.

- Where the native soils do not meet the desired soil conditions, the soil shall be improved by amending the soil as discussed in Section 3.14. The depth of the soil amendment should be determined by the designer with deeper amendments, up to 4 feet, allowing a smaller foot print for amended areas. The bottom depth shall also be kept above the seasonal high groundwater level or other impermeable layer as specified previously.

- Infiltration rates of the native soil (i.e., the undisturbed soil below the imported and/or amended facility soil) must be used when sizing and modeling bioretention facilities. The native infiltration rate shall be determined using the methods outlined in Volume III, Appendix III-A. Rain gardens may be designed using the sizing table presented below in Table 3.1.

Underdrain (Optional)

The area above an underdrain pipe in a bioretention or rain garden provides attenuation and pollutant filtering. Underdrain systems should be installed only if the bioretention or rain garden is:

- Located where infiltration is not permitted and a liner is used

- In soils with infiltration rates that are not adequate to meet maximum pool drawdown time.

The underdrain pipe diameter will depend on hydraulic capacity required (4 to 8 inches is common). The underdrain can be connected to a downstream BMP such as another bioretention/rain garden facility as part of a connected system, or to an approved discharge point. A geotextile fabric (specifications in Volume V, Appendix V-A) must be used between the soil layer and underdrain.

Planting

The design intent for bioretention and rain garden plantings is to replicate, to the extent possible, the hydrologic function of a mature forest including succession plants and groundcover. Plant roots aid in the physical and chemical bonding of soil particles that is necessary to form stable aggregates, improve soil structure, and increase infiltration capacity.

The primary design considerations for plant selection include:

- Soil moisture conditions – plants should be tolerant of summer drought, ponding fluctuations, and saturated soil conditions for the lengths of time anticipated by the facility design.
- Above and belowground infrastructure in and near the facility – plant size and wind firmness should be considered within the context of the surrounding infrastructure. Rooting depths should be selected to not damage underground utilities if present. Slotted or perforated pipe shall be 5 feet minimum from tree locations and all sidesewer pipes.
- Adjacent plant communities and potential invasive species control – if adjacent to invasive species, consider planting fast growing, hearty species. Shrubs may be used to help shade-out invasive weeds.
- Aesthetics – These facilities should be designed to blend into the surrounding landscaping, which will provide a more aesthetically pleasing stormwater facility. In addition, visually pleasing plant designs add value to the property and encourage community and homeowner acceptance.

In general, the predominant plant material utilized in bioretention and rain garden facilities are facultative species adapted to stresses associated with wet and dry conditions. Soil moisture conditions will vary within the facility from saturated (bottom of facility) to relatively dry (rim of facility). Accordingly, wetland plants may be used in the lower areas, if saturated soil conditions exist for appropriate periods, and drought-tolerant species planted on the perimeter of the facility or on mounded areas.

Native plant species, placed appropriately, tolerate local climate and biological stresses and usually require no nutrient or pesticide application in properly designed soil mixes. Natives can be used as the exclusive material in a bioretention or rain garden facility, or in combination with hardy cultivars that are not invasive and do not require chemical inputs. To increase survival rates and ensure quality of plant material, the following guidelines are suggested:

- As a general guideline, a minimum of three trees, three shrubs, and three herbaceous species should be incorporated to protect against facility failure due to disease and insect infestations of a single species. Grass coverage alone will be acceptable. The planting arrangement should be designed to create a dense coverage of plants, shrubs, and trees.
- Plants should conform to the standards of the current edition of American Standard for Nursery Stock as approved by the American Standards Institute, Inc., or the 2005 Puget Sound Action Team Low Impact Development Technical Guidance Manual for Puget Sound (PSAT 2005). All plant grades shall be those established in the current edition of American Standards for Nursery Stock (current edition: ANSI Z60.1-2004).
- All plant materials should have normal, well-developed branches and root systems, and be free from physical defects, plant diseases, and insect pests.
- Plant size – small plant material provides several advantages and is recommended. Specifically, small plant material requires less careful handling, less initial irrigation, experiences less transplant shock, is less expensive, adapts more quickly to a site, and transplants more successfully than larger material. Small trees and shrubs are generally supplied in pots of 3 gallons or less.
- All plants should be tagged for identification when delivered.
- Optimum planting time is typically fall (beginning mid October). Winter planting is acceptable; however, extended freezing temperatures shortly after installation can increase plant mortality. Spring is also acceptable, but requires more summer watering than fall plantings. Summer planting is the least desirable and requires regular watering for the dry months immediately following installation.

A permanent irrigation system using potable water may be used, but an alternative means of irrigation, such as air conditioning condensate or another readily available nonpotable source should be considered to maximize efficient use of resources. Any nonpotable sources must be analyzed to ensure that they do not contain chemicals that might harm or kill the vegetation. Any permanent irrigation system that relies on potable water should be designed to apply no more than 0.2 inches of water every 14 days from June through September, after the 2-year establishment period.

Mulch Layer

Bioretention and rain garden facilities should be designed with a mulch layer or a dense groundcover. Research indicates that most attenuation of heavy metals in bioretention cells occurs in the first 1 to 2 inches of the mulch layer. That layer can be easily removed or added to as part of a standard and periodic landscape maintenance procedure. Properly selected mulch material also reduces weed establishment, regulates soil temperatures and moisture, and adds organic matter to soil. Mulch should be:

- Compost in the bottom of the facilities (compost is less likely to float than wood chip mulch and is a better source for organic materials)
- Wood chip mulch composed of shredded or chipped hardwood or softwood on cell slopes
- Free of weed seeds, soil, roots and other material that is not trunk or branch wood and bark
- A maximum of 3 inches thick for compost or 4 inches thick for wood chips (thicker applications can inhibit proper oxygen and carbon dioxide cycling between the soil and atmosphere).

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.

Modeling and Sizing

- Sizing of a **rain garden** (lot-scale facility, contributing area less than 2,000 square feet) can be done by relating the square footage of the bottom of the rain garden to the contributing area of rooftop in accordance with Table 3.1 below. Note that for roof areas that fall between the areas represented by each column in the table, the required footprint area may be interpolated based on the information in the tables. This same method of sizing can also be used for rain gardens receiving driveway runoff provided that the soils meet the water quality treatment requirements outlined previously, or the runoff passes through a basic treatment facility before reaching the rain garden. Collection areas greater than 2,000 square feet must be designed by a professional engineer.

Table 3.1. Sizing Table for Rain Gardens.

Square Feet of Rain Garden Bottom				
Engineered Soil Depth (ft)	**Contributing Area (square feet)**			
	500	**1,000**	**1,500**	**2,000**
1.5	166	332	583	833
2.0	157	314	553	791
2.5	148	296	523	749
3.0	139	278	493	707
3.5	130	260	463	665
4.0	121	242	433	623

Notes:
Collection areas greater than 2,000 square feet must be designed by a professional engineer.
One foot of separation between groundwater and the bottom of engineered soil is required. Well draining soil is required in this area.

- **Bioretention facilities** (i.e., facilities managing larger areas or greater than one lot) receiving runoff from roads or a combination of roads and other impervious/pervious surfaces will be larger than rain gardens. Sizing will be determined by using an approved continuous simulation model and treating the facility as an infiltration facility with appropriate stage-storage and overflow/ outflow rates.

When using continuous modeling to size bioretention facilities, the assumptions listed in Table 3.2 shall be applied. It is recommended that bioretention cells be modeled as a layer of soil (with specified infiltration rate) with infiltration to underlying soil, ponding, and overflow. The tributary areas, cell bottom area, and ponding depth should be iteratively sized until the duration curves and/or peak values meet the applicable flow control requirements (see Volume I). For additional guidance on infiltration facility sizing see Volume III, Section 3.3.

At the time of publication of this volume, the professional version of WWHM includes a bioretention module that can be used to size the cell with or without an underdrain as a function of tributary area, land use type, native soil infiltration rate, side slopes, etc. It is anticipated that other modeling programs will develop similar modules to represent bioretention cells in the future.

Table 3.2. Continuous Modeling Assumptions for Bioretention Cells.

Variable	Assumption
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 (always activated in WWHM bioretention module)
Bioretention Soil Infiltration Rate	For imported soil, rate is 2.5 inch per hour. For compost amended native soil, rate shall be equal to native soil design infiltration rate.
Bioretention Soil Porosity	40%
Bioretention Soil Depth	Minimum of 18 inches
Native Soil Infiltration Rate	Measured infiltration rate, including applicable safety factors (see Volume III, Appendix III-A)
Infiltration Across Wetted Surface Area	Only if side 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.

3.9 Roof Downspout Controls

Roof downspout controls are simple pre-engineered designs for infiltrating and/or dispersing runoff from roof areas for the purposes of increasing opportunities for groundwater recharge and reduction of runoff volumes from new developments. Roof downspout controls are required as part of Minimum Requirement #5, if applicable (see Volume I, Chapter 2). This section presents an overview of the types and applications of roof downspout controls. Additional details on specific BMPs are provided in subsequent sections.

3.9.1 Selection of Roof Downspout Controls

Large lots in rural areas typically have enough area to infiltrate or disperse roof runoff. Lots created in urban areas will typically be smaller and have a limited amount of area in which to incorporate infiltration or dispersion trenches.

Downspout infiltration must be used in those soils that readily infiltrate (coarse sands and cobbles to medium sands). This clean runoff does not require pretreatment prior to the storage/discharge facility provided that it is not mixed with other contaminated runoff. Dispersion BMPs must be used in areas with less permeable soils where infiltration is not feasible.

Where dispersion is not feasible due to impermeable soils or where downspout disconnection or dispersion could cause downstream flooding or erosion concerns, downspouts should be connected to a county approved discharge point (e.g., stormwater management facility and/or conveyance system).

The feasibility or applicability of downspout infiltration and dispersion must be evaluated for all subdivision single-family lots. Single family subdivision projects subject to Minimum Requirement #5 or #7 (Volume I, Chapter 2) must provide for individual downspout infiltration or dispersion systems where practicable. Single family projects not subject to Minimum Requirement #7 must follow the requirements in Volume I, Appendix I-A.

3.9.2 Applicability

Where roof downspout controls are required or planned, the following two types must be considered in order of preference:

- Downspout infiltration systems (Section 3.10)
- Downspout dispersion systems (Section 3.11).

Other innovative downspout control BMPs such as rain barrels, ornamental ponds, downspout cisterns, or other downspout water storage devices may also be used with prior approval by the county. Any alternative methods proposed will be required to meet the performance criteria of all applicable minimum requirements, particularly Minimum Requirements #5 or #7.

Downspout disconnection or dispersion will not be allowed in situations where the disconnection could cause erosion or flooding problems, either on site or on adjacent lots. The design engineer must demonstrate that the proposed release rate will not have an adverse downstream impact. The county will review each proposal on a case-by-case basis due to the uniqueness of each site condition.

In rural densities of one dwelling unit per acre or less, gutters and downspouts may be eliminated to allow rooftop stormwater to drip from the roof edge into vegetation planted at the drip line when designed in conformance with IBC requirements.

The following two sections outline design information specific to roof downspout infiltration (Section 3.10) and dispersion (Section 3.11).

3.10 Downspout Infiltration Systems

Downspout infiltration systems are trench or drywell designs intended only for use in infiltrating runoff from roof downspout drains. They are not designed to directly infiltrate runoff from pollutant-generating impervious surfaces. See Volume V, Chapter 6 for infiltration treatment requirements.

Infiltration of roof runoff shall be considered before dispersion and bioretention techniques.

3.10.1 Flow Credit for Roof Downspout Infiltration

If roof runoff is infiltrated according to the requirements of this section, the roof area may be discounted from the project area used for sizing stormwater facilities. This is done by clicking on the "Credit" button in WWHM and entering the percent of roof area that is being infiltrated.

Options for downspout infiltration systems include infiltration trenches and drywells. The county has developed standardized tables that can be used to facilitate sizing of infiltration trenches and drywells for smaller site applications. Prior to selecting and designing an infiltration facility, the project must prepare a soils investigation and report, as discussed in the next section.

3.10.2 Procedure for Evaluating Soils Feasibility

- A soils report must be prepared by a professional soil scientist certified by the Soil Science Society of America (or an equivalent national program), a locally licensed onsite sewage designer, or by a professional engineer, geologist, hydrogeologist, or engineering geologist registered in the State of Washington to determine if soils suitable for infiltration are present on the site. The report must reference a sufficient number of soils logs to establish the type and limits of soils at the proposed trench locations. The report shall at a minimum identify the limits of any *outwash type soils* (i.e., those meeting USDA soil texture classes ranging from coarse sand and cobbles to medium sand) versus other soil types and include an inventory of topsoil depth.

- For projects using the sizing tables presented in Table 3.3, individual lot or site tests must consist of at least one soils log at the location of the infiltration system, a minimum of 4 feet in depth (from proposed grade), identifying the Natural Resources Conservations Service (NRCS – formerly the SCS) series of the soil and the USDA textural class of the soil horizon through the depth of the log, and noting any evidence of high groundwater level, such as mottling. Soils in the location of the proposed infiltration system shall not be silty clay loam, clay loam, clay, or any other soil having a percolation rate slower than 1 inch per hour.

- Site-specific tests must indicate 18 inches or more of permeable soil from the proposed final grade to the seasonal high groundwater table.

- For sites that do not use the sizing tables presented in Table 3.3, the site infiltration rates must be determined using the procedures outlined in Volume III, Appendix III-A.

Table 3.3. Sizing Table for Downspout Infiltration Trenches.

Square Feet of Trench Bottom for Gravel/Type A Soils (60 in/ hour)

Total Depth Below Ground Surface [a] (ft)	Roof Area (square feet)				
	500	1,000	2,000	3,000	4,000
2.5	12.0	24	48	72	96
3.0	10.8	21	43	65	86
3.5	9.5	19	38	57	76
4.0	9.0	18	36	54	72
4.5	8.5	17	34	51	68
5.0	7.9	16	32	47	63
5.5	7.5	15	30	45	60

Square Feet of Trench Bottom for Medium Sand/Type A Soils (12 in/hour)

Total Depth Below Ground Surface [a] (ft)	Roof Area (square feet)				
	500	1,000	2,000	3,000	4,000
2.5	29	58	116	173	231
3.0	26	52	104	155	207
3.5	23	46	92	137	183
4.0	22	43	86	129	171
4.5	20	41	82	123	164
5.0	19	38	76	113	151
5.5	18	36	72	108	144

Square Feet of Trench Bottom for Loamy Sand/Type A Soils (4 in/hour)

Total Depth Below Ground Surface [a] (ft)	Roof Area (square feet)				
	500	1,000	2,000	3,000	4,000
2.5	50	101	202	303	404
3.0	45	90	181	271	361
3.5	40	80	160	240	320
4.0	38	75	150	225	300
4.5	36	71	143	215	286
5.0	33	66	132	198	264
5.5	32	63	126	189	252

Table 3.3 (continued). Sizing Table for Downspout Infiltration Trenches.

Square Feet of Trench Bottom for Loam/Type B Soils (2 in/hour)

Total Depth Below Ground Surface [a] (ft)	Roof Area (square feet)				
	500	1,000	2,000	3,000	4,000
2.5	72	144	288	432	576
3.0	65	129	258	387	516
3.5	57	114	228	342	456
4.0	54	107	214	321	428
4.5	51	102	204	306	408
5.0	47	94	188	282	376
5.5	45	90	180	270	360

Square Feet of Trench Bottom for Porous Silt Loam/Type C Soils (1 in/hour)

Total Depth Below Ground Surface [a] (ft)	Roof Area (square feet)				
	500	1,000	2,000	3,000	4,000
2.5	103	206	412	618	824
3.0	93	184	369	553	737
3.5	82	163	327	490	653
4.0	77	153	306	459	612
4.5	73	146	292	438	584
5.0	68	134	269	404	538
5.5	64	129	258	387	515

[a] The “total depth below ground surface” is the depth of the trench bottom. The trench consists of gravel covered by 6 inches of compacted backfill. Hence, the gravel thickness is 6 inches less than the depth listed.

3.10.3 Design Criteria for Infiltration Trenches

Attachments Section A, Detail 11.1 provides a typical downspout infiltration trench system. These systems are designed as specified below.

The following standardized design criteria are intended to guide the applicant in providing an acceptable design for an individual downspout infiltration system. A professional engineer will not be required to design an individual downspout infiltration system provided that: 1) the proposed site development does not result in a net increase in impervious surfaces of 5,000 square feet or more, 2) the project has prepared a soils report as outlined above, 3) the system is sized according to the sizing chart shown in Table 3.3 and the general guidelines below, and 4) the system is to be constructed according to the standard design shown in Attachments Section A, Detail 11.1. Any deviation in design or construction from the items above or the standardized design criteria detailed below will result in it being required that the individual downspout infiltration be designed by a professional engineer in accordance with the guidelines presented in this volume as well as Volume III.

Table 3.3 above outlines an approved prescriptive design for downspout infiltration trenches that meet Pierce County flow control requirements. The tables present trench footprint areas based on various depths, contributing areas, and infiltration rates. All trenches must be constructed according to the standard design shown in Attachments Section A, Detail 11.1. Note that for roof areas that fall between the areas represented by each column in the table, the required trench footprint area may be interpolated based on the information in the tables. However, for infiltration rates that fall between the rates represented in each table, the designer must use the more conservative (i.e., lower) infiltration rate in their design. All sites have the option to do their own engineered design for infiltration trenches in lieu of using the tables below (in accordance with Volume III requirements), subject to approval by the county. In addition to the sizing requirements outlined in the tables, the following design requirements apply:

- Maximum length of trench must not exceed 100 feet from the inlet sump.
- Minimum spacing between distribution pipe centerlines must be 6 feet.
- The aggregate material for the infiltration trench shall consist of 1.5- to three-fourth-inch washed round rock.

- Geotextile filter fabric shall be wrapped entirely around trench drain rock prior to backfilling EXCEPT that a 6-inch layer of sand below the trench bottom may be used in-lieu of a filter fabric liner on the bottom.

- Infiltration trenches may be placed in fill material if the fill is placed and compacted under the direct supervision of a geotechnical engineer or professional civil engineer with geotechnical expertise, and if the measured infiltration rate is at least 8 inches per hour. Infiltration rates can be tested using the methods described in Volume III, Appendix III-A.

- Infiltration trenches shall be set back at least 50 feet from top of slopes steeper than 20 percent and greater than 10 feet high. A geotechnical analysis and report must be prepared addressing the potential impact of the facility on the slope. The geotechnical report may recommend a reduced setback, but in no case shall the setback be less than the vertical height of the slope.

- All trenches shall be a minimum of 10 feet away from any structure or property line.

- A structure with a sump (see Attachments Section A, Details 11.0 and 11.1) shall be located upstream of the trench, which provides a minimum of 12 inches of depth below the outlet riser. The outlet riser pipe bottom shall be designed so as to be submerged at all times, and a screening material shall be installed on the pipe outlet.

- Trenches may be located under pavement if designed by a professional engineer. Trenches must include an overflow at least 1 foot below the pavement, and in a location which can accommodate the overflow without creating a significant adverse impact to downhill properties or drainage systems. This is intended to prevent saturation of the pavement in the event of system failure. The trench depth must be measured from the overflow elevation, not the ground surface elevation.

- Prior to approval of an individual downspout infiltration system, a site plan must be submitted showing the location of the proposed infiltration system together with adjacent buildings, structures, wells, septic drainfields, and property lines. Prior to final approval of construction, an as-built (record) drawing must be submitted to the county that includes the site plan together with the actual constructed square footage of the infiltration system.

- See Volume III, Section 3.3.4, for additional required setbacks for infiltration facilities.

3.10.4 Design Criteria for Infiltration Drywell Systems

Attachments Section A, Detail 14.0 provides a typical downspout infiltration drywell system. The drywell shall include a settling chamber (as shown in Attachments Section A, Details 11.0 and 11.1), or its equivalent upstream of the drywell for particulate removal. These systems are designed as specified below:

- Drywell bottoms must be a minimum of 1 foot above seasonal high groundwater level or impermeable soil layers.
- Soils in the proposed location shall not be silty clay loam, clay loam, clay, or any other soil having percolation rates slower than 1 inch per hour.
- If using drywells, size the facilities according to the area and depth requirements outlined in Table 3.3. For roof areas that fall between the areas represented by each column in the table, the required trench footprint area may be interpolated based on the information in the tables. For infiltration rates that fall between the rates represented in each table, the designer must use the more conservative (i.e., lower) infiltration rate in their design. All sites have the option to do their own engineered design for infiltration trenches in lieu of using the tables below, subject to approval by the county.
- Typically drywells are 48 inches in diameter (minimum) and have a depth of 5 feet (4 feet of gravel and 1 foot of suitable cover material).
- Filter fabric (geotextile) must be placed on top of the drain rock and on trench or drywell sides prior to backfilling.
- Spacing between drywells must be a minimum of 4 feet.
- Downspout infiltration drywells must not be built on slopes greater than 25 percent (4:1). Drywells may not be placed on or above an active landslide hazard area or slopes greater than 15 percent without evaluation by a professional engineer with geotechnical expertise or a licensed geologist, hydrogeologist, or engineering geologist, and with jurisdiction approval.
- See Volume III, Section 3.3.4, for additional required setbacks for infiltration facilities.

3.11 Downspout Dispersion Systems

Downspout dispersion systems are gravel-filled trenches or splash blocks, which serve to spread roof runoff over vegetated pervious areas.

Dispersion attenuates peak flows by slowing entry of the runoff into the conveyance system, allows for some infiltration, and provides some water quality benefits. General applicability of downspout dispersion is as follows:

- Dispersing roof runoff shall be considered after infiltration and bioretention techniques have been determined infeasible due to soil types or high groundwater.
- The layout of the natural resource protection areas adjacent to and down gradient of individual lots can provide opportunities to disperse runoff into the natural resource protection area.

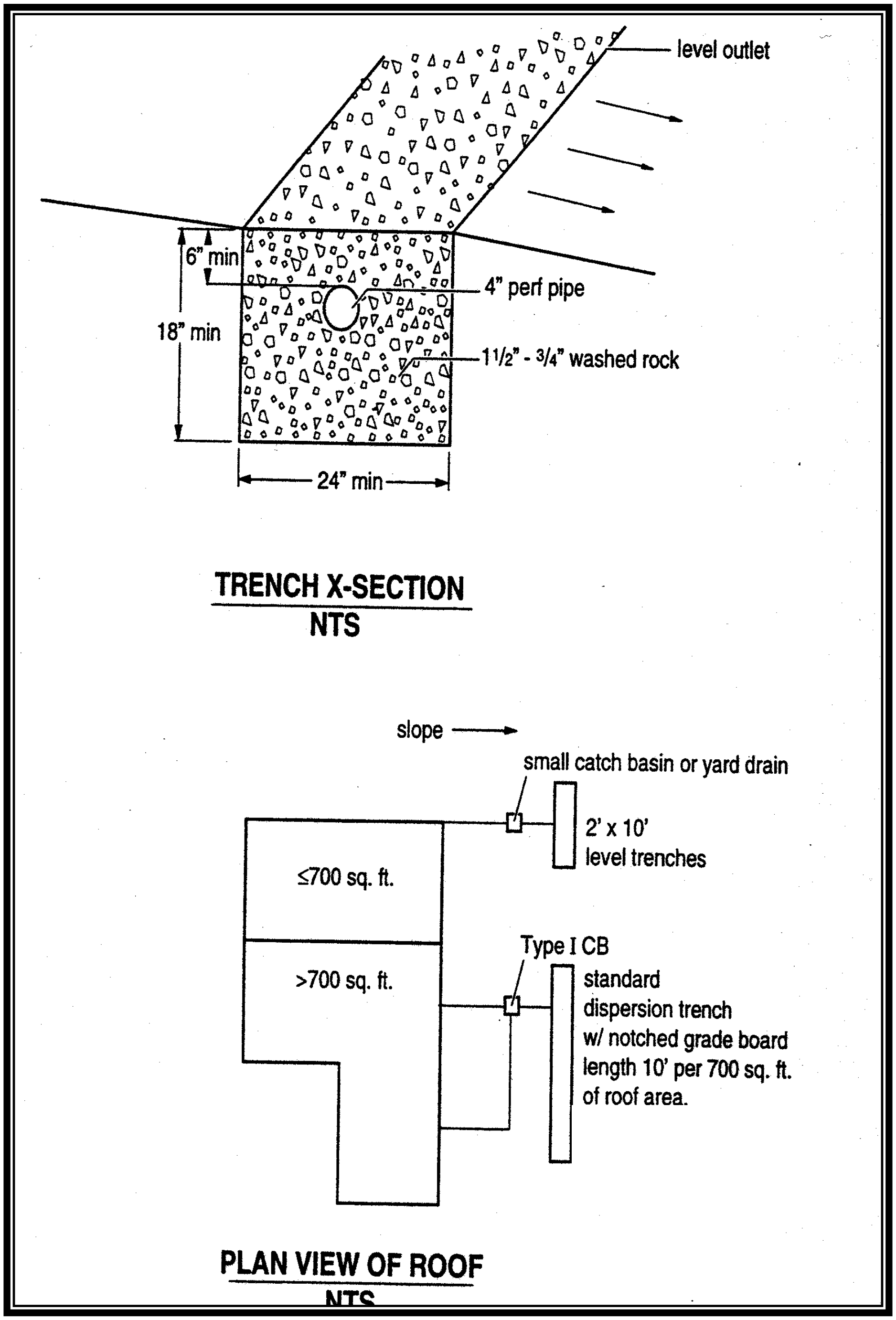
3.11.1 Flow Credit for Roof Downspout Dispersion

If roof runoff is dispersed according to the requirements of this section over a vegetative flow path that is 25 feet or longer (for trenches) or 50 feet or longer (for splashblocks) through undisturbed native landscape or an area that meets the soils criteria outlined in Section 3.14, the roof area may be modeled as grassed surface.

3.11.2 Downspout Dispersion Design Criteria

This section provides design criteria for both dispersion trenches and splash blocks:

- Dispersion trenches shall be designed as shown in Figure 3.3 and Attachments Section A, Detail 1.0.
- Splash blocks shall be designed as shown in Figure 3.4.
- A vegetated flowpath of at least 25 feet in length must be maintained between the outlet of a trench and any property line; structure; critical area (i.e., stream, wetland), or impervious surface. Natural resource protection areas and critical area buffers may count towards flowpath lengths. However, the area must be permanently protected from modification through a covenant or easement, or a tract dedicated by the proposed project. This does not include steep slopes. See steep slope setbacks are outlined below.
- Trenches serving up to 700 square feet of roof area may be simple 10-foot long by 2-foot wide gravel filled trenches as shown in Figure 3.3. For roof areas larger than 700 square feet, a dispersion trench with notched grade board as shown in Attachments Section A, Detail 1.0 shall be used. The total length of this design must not exceed 50 feet and must provide at least 10 feet of trench per 700 square feet of roof area. In both systems it is important to



Source: King County

Figure 3.3. Typical Downspout Dispersion Trench.

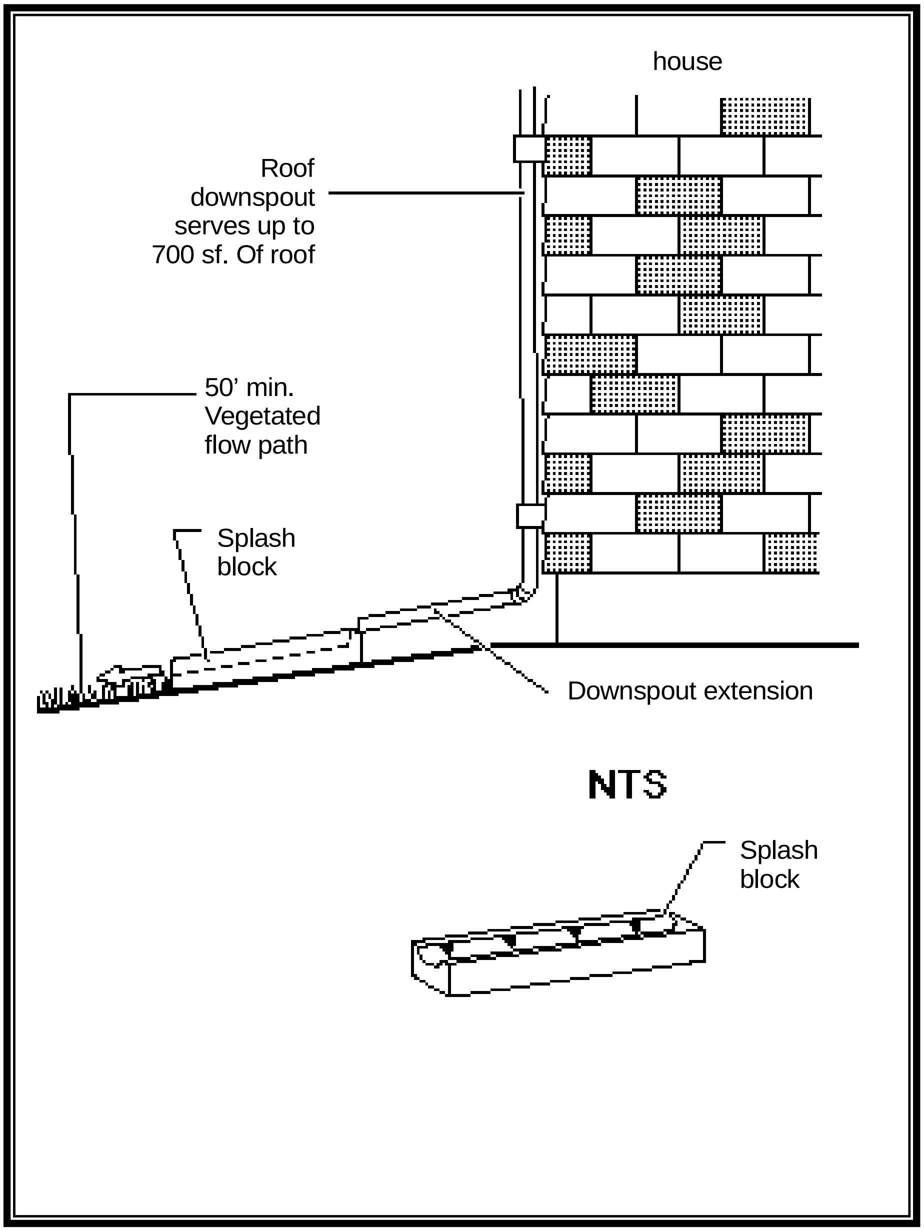


Figure 3.4. Typical Downspout Splashblock Dispersion.

include a cleanout structure prior to discharge into the dispersal area. Although the figures refer at times to a Type 1 catch basin being used, it is also acceptable to utilize an equivalent type structure which includes a lid, 1-foot minimum sump, and T-type outlet with screen as shown in Attachments Section A, Detail 11.1.

- Splash blocks shown in Figure 3.4 may be used for downspouts discharging to a vegetated flow path at least 10 feet in width and 50 feet in length as measured from the downspout to the downstream property line; structure; critical areas (i.e., stream, wetland), or other impervious surface. Flow path measurement may traverse a property line into an adjacent natural resource protection area or critical area buffer-provided that the area is permanently protected through a covenant, easement, or a tract dedicated as part of the proposed project. This **does not** include steep slopes. See steep slope setbacks below.
- A maximum of 700 square feet of roof area may drain to each splash block. When flow paths of multiple splash blocks are combined the vegetated flow path width shall increase by 50 percent with each additional splashblock.
- No erosion or flooding of downstream properties may result.
- For both trenches and splashblocks, the vegetated flowpath must be covered with well-established vegetation to prevent erosion and promote partial infiltration. Vegetated flowpaths shall consist of undisturbed native landscape area or an area that meets the requirements of Section 3.14.
- For sites with septic systems, the discharge point must be downslope of the primary and reserve drainfield areas. This requirement may be waived if site topography clearly prohibits flows from intersecting the drainfield.
- Dispersion systems shall be set back at least 50 feet from top of slopes steeper than 20 percent and greater than 10 feet high. A geotechnical analysis and report must be prepared addressing the potential impact of the facility on the slope. The geotechnical report may recommend a reduced setback, but in no case shall the setback be less than the vertical height of the slope.

3.12 Concentrated Flow Dispersion

Dispersion of concentrated flows from driveways or other pavement through a vegetated pervious area attenuates peak flows by slowing entry of the runoff into the conveyance system, allows for some infiltration, and provides some water quality benefits. See Figure 3.5.

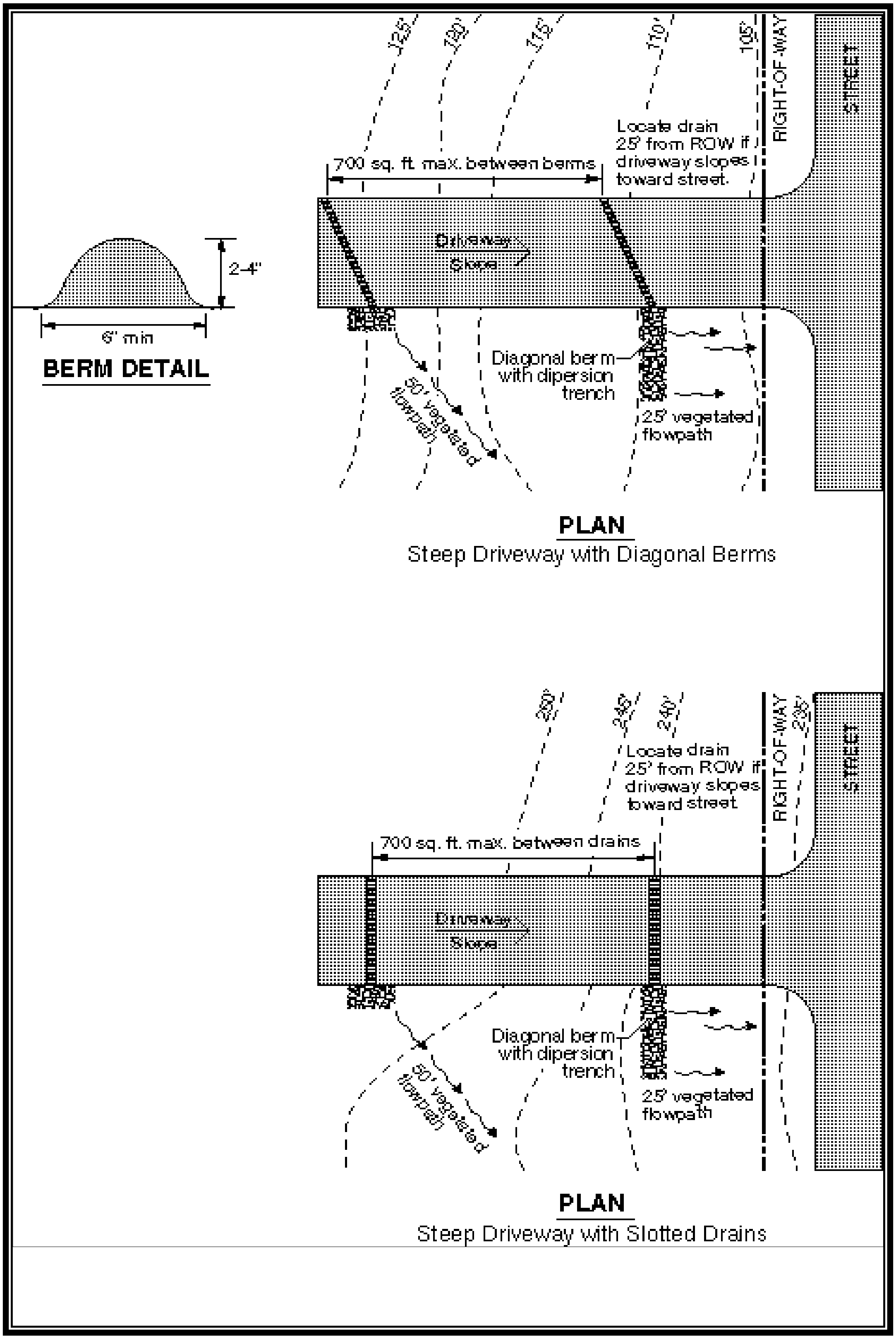


Figure 3.5. Typical Concentrated Flow Dispersion for Steep Driveways.

3.12.1 Applicability

- Any situation where concentrated flow can be dispersed through vegetation.
- Dispersion for driveways will generally only be effective for single-family residences on large lots and in rural short plats. Lots proposed by short plats in urban areas will generally be too small to provide effective dispersion of driveway runoff.
- Figure 3.6 shows two possible ways of spreading flows from steep driveways.

3.12.2 Flow Credit for Concentrated Flow Dispersion

Where concentrated flow dispersion is used to disperse runoff into an undisturbed native landscape area or an area that meets Section 3.14, and the vegetated flow path is at least 50 feet, the impervious area may be modeled as landscaped area.

3.12.3 Concentrated Flow Dispersion Design Criteria

- A vegetated flowpath of at least 50 feet must be maintained between the discharge point and any property line, structure, steep slope, stream, lake, wetland, lake, or other impervious surface.
- A maximum of 700 square feet of impervious area may drain to each concentrated flow dispersion BMP.
- A pad of crushed rock (2 feet wide by 3 feet long by 6 inches deep) shall be placed at each discharge point.
- No erosion or flooding of downstream properties may result.
- Runoff discharged towards active landslide hazard areas must be evaluated by a geotechnical engineer or qualified geologist. The discharge point shall not be placed on or above slopes greater than 20 percent or above erosion hazard areas without evaluation by a geotechnical engineer or qualified geologist and approval by Pierce County.
- For sites with septic systems, the discharge point must be downgradient of the drainfield primary and reserve areas. This requirement may be waived by Pierce County if site topography clearly prohibits flows from intersecting the drainfield.

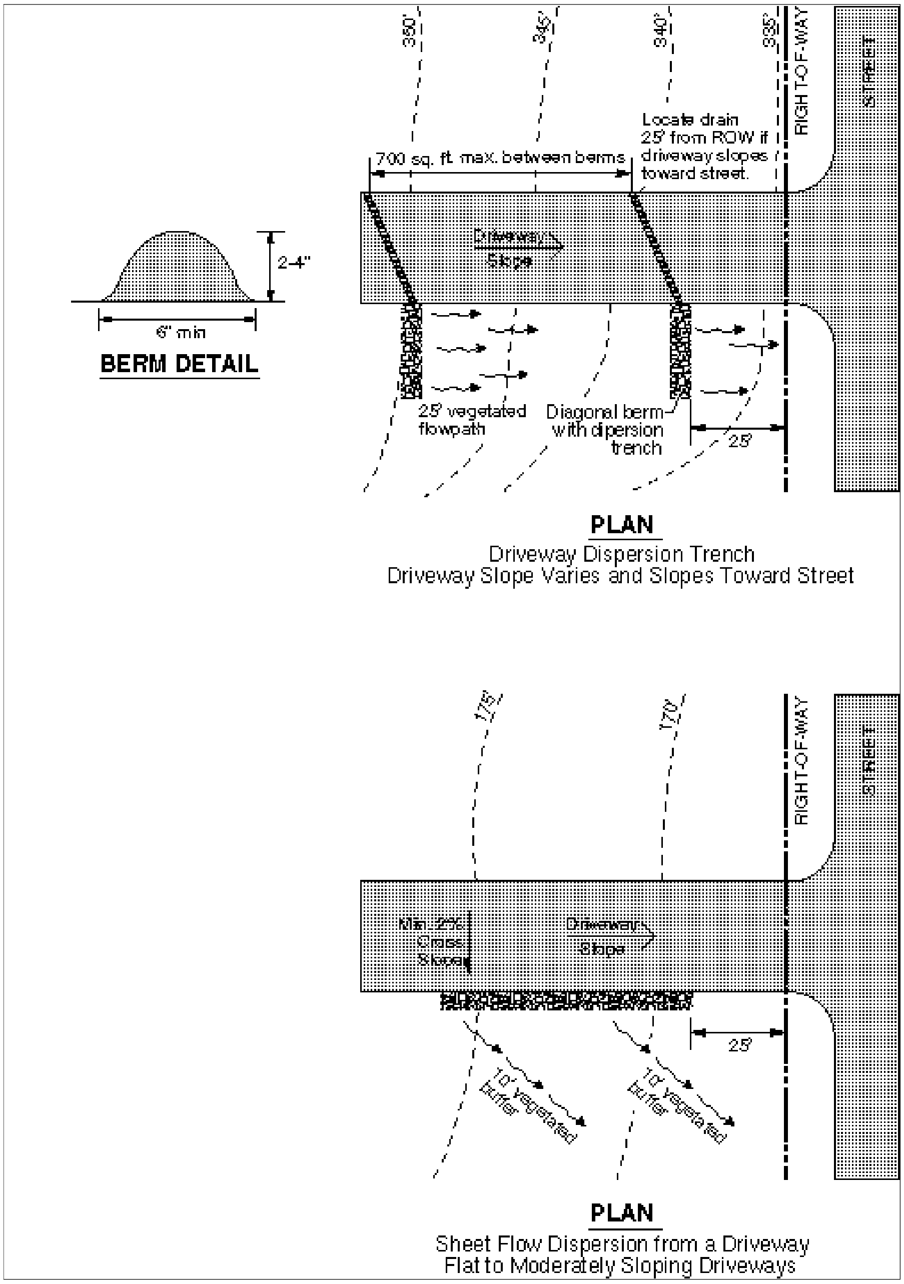


Figure 3.6. Sheet Flow Dispersion for Driveways.

3.13 Sheet Flow Dispersion

Sheet flow dispersion is the simplest method of runoff control. This BMP can be used for any impervious or pervious surface that is graded so as to avoid concentrating flows. Because flows are already dispersed as they leave the surface, they need only traverse a narrow band of adjacent vegetation for effective attenuation and treatment.

3.13.1 Applicability

Flat or moderately sloping (less than 15 percent slope) impervious surfaces such as driveways, sport courts, patios, and roofs without gutters; sloping cleared areas that are comprised of bare soil, non-native landscaping, lawn, and/or pasture; or any situation where concentration of flows can be avoided.

3.13.2 Flow Credit for Sheet Flow Dispersion

- Where sheet flow dispersion is used to disperse runoff into an undisturbed native landscape area or an area that meets the requirements of Section 3.14, the impervious area may be modeled as landscaped area.

3.13.3 Sheet Flow Dispersion Design Criteria

- See Figures 3.5 and 3.6 for details for driveways.
- A 2-foot-wide transition zone to discourage channeling should be provided between the edge of the driveway pavement and the downslope vegetation, or under building eaves. This may be an extension of subgrade material (crushed rock), modular pavement, drain rock, or other material approved by Pierce County.
- A vegetated buffer width of 10 feet of vegetation must be provided for up to 20 feet of width of paved or impervious surface. An additional 5 feet of width must be added for each additional 20 feet of width or fraction thereof.
- A vegetated buffer width of 25 feet of vegetation must be provided for up to 150 feet of contributing cleared area (i.e., bare soil, non-native landscaping, lawn, and/or pasture). Slopes within the 25-foot minimum flowpath through vegetation must be no steeper than 8 percent. If this criterion cannot be met due to site constraints, the 25-foot flowpath length must be increased 1.5 feet for each percent increase in slope above 8 percent.
- No erosion or flooding of downstream properties may result.

- Runoff discharge shall be set back at least 50 feet from top of slopes steeper than 20 percent and greater than 10 feet high. A geotechnical analysis and report must be prepared addressing the potential impact of the facility on the slope. The geotechnical report may recommend a reduced setback, but in no case shall the setback be less than the vertical height of the slope.

- For sites with septic systems, the discharge point must be downgradient of the drainfield primary and reserve areas. This requirement may be waived by Pierce County if site topography clearly prohibits flows from intersecting the drainfield.

3.14 Soil Amendments, Quality, and Depth

Traditional grass yards are less pervious than native forest or prairie. Amending soils is a method of regaining some of the absorption and infiltration capability of the soil, and increasing a yard’s ability to retain runoff and filter pollutants. This can be especially important if runoff from adjacent impervious surfaces, such as roofs or driveways, is dispersed over the yard. Within both LID projects and traditional development projects, the soil and landscape system shall be viewed as tools for at least partial stormwater infiltration, water conservation, and pollution control.

3.14.1 Applicability

- Soil amendments are required for the disturbed areas of sites subject to Minimum Requirement #5, as outlined in Volume I.

- For sites where Minimum Requirement #5 does not apply, if the site is acceptable for traditional lawn installation, then a compost-amended soil lawn is strongly recommended. A compost-amended lawn will drain equally well, while providing the incidental stormwater retention and detention benefits.

- If the site being considered for turf establishment already does not drain well, an alternative to planting a lawn should be considered. If the site is not freely draining, and turf replacement is still being attempted, compost amendment will still provide stormwater benefits but should be incorporated into the soil at a reduced ratio of no more than 30 percent by volume. This upper limit is suggested in the Pacific Northwest because regions extended saturated winter conditions may create water logging of the lawn. The landscape professional should also provide a drainage route or subsurface collection system.

- Soil amendments shall be used in areas that are to be incorporated into the stormwater drainage system such as vegetated channels, rain gardens, and bioretention areas and also into the lawn and landscape areas of the development. (Note: See the design criteria below and under each individual BMP for the application rate for each particular BMP technique.)

- Soil amendments may also be used to improve permeability of soils graded and/or partially compacted in preparation for use of minimal excavation foundation systems.

3.14.2 Limitations

- There is the potential that increasing the moisture content within the soil could also increase soil instability in areas with steep slopes. However, the Washington State Department of Transportation (WSDOT) has been incorporating compost-amendment in almost all of its vegetated sites since 1992 and has not experienced problems, even on the steepest sites (33 percent slope), as a result of the increased moisture holding capacity within the soils. (Note: See design criteria below for requirements of steep slope soil amendment.)

3.14.3 Design Criteria

- As a first priority, native soils with robust native landscapes must be protected from disturbance whenever possible, especially in natural resource protection areas where postconstruction soil rehabilitation is not planned. See Section 2.3.1 Vegetation Retention, Vegetation Protection during Construction Phase for protection requirements of natural resource protection areas during construction.

- The designer can typically choose from several options listed below for creating the appropriate soil quality and depth. There are different desired soil quality and depths depending on the function at the location you are amending (e.g., either a part of the stormwater drainage system, landscaped area, or lawn). Follow the option that works best with your site and then refer to Table 3.4 for estimating soil depth and height changes when applying soil amendments.

- Note: information on required compost composition and quality is provided at the end of this section.

Table 3.4. Estimating Soil Depth and Height Changes.

Procedure	Calculation	Relative Elevation Inches
Beginning Elevation		0
Rototill soil to a depth of 6 inches and assuming 1.4-inch fluff factor	Depth achieved by machinery x fluff factor of soil: (6 x 1.4) = 8.4 8.4 – 6 = 2.4	+2.4
Add compost, 2 units soil to 1 unit compost, by loose volume	Depth of soil ÷ 2: 8.4 ÷ 2 = 4.2	+4.2
Filling of pore spaces	Depth of loose soil x percentage of pore space filled by compost addition: 8.4 x (-.15) = -1.3	-1.3
Rototill compost into soil and roll site to compact soil, assuming compression factor of 1.2	(Amended soil depth ÷ compression factor) – amended soil depth:	-2.1
Resulting Elevation Change	Sum	+3.2

OPTION 1 – Amend Existing Soils in Place

Scarify or till existing subgrade to 4 inches depth (or to depth needed to achieve a total depth of 12 inches of uncompacted soil after calculated amount of amendment is added, see specific subsections below). Entire surface should be disturbed by scarification. Do not scarify within drip line of existing trees to be retained.

Within *Stormwater Drainage System* locations or *Landscaped Areas (10 percent organic content)* – Place and rototill 3 inches of composted material into 5 inches of soil (a total depth of about 9.5 inches, for a settled depth of 8 inches). As noted previously, subsoils below this layer should be scarified at least 4 inches, for a finished minimum depth of 12 inches of uncompacted soil. Rake beds to smooth and remove rocks larger than 2 inches diameter. Mulch areas with 2 inches of organic mulch.

Within *Lawn Areas (5 percent organic content)* – Place and rototill 1.75 inches of composted material into 6.25 inches of soil (a total amended depth of about 9.5 inches, for a settled depth of 8 inches). As noted previously, subsoils below this layer should be scarified at least 4 inches, for a finished minimum depth of 12 inches of uncompacted soil. Water or roll to compact soil to 85 percent of maximum. Rake to level, and remove surface woody debris and rocks larger than 1 inch in diameter.

OPTION 2 – Stockpile Site Topsoils Prior to Grading for Reapplication

If placed topsoil plus compost or other organic material will amount to less than 12 inches: scarify or till subgrade to depth needed to achieve 12 inches of loosened soil after topsoil and amendment are placed. Entire surface should be disturbed by scarification. Do not scarify within drip line of existing trees to be retained.

Stockpile and cover soil with weed barrier material that sheds moisture yet allows air transmission, in approved location, prior to grading.

Replace stockpiled topsoil prior to planting.

Within *Stormwater Drainage System* locations or *Landscaped Areas (10 percent organic content)* – Place and rototill 3 inches of composted material into 5 inches of replaced soil (a total depth of about 9.5 inches, for a settled depth of 8 inches). Subsoils below this layer should be scarified at least 4 inches, for a finished minimum depth of 12 inches of uncompacted soil. Rake beds to smooth and remove rocks larger than 2 inches in diameter. Mulch areas with 2 inches of organic mulch or stockpiled duff.

Within *Lawn Areas (5 percent organic content)* – Place and rototill 1.75 inches of composted material into 6.25 inches of replaced soil (a total amended depth of about 9.5 inches, for a settled depth of 8 inches). Subsoils below this layer should be scarified at least 4 inches, for a finished minimum depth of 12 inches of uncompacted soil. Water or roll to compact soil to 85 percent of maximum. Rake to level, and remove surface woody debris and rocks larger than 1 inch in diameter.

OPTION 3 – Import Topsoil Meeting Organic Matter Content Standards

Scarify or till subgrade in two directions to 6 inches depth. Entire surface should be disturbed by scarification. Do not scarify within drip line of existing trees to be retained.

Within *Stormwater Drainage System* locations or *Landscaped Areas (10 percent organic content)* – Use imported topsoil mix containing 10 percent organic matter (typically around 40 percent compost). Soil portion must be sand or sandy loam as defined by the USDA. Place 3 inches of imported topsoil mix on surface and till into 2 inches of soil. Place 3 inches of topsoil mix on the surface. Rake smooth and remove surface rocks over 2 inches diameter. Mulch planting beds with 2 inches of organic mulch.

Within *Lawn Areas (5 percent organic content)* – Use imported topsoil mix containing 5 percent organic matter (typically around 25 percent compost). Soil portion must be sand or sandy loam as defined by the USDA. Place 3 inches of imported topsoil mix on surface and till into 2 inches of soil. Water or roll to compact soil to 85 percent maximum. Rake to level, and remove surface rocks larger than 1 inch in diameter.

Additional Information on Soil Depth

After determining the elevation to which a site must be graded for drainage and other reasons, estimation of the changes in soil depth and height need to be calculated. A final grade of the soil should range between one-half inch and 2 inches below the elevation of sidewalks, driveways, and other impervious surfaces on the site.

The difference in volume of the dense verses the loose soil condition is determined by the “fluff factor” of the soil. The fluff factor of compacted subsoils in the Puget Sound Area tends to be between 1.3 and 1.4. Rototilling typically penetrates the upper 6 to 8 inches of the existing soil. Assuming only a 6-inch depth is achieved, this depth adjusted by the fluff factor will correspond to a 7.8- to 8.4-inch depth of loose soil. This loose volume would then be amended at a 2:1 ratio of loose soil to compost, corresponding to an imported amendment depth of approximately 4 inches for this example. In the loose state, both the soil and compost have a high percentage of pore spaces (volume of total soil not occupied by solids). The resulting change in elevation must account for compost settling into void spaces of the loose soil (assume 15 percent of the soils’ void spaces become occupied by compost particles). After compost incorporation, the amended site will undergo some degree of compaction by the rolling procedure and the weight of the soil itself. Assume a compression factor of 1.15 for soils with a 1.3 fluff factor and 1.2 for soils with a 1.4 fluff factor (15 to 20 percent of the soils’ void spaces will become occupied by compost particles.) The resulting change in elevation for a site amended to a 6-inch depth will be approximately 3 inches.

Compost Quality

- Compost shall be prepared by the controlled decomposition of organic materials. Acceptable feedstocks include, but are not limited to, yard debris, wood waste, land-clearing debris, brush, branches, manure, biosolids, food residuals, and forest byproducts. The product shall have a uniform, dark, soil-like appearance and an earthy loam-like odor. No ammonia or putrid smells shall be present. Minimum organic matter shall be 35 percent (dry-weight basis). Particles shall be 100 percent passing the 1-inch sieve. pH range shall be between 6.0 and 8.5 for wetlands and streamside locations, and 6.0 and 8.0 for other locations. Foreign material shall be no more than 2 percent on a dry-weight or volume basis, whichever provides the least foreign material. Material shall come from a source that is permitted by (or exempt from) Tacoma-Pierce County Health Department (TPCHD) rules.

Compost for the approved rates listed above must be Class A compost per Washington State Department of Ecology (Ecology) interim Compost Quality Guidelines ("composted materials" defined in Washington Administrative Code (WAC) Chapter 173-350 Section 220) or topsoil manufactured from these composts plus sand or sandy soil. Products should be identified on the site development plans and recent product test sheets provided showing that they meet additional requirements for organic matter content and a carbon to nitrogen ratio below 25:1. The carbon to nitrogen ratio may be as high as 35:1 for plantings composed entirely of plants native to the Puget Sound Lowlands region.

- Utilize alternatives to straw mulch, such as composted mulch or wood-based mulch, for construction erosion and sediment control.
- Apply compost on slopes instead of hydromulch.
- Soils amendments should be installed postconstruction, prior to installation of landscaping and turf, unless used as a step in the lot preparation process involving minimal excavation foundation systems.

Steep Slope Areas

Existing Steep Slope Areas – On-site steep slope areas, which have native soils with robust native landscapes, should be protected from disturbance as a preference to re-grading and augmenting the disturbed soil with soil amendment. Also, steep slope areas may be subject to critical area protection per Title 18E PCC, which outlines criteria for classification of erosion and active landslide hazard areas.

Steep slopes that remain on site which are not constructed as part of the development AND where native soils and vegetation is sparse should be amended by planting deep rooting vegetation. Soil amendments shall be applied via a pit application at least twice as wide as the root ball of the vegetation being planted with a mix of 50 percent compost to 50 percent soil mixture.

Constructed Steep Slopes – In lawn and landscaped areas, the slope angle should be minimized to the greatest extent possible for both stability and lawn maintenance concerns. Terracing is recommended to minimize steep slope angles. A recommended method of interim slope stabilization for slopes steeper than 40 percent is brush layering with geotextile soil wrap (see Figure 3.7). Brush layering can be used on fill slopes and on cut slopes that are over-excavated and rebuilt with the soil wraps. Other plant species may be substituted which meet the requirement of rapid establishment of deep root systems.

Adequate drainage systems must be installed on steep slope areas where it is determined that retained runoff may cause instability. To provide adequate drainage, a professional engineer must determine the drainage pattern of the slope and design/install controlled drainage at the outfall of these areas. A subsurface collection system should be installed at the base of each terrace to redirect water away from any retaining structures. Subsurface collection systems may also be necessary in low depressions of a non-uniform site, although it is recommended that these areas be left undisturbed so as to serve as natural stormwater retention areas. An appropriate receiving area for the water collected and concentrated by the subsurface drainage system must be provided.

Additional guidelines for this BMP can be found in *Building Soil: Guidelines and Resources for Implementing Soil Quality and Depth BMP T5.13 in Ecology Stormwater Management Manual for Western Washington*, which is available at www.soilsforsalmon.org under the “How-To” section, or at <www.buildingsoil.org>.

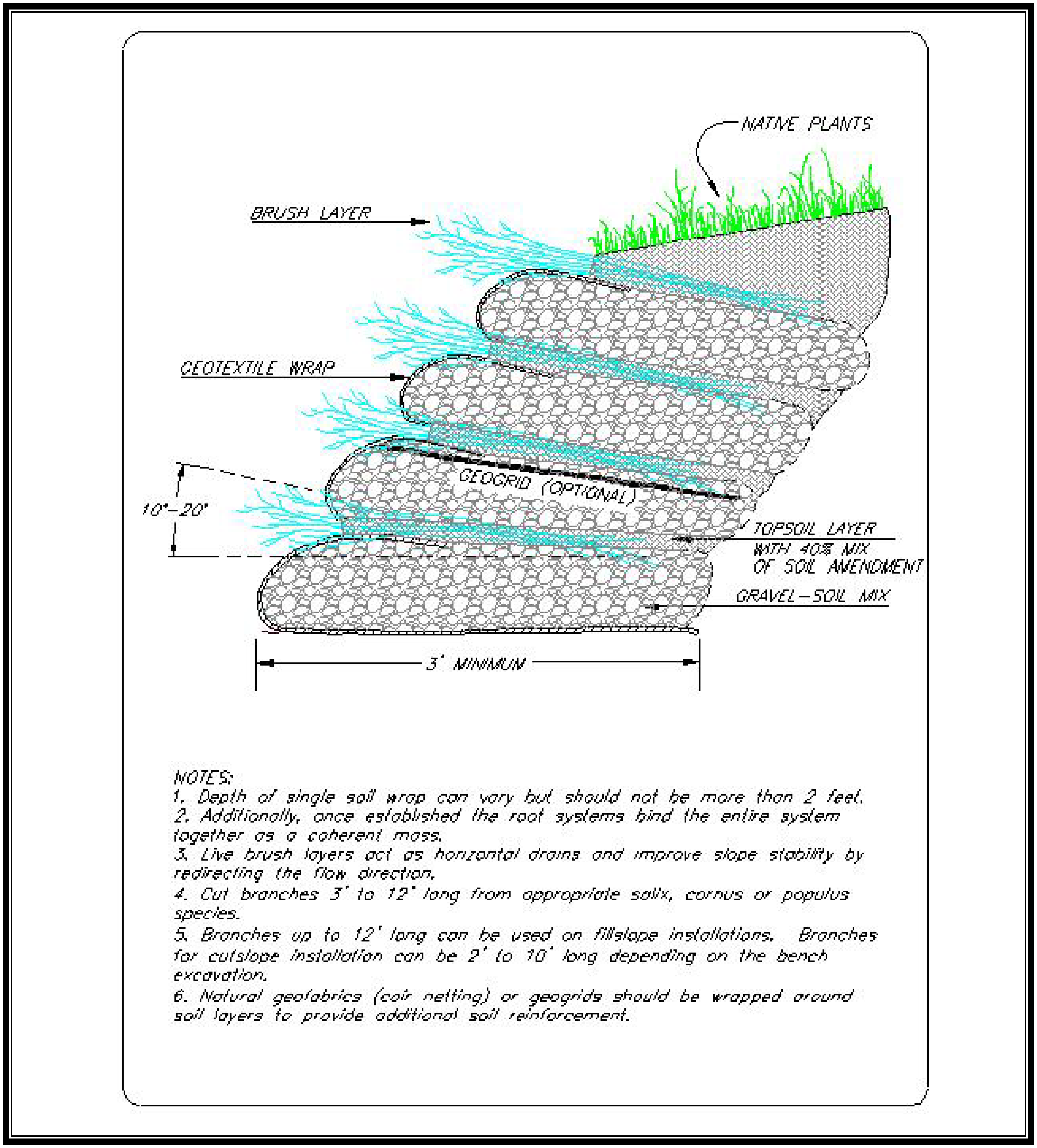


Figure 3.7. Brush Layering with Geotextile Soil Wrap.

3.15 Vegetated Open Channels

The order of preference for stormwater treatment on LID developments uses BMPs for infiltration and dispersion to the greatest extent possible before collection and conveyance techniques are utilized. However there are still instances, due to site and layout constraints, where conveyance will be required. In these cases vegetated open channels should be used, where possible, in lieu of piped conveyance systems. Along with conveying stormwater, vegetated open channels provide opportunities for groundwater recharge in smaller storm events and provide greater storage capacity and attenuation of peak flows than piped systems.

Vegetated open channels are meant to be very different than a typical roadside ditch, with shallower depths and gentler side slopes. Where roadside ditches usually convey runoff from large areas and grow continually deeper as their length increases, the vegetated open channels are meant to drain only small scale drainage areas and convey the water only short distances.

See also Volume III, Section 4.11 for additional design guidelines on open conveyances.

3.15.1 Applicability

- Vegetated open channels are most applicable adjacent to the roadways where the linear nature of the road often makes it difficult to provide enough area within the right-of-way for treatment by infiltration or dispersion. Roadside vegetated channels can be used to seamlessly blend into the adjacent lot landscaping or act as a buffer between the road and the sidewalk.

- Depending on the site conditions, vegetated open channels can be designed to provide retention within the channel. They can promote infiltration of a majority of the stormwater while releasing stormwater along the channel only during major storm events.

- Vegetated channels spaced strategically throughout the development can act as interceptor points along the identified interflow pathways from rain gardens and bioretention areas. With the elevation of the vegetated channel bottom set below the upper soil profile, it will be possible for interflow to seep from the side slopes of the channel during heavily saturated conditions. This allows some alleviation from excess saturation of the upper soil structure and also can pick up overflows from the bioretention facilities.

- Vegetated channels should have termination points in either bioretention areas, stormwater ponds, or in dispersion trenches sheet flowing into natural resource protection areas.

3.15.2 Flow Credit for Vegetated Open Channels

Vegetated open channels are generally preferred for site conveyance, but may not always receive additional flow control or water quality credit. Designers who wish to use vegetated open channels to meet either the flow control and/or water quality minimum requirements outlined in Volume I will have to demonstrate that the facility will perform comparatively to other approved flow control and treatment BMPs. Given the variety of performance functions of vegetated open channels (e.g., filtration, infiltration, and detention), the design approach required to meet the applicable minimum requirements may vary.

In general, vegetated open channels intended to meet water quality requirements will have to meet the design criteria outlined for biofiltration swales, filter strips, bioretention, or bioinfiltration swales. Vegetated open channels intended to meet flow control requirements will have to meet the design criteria outlined for infiltration facilities, or bioretention facilities (as designed for flow control specifically). Note that these flow control facilities can also be modified to provide water quality treatment.

Designers who wish to use vegetated open channels for conveyance, but without credit for flow control or treatment need only follow the below criteria. Incidental flow control or treatment credit may be warranted if the designer engineer can demonstrate to the county specifically how some or all of the applicable flow control or water quality treatment requirements will be met.

3.15.3 Vegetated Open Channel Design Criteria

- The geometry of vegetated channels is meant to blend into the surrounding landscape as seamlessly as possible. Vegetated channels are trapezoidal in shape with recommended side slopes of 4:1 but no steeper than 2H:1V, and have no sharp corners in the transition with the adjacent landscaping. Sizing of the channel width should depend on the contributing area but the bottom width of the channel should be at least 1-foot wide and widths larger than 3 feet should incorporate some sort of structural measures such as logs or spreader boards to maintain sheet flow. Longitudinal slopes should be in the range of 2 to 4 percent.

- The recommended soil composition within a vegetated channel is a sandy loam topsoil layer, with an organic matter content of 10 percent, and no more than 20 percent clay. The specified depth of uncompacted soil after amendments are placed is 12 inches (scarified subgrade, 3 inches of compost material added to 5 inches of topsoil). See Section 3.14, for applications within stormwater facilities. If the soils test indicates that the existing soil is of a suitable composition and depth as described above soil amendments will not be necessary.

- Vegetated channels should have dense vegetated cover of grass or shrubs. When the vegetated channel is located along the roadway, vegetation over 18 inches in height located within the county right-of-way for a local road within the boundaries of a plat shall be placed a minimum of 6 feet back from the back of shoulder when no curb is used.

- A Manning's roughness coefficient (n) value of 0.20 is recommended for vegetated channels with grass cover that are routinely mowed. Use of slow growing grasses can effectively eliminate the need for mowing. Select grass species that produce a uniform cover of fine-hardy vegetation that can withstand the prevailing moisture condition. Wetland adapted species such as Juncus and Scirpus may be utilized if drainage is poor.

- Trees: Trees placed within the bottom and sides of the vegetated channels can help intercept rainfall with their canopy, withdraw water out of the soils, and provide a visual break between the sidewalk and the roadway. Maintenance to remove fallen leaves and prevent clogging pervious soils or killing grass may increase as a result of incorporating trees in the design. In Pierce County, the minimum setback from the face of the curb to the face of the tree trunk is 6 feet.

- Water Table: Designers should determine the level of the seasonal high water table. If the water table is within a foot of the bottom of the swale, it may be advisable to select water tolerant plant species.

- Additional detention can be designed within the channel by expanding the cross-section of the vegetated channel. Expanding the cross-section should benefit the efforts to blend into the surrounding landscape by flattening the side slopes and providing a gentler transition into the surrounding landscape.

- Infiltration can be promoted for smaller storm events within the vegetated channel by elevating the outlet of the channel by 2 to 6 inches. When infiltration is designed into the vegetated channel the bottom of the channel shall be amended with compost to a depth of 13 inches.

- Another approach to design infiltration into the vegetated channel is to install an underdrain system beneath the channel bottom. This design is similar to the bioretention areas, in that the outlet to the channel is through the collection of runoff in the underdrain system except when the channel is in overflow. Overflow can be through a designated surface flow path or by elevating a catch basin rim with a bee hive grate. The outlet or the underdrain system can be to another stormwater facility or dispersed into a natural resource protection area.

- Where vegetated channels cross driveways, the conveyance under the driveway can be by traditional mechanisms such as culverts or by open graded rock pads placed under the driveway surfacing. Geotextile fabric should be placed under the rock pad to prevent movement of the rock into the subgrade. To keep the rock pad from clogging with silt during the stabilization of the vegetated channel the fabric should be installed longer on each side of the driveway and temporarily flipped up over the end of the rock to trap any silt before it can enter into the rock pad. Once the vegetation is established and the site stabilized these ends can be cut off. Rock pads can work well with the subgrade designs of alternative paving surfaces for driveways which incorporate open graded gravels to promote runoff movement through the subgrade.

3.16 Alternative Paving Surfaces

Alternative paving surfaces include porous asphalt pavement; porous concrete; grid or 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.

3.16.1 Applicability

- Appropriate applications for alternative porous surfaces include parking overflow areas, parking stalls, low volume residential roads, alleys, driveways, sidewalks/pathways, and patios.

- Porous paving surfaces can provide some attenuation and uptake of stormwater runoff even on cemented till soils while still providing the structural integrity required for a roadway surface to support heavy truck loads.

- Porous paving surfaces work well in concert with other LID BMPs such as porous parking stalls adjacent to bioretention areas, and porous roadway surfaces bordered by vegetated swales.

- Recent research of porous paving surfaces has shown that although there is a drop off in infiltration rates over time, the long-term infiltration rate is still substantial enough to provide significant reductions in runoff.

3.16.2 Limitations

- Because of water quality concerns related to stormwater with high concentrations of oils or other contaminants infiltrating through the surface and contaminating groundwater, pervious pavement surfaces shall not be allowed with land uses that generate heavy loadings of these pollutants. These include Pierce County Land Use Codes related to Automotive Commercial Service, which include but are not limited to gas stations, small mini marts, commercial fueling stations, autobody shops, automobile repair services, and automobile wash services.

- An apparent limitation of porous paving surfaces is the increased potential for clogging when runoff generated from other surfaces (i.e., run-on) is directed onto the porous paving surface, especially as a point discharge, thereby potentially conveying sediment onto the porous paving surface (see the Maintenance Criteria Below for measure to prevent clogging). The potential sediment loading for each application should be considered when determining if the application is appropriate for an alternative paving surface.

- To reduce the potential of clogging, runoff generated from lawns or other pervious surfaces may not be directed onto a porous pavement surface. Absolutely no point discharges may be directed onto porous pavement surfaces. Runoff as sheet flow from a paved surface may be directed onto a porous pavement surface (as with a paved travel lane sheet flowing onto adjacent porous parking stalls) 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.

3.16.3 Paving Surface Design Criteria

- Recommended maximum slopes for alternative paving surfaces are 5 percent (porous asphalt), 6 percent (porous concrete), 10 percent (interlocking pavers), and 5 to 6 percent (grid and lattice systems).

- Modeling of runoff from areas of porous pavement surfaces designed in accordance with this volume must conform to requirements of the 2005 Ecology Stormwater Management Manual for Western Washington, Volume III, Appendix C; the modeling methods provided in an Ecology and Pierce County-approved continuous simulation model; or subsequent Ecology and Pierce County-approved technical documentation.

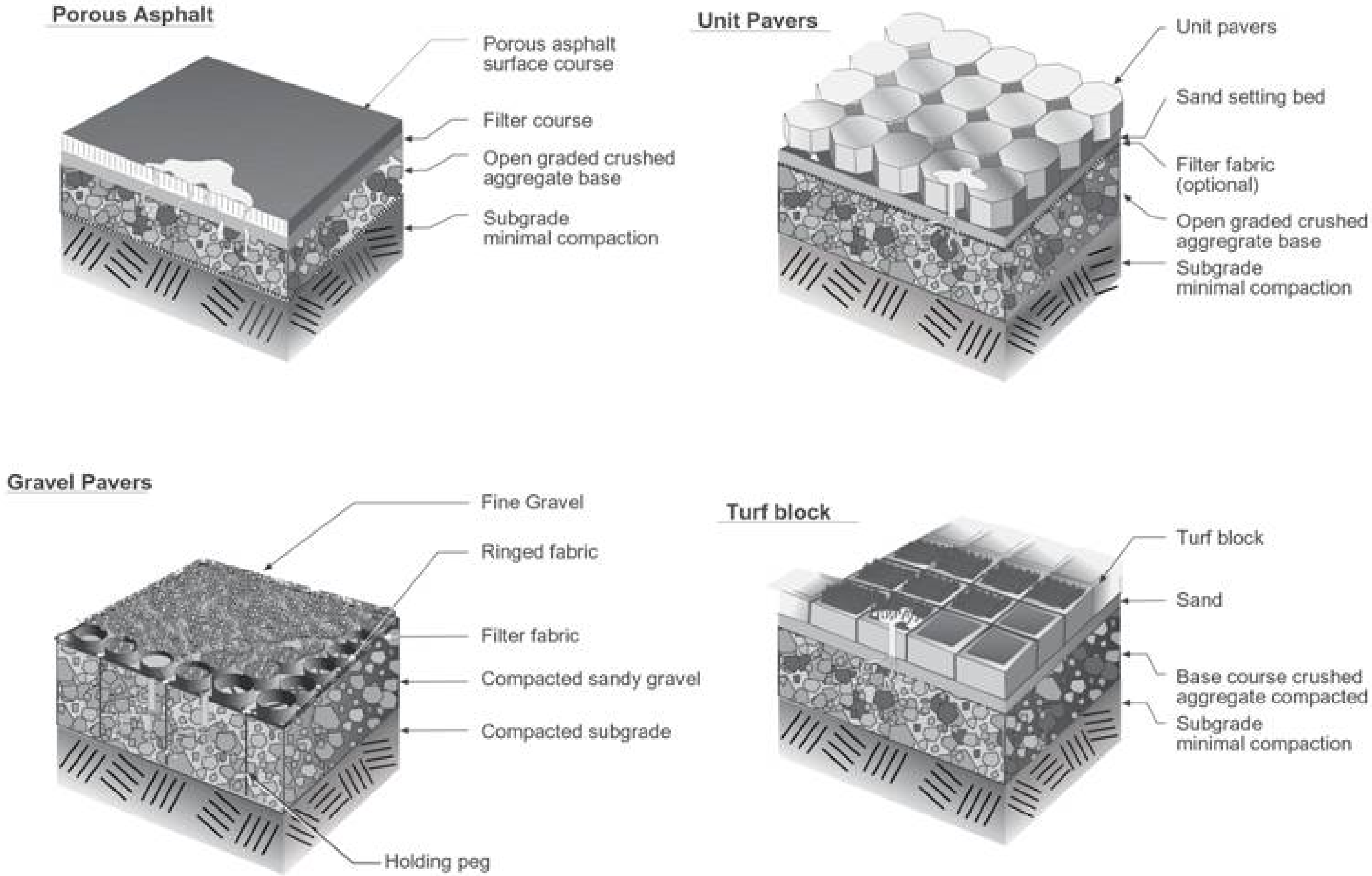
- Where individual porous paving surfaces have multiple design configurations approved by the manufacturer, the designer should choose the design configuration with the maximum porosity. Base materials of porous pavement systems can be designed to infiltrate vertically into outwash soils or move runoff laterally along the subgrade for release by seepage into vegetated channels. Manufacturer's recommendations on design, installation, and maintenance shall be followed for each application.

- Subgrade infiltration rates less than 2.4 inches per hour and a cation exchange capacity of 5 milliequivalents CEC/100 grams dry soil (or greater) will provide water quality treatment, satisfying applicable Minimum Requirement #5 requirements.

- Typical cross-sections of porous paving systems consist of a top layer (pervious wearing course) with either porous asphalt; porous concrete; concrete block pavers; or a plastic grid paver filled with sand, topsoil, or gravel. Supporting the top layer is an aggregate subbase with larger rock at the bottom and smaller rock directly under the top surface (e.g., a gradient from 2 to 5/8 inch). The aggregate subbase has minimal fines and is compacted to support the traffic load while allowing for the design infiltration rate and storage. For open-celled paving grids and concrete block pavers, a leveling course consisting of finer aggregate. Between the underlying soil layer and the base layer of stone is a geo-textile fabric which allows water to infiltrate but restricts movement of other particles into the gravel. See Figures 3.8 and 3.9 for example illustrations and details.

- Structural designs for porous surfaces should be per the manufacturer's specifications. If any deviations are made from the manufacturer's recommendations or if the manufacturer's recommendations require engineering judgments to be made, the design shall be stamped by a geotechnical engineer.

- Where cemented till layers of soil exist under a parking lot, a pervious pavement system can still be effective to attenuate peak flows. In small area applications, the subgrade of the parking lot can be built up with porous base material and graded to direct runoff through this material to an eventual outfall, such as bioretention areas. In larger areas, an underdrain system should be installed to collect and convey runoff to bioretention areas or open space. In this manner, stormwater is stored and metered out slowly, similar to the way the existing topsoil on a site captures and slowly releases runoff.



Not to Scale

Figure 3.8. Alternative Paving Surfaces.

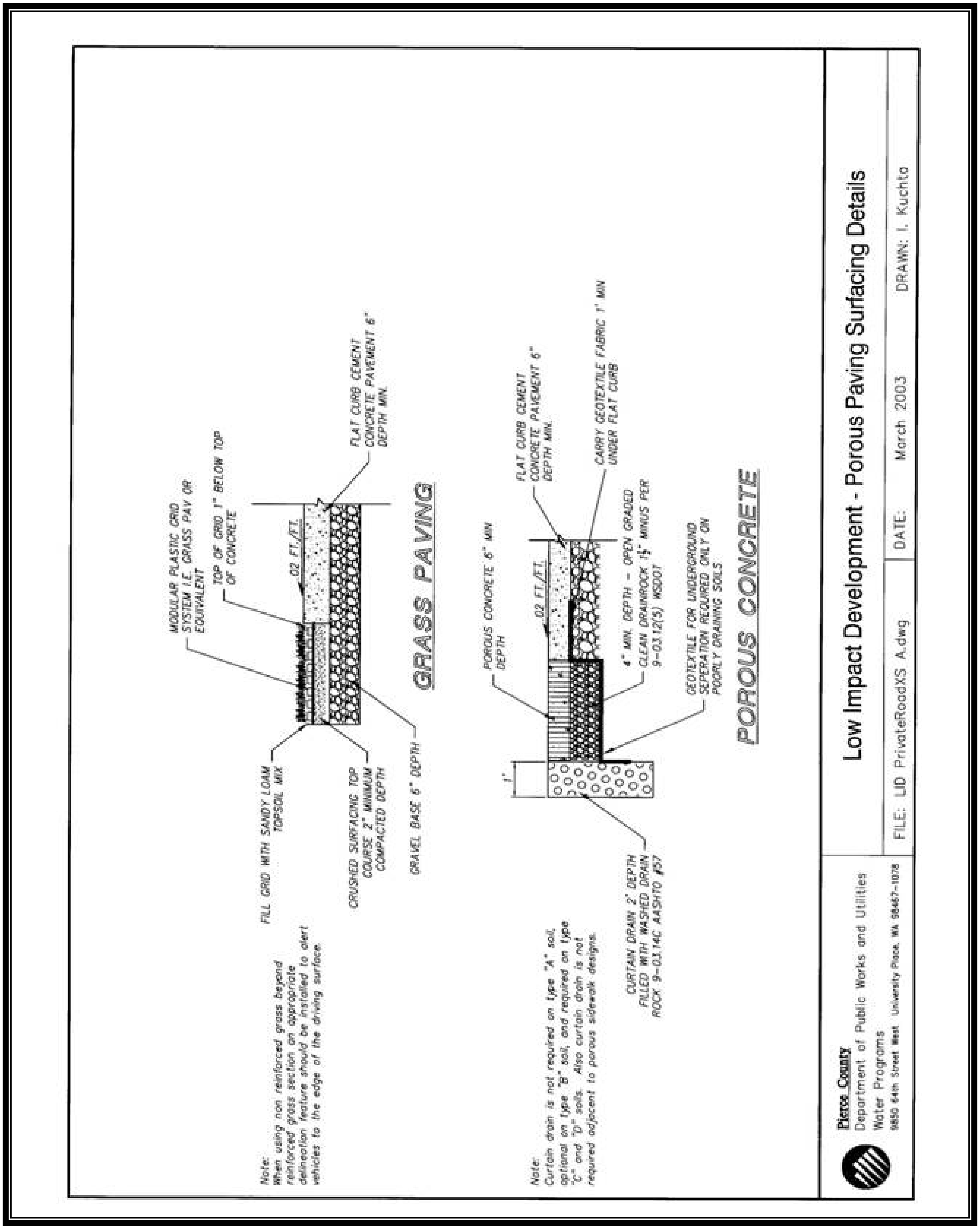


Figure 3.9. Porous Paving Surfacing Details.

- Both gravel and soil with vegetation can be used to fill the openings in paver and rigid grid systems and manufacturer recommendations should be followed to apply the appropriate material for each application.

- Porous systems that utilize pavers need to be confined with a rigid edge system to prevent gradual movement of the paving stones.

- ADA compliance should be requested from the manufacturer and is a consideration in determining where to use alternative paving surfaces.

Pervious Wearing Course

The wearing course or surface layer of the alternative paving surface may consist of permeable asphalt, permeable concrete, interlocking concrete pavers, or open-celled paving grid with vegetation or gravel. The wearing course must provide adequate porosity for stormwater infiltration.

- Positive surface drainage should be provided to eliminate risk of ponding on pavement surface (minimum surface slope of 1 percent)

- For a vegetated open-celled paving grid, topsoil should have a minimum 4 percent organic matter by dry weight. If receiving run-on from other surfaces, it must be demonstrated that run-on is infiltrated through the pervious wearing course to the storage reservoir without ponding.

Leveling Course

Depending upon the type of permeable pavement installation, a leveling course (also called a bedding or choker course) may be required (per manufacturer recommendations). A leveling course is often required for open-celled paving grids and interlocking concrete pavers. This course is a layer of aggregate that provides a more uniform surface for laying pavement or pavers and consists of crushed aggregate smaller in size than the underlying aggregate subbase. Course thickness will vary with permeable pavement type.

Aggregate Subbase

The aggregate subbase in an alternative paving surface serves as the road, parking, or pedestrian area's support base and must be sufficiently thick to support the expected loads and be free draining. The subbase should meet the following criteria:

- A 2-inch minimum depth of aggregate subbase is recommended under the pervious wearing course and leveling course (if any)

- Aggregate subbase should consist of larger rock at the bottom and smaller rock directly under the top surface (e.g., a gradient from 2 to five-eighths inch)

- The bottom and sides of the aggregate subbase should be contained by a nonwoven geotextile.

Nonwoven Geotextile

As part of the pavement section design, the designer should review the existing native soil or subbase characteristics and determine if a nonwoven geotextile is needed for separation of subbase from underlying soils.

3.16.4 Installation Criteria

- Proper installation is one of the key components to ensure the success of porous paving surfaces. As with any pavement system, porous pavement system requires careful preparation of the subgrade and base course to ensure success in terms of strength and permeability. The compressive strength of a permeable paver system relies in large part on the strength of the underlying soils, particularly in the case of modular or plastic units where the pavement itself lacks rigidity. Design and installation of alternative paving surfaces should be according to manufacturer recommendations.

- Install appropriate source and erosion control BMPs to prevent sediment transport from construction activities onto the base material or top course when the porous surface is applied prior to the completion of construction and stabilization of the entire site.

- If possible, the temporary roads should be used during construction and final construction of the base material and porous surfacing completed after building construction is complete. This construction method is similar to the installation of leveling courses of asphalt in a subdivision prior to building individual lots and installation of the final wearing course upon completion of building construction.

3.16.5 Maintenance Criteria

- See Minimum Requirement #10 in Volume I; Volume I, Section 3.3.4; and Volume I, Appendix I-B for additional information on maintenance requirements.

- Clogging is the primary mechanism that degrades infiltration rates. However, as discussed above, the surface design can have a significant influence on clogging of void space.

- Studies have indicated that infiltration rates on moderately degraded porous asphalts and concrete can be partially restored by suctioning and sweeping of the surface. Highly degraded porous asphalts and concrete require high pressure washing with suction.

- Maintenance frequencies of suctioning and sweeping shall be specified in the stewardship and management plans (Section 4.2), or as specified in Volume I, Appendix I-B, whichever is more stringent.

- Porous pavement systems designed with pavers have advantages of ease of disassembly when repairs or utility work is necessary. However, it is important to note that the paver removal area should be no greater than the area that can be replaced at the end of the day. If an area of pavers is removed, leaving remaining edges unconfined, it is likely that loading in nearby areas will create movement of the remaining pavers thereby unraveling significantly more area than intended.

3.17 Rainfall Reuse Systems

Rainfall reuse systems are systems designed to collect stormwater runoff from non-polluting surfaces, such as roofs, and to make use of the collected water. Reuse of the runoff can be for irrigation, potable, and non-potable uses but would require different levels of storage and water quality treatment depending on the intended use. Although sophisticated rainfall reuse systems have not been widely used throughout the Northwest, there have been systems designed and installed by a growing group of professionals such as “Northwest Water Source” located in Friday Harbor. The most abundant use of water reuse systems in the Northwest has been on some of the island communities where potable water has not been available. In these cases the systems have been sized and designed to capture all rooftop runoff with adequate treatment for reuse as a potable water source. Rainfall reuse systems are also coined under the terminology “Rainfall Catchment” and “Rainwater Harvesting.”

3.17.1 Applicability

- Highly developed areas or commercial centers where larger buildings, especially multistory buildings, encompass nearly all of the area are highly suitable for water reuse systems where it might not be feasible to preserve natural protection areas. In these areas, any type of stormwater management is expensive due to the high cost of land and therefore the cost of a water reuse system can be more competitive. Multistory buildings require a more constant and larger demand for non-potable water and therefore the required storage of rooftop runoff won't be as large further reducing the costs of these systems.

- Rainfall reuse systems have the additional benefit of decreasing demands on the treated potable water supply

- Approval of a water reuse system as a potable source will require approval of the appropriate state and local agencies as required for any water right.

3.17.2 Limitations

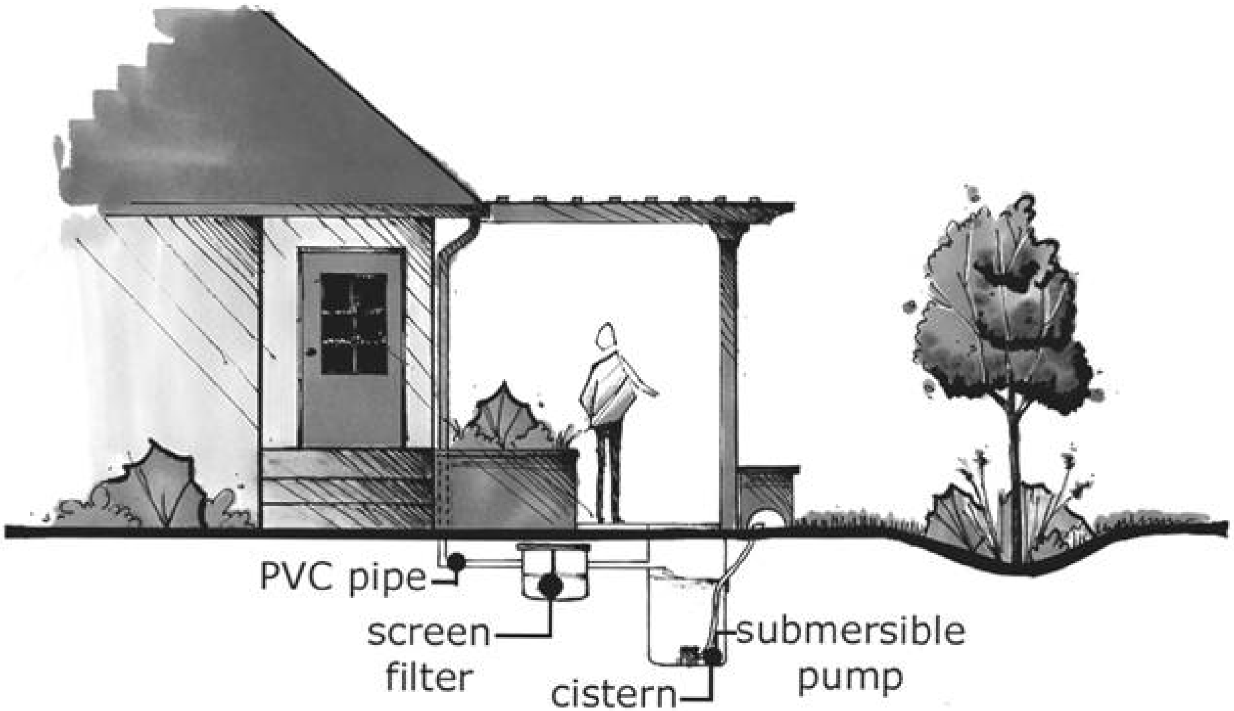
- Although use of rain barrels for capturing rainfall can be beneficial for providing a small amount of irrigation and also provide an educational aspect to the benefits of water reuse, they generally do not provide enough storage of seasonal runoff to be considered to meet the performance goals of Minimum Requirement #5 or #7 or the general performance requirements of LID projects, unless prior approval is obtained from the county.

3.17.3 General Rainfall Reuse Design Criteria

- Because of the complicated nature of storage and treatment it is required that any rainfall reuse system shall be designed by a qualified designer.

- The cistern can be designed as part of the foundation to fit under the house (adding about 1 foot in height), or can be placed next to the house, either above or below ground. When the storage of runoff is incorporated into the building design it shall be approved as part of the building permit. Figure 3.10 provides an illustration of an example cistern installation.

- Rainfall reuse systems that supply non-potable water should be designed to augment the supply of treated water and therefore should be designed to use the stored rainfall runoff first and use the treated water supply when the rainfall runoff is depleted.



Not to Scale

Figure 3.10. Cistern.

- Cisterns should be sized according to roof area, monthly rainfall patterns, and anticipated water usage of connected plumbing facilities. To estimate the storage volume required for non-potable uses, the volume of rainfall off the roof surface should be plotted over time against curves showing the amount of water used inside the house. Monthly average rainfall for Pierce County shown in Table 3.5 below should be used (40.23 inches annually). Rainwater collection systems have losses due to roofing material texture, evaporation, and inefficiencies in the collection process, which can account for up to a 25 percent loss of annual rainfall. The plot below the table shows rainfall storage needs for a typical 1,500 square foot home with a variety of reuse applications, and following Table 3.6 provides the typical amount of water used daily per person by type of fixture.

Table 3.5. Pierce County Monthly Average Rainfall.

January	5.75 inches	July	0.88 inches
February	4.46 inches	August	1.30 inches
March	3.90 inches	September	1.93 inches
April	2.80 inches	October	3.28 inches
May	1.98 inches	November	6.00 inches
June	1.77 inches	December	6.18 inches

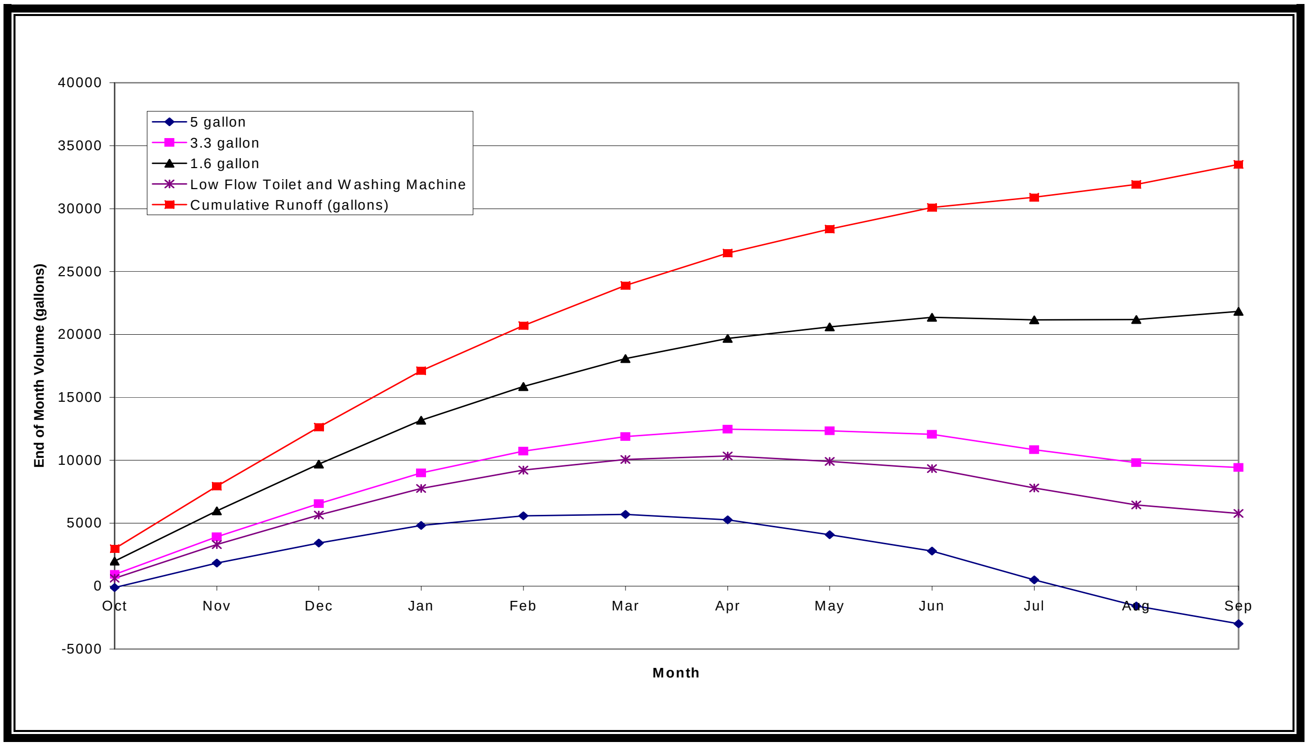


Table 3.6. Typical Water Used Daily per Person by Type of Fixture.

Typical Water Usage		
Type of Use	**Gallons per person per day**	**Percent of Total***
Showers	8.2	17
Toilets	6.4	13
Toilet leakage	4.1	8
Baths	7.0	14
Faucets	8.5	17
Dishwashers	2.4	5
Washing Machines	12.6	26

* The average inside water use for homes that conserve water is approximately 49.2 gallons per person per day (Maddaus, William O., 1987, Water Conservation, American Water Works Assc).

3.17.4 Maintenance Criteria

- Rainfall reuse systems shall require a maintenance agreement in the same manner as other types of stormwater BMPs. Examples of the maintenance agreements are given in Volume I, Appendix I-B of this manual.

- Maintenance agreements should provide for annual inspections of systems to assure pumps and filters are working properly and the design level of water quality is being maintained.

3.18 Vegetated Roofs

Vegetated roofs are areas of living vegetation installed on top of buildings to provide flow control via detention, attenuation, soil storage, and losses to interception, evaporation, and transpiration. Vegetated roofs are also known as ecoroofs, green roofs, and roof gardens. Vegetated roofs have the additional benefits of providing relaxing green space, reducing temperature within urban centers, and have a longer life span than traditional roofing materials.

A vegetated roof consists of a system in which several materials are layered to achieve the desired vegetative cover and drainage characteristics (see Figure 3.11). Design components vary depending on the vegetated roof type and site constraints, but typically include a waterproofing material, a drain system, a drainage layer, a separation fabric, a growth medium (soil), and vegetation.

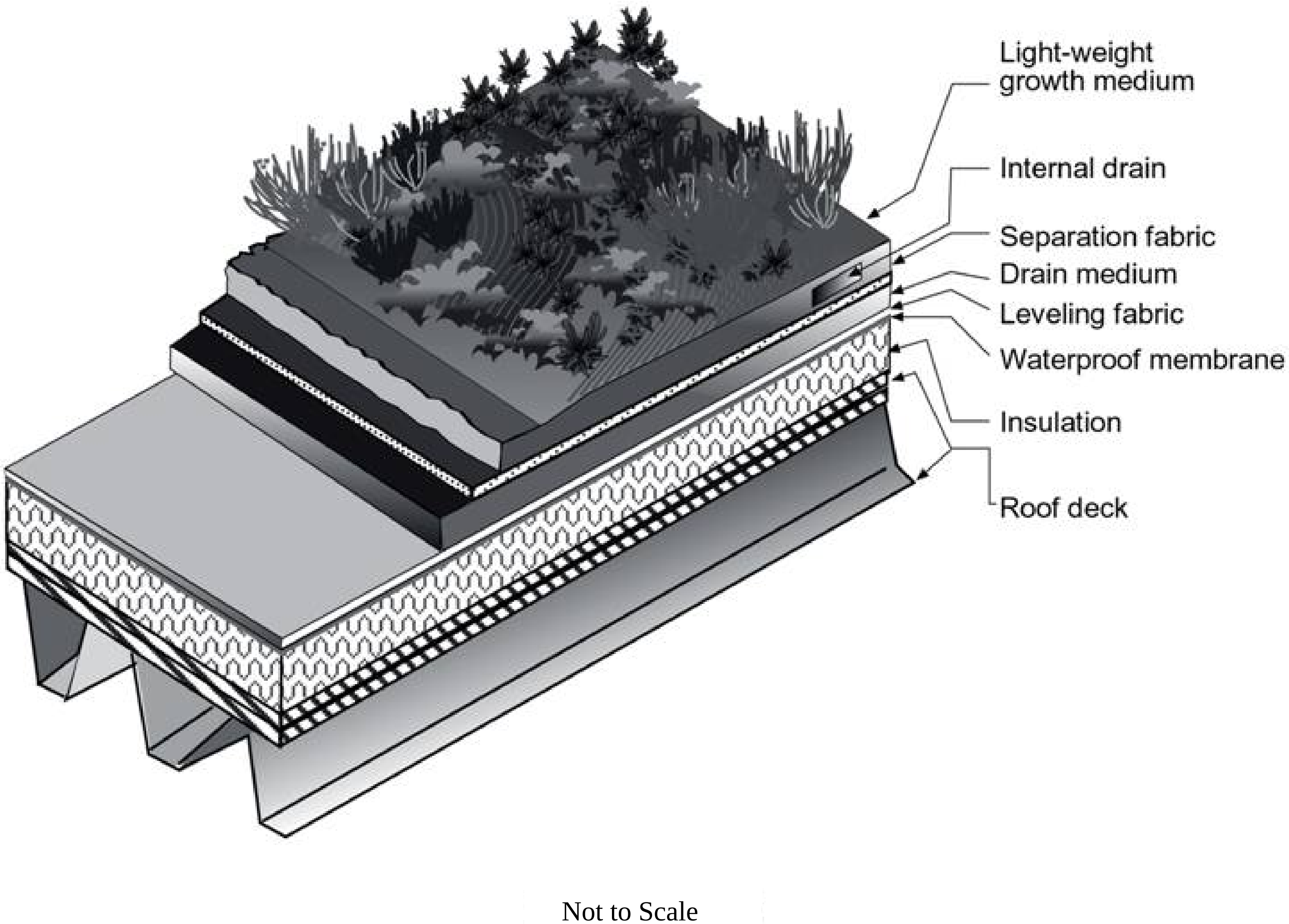


Figure 3.11. Vegetated Roof.

Vegetated roofs are categorized by the depth and the courses used in their construction. Deeper installations, referred to as “intensive” roofs, are comprised of at least 6 inches of growth media and are planted with groundcovers, grasses, shrubs, and sometimes trees. These systems require regular landscape maintenance. Shallower installations, referred to as “extensive” roofs, are comprised of less than 6 inches of growth media and use a planting palette of drought-tolerant, low maintenance groundcovers. Extensive systems are further divided into “single-course” systems which consist of a single media designed to be freely draining and support plant growth, and “multi-course” systems that include both a growth media layer and a separate, underlying drainage layer. Extensive vegetated roofs have the lowest weight and are the most suitable for placement on existing structures.

3.18.1 Applicability

The use of vegetated roofs shall be evaluated on a case-by-case basis.

- Vegetated roofs, like rainfall reuse systems, are very applicable in highly developed environments where other LID practices of forest retention or infiltration are not feasible. Vegetated roofs have the additional benefits of providing relaxing green space, reducing temperature within urban centers, and a longer life span than traditional roofing materials.

- Vegetated roofs can be applied to a range of rooftop slopes. However, steeper slopes, such as those on single family residences, may result in reduced flow control performance and may trigger additional design requirements (e.g., underlying drainage layer and lateral support measures). In addition, applications on slopes steeper than 20 percent (5H:1V) will not qualify for flow control credits. Nearly flat roofs, those with a pitch of up to 1/4”:12” (1/4 inch fall per foot), 50H:1V, or 2 percent, are the easiest to install, are the least complex, and generally provide the greatest stormwater storage capacity per inch of growth medium. These guidelines do not preclude the use of vegetated roofs on steeper slopes, but it will be up to the designer to demonstrate that these applications still have the effectiveness of eliminating runoff from the smaller storm events and attenuating runoff from larger storms.

3.18.2 Vegetated Roof Design Criteria

This section focuses on the guidelines and minimum requirements that must be included in vegetated roof designs to achieve effective stormwater management. Additional loading, structural, waterproofing, fire resistance, and horticultural considerations will apply and must be adhered to when incorporating vegetated roof systems. While some of these issues are noted, related design methods and requirements are not included. Vegetated roofs shall also require approval from the local Fire Marshal to demonstrate adequate ventilation or ability to ventilate in cases of a fire. The design team must include qualified professionals to address all design considerations.

Vegetated roofs typically consist of the following components, each of which is discussed in this section:

- Waterproof membrane
- Root barrier
- Drainage layer
- Separation fabric (for multi-course systems)
- Growth medium (soil)
- Vegetation
- Irrigation plan
- Drain system.

Waterproof Membrane

Waterproof membranes are made of various materials, including reinforced polyvinyl chloride (PVC), synthetic rubber (EPDM), thermoplastic polyolefins, high-density polyethylene (HDPE), modified asphalts (bitumens), and hypalon (CPSE). Some waterproofing materials come in sheets or rolls and some are available in liquid form. Each material has different strengths and functional characteristics.

Root Barrier

To discourage roots from damaging the waterproofing membrane, a physical root barrier may be required. The need for a root barrier depends primarily on the particular waterproof membrane selected. Some waterproofing membranes have root barrier capabilities intrinsic to the material. Modified asphalts usually require a root barrier, while EPDM and reinforced PVC typically do not. The manufacturer must be consulted to determine whether a root barrier is recommended for a particular product.

During installation, treatment to prevent root penetration should not be restricted to parts of the roof that will be covered with vegetation, as the roots will extend beyond the areas in which vegetation shows at the surface. Care should be taken to fully treat the areas at joints, borders, and seams.

The root barrier shall not contain leachable water quality contaminants (e.g., herbicides, copper, and zinc). To demonstrate this, a material safety data sheet must be submitted.

Drainage Layer

For intensive and extensive multi-course vegetated roof systems, a drainage layer must underlie the growth medium. The drainage layer is a multipurpose layer designed to provide void spaces to hold a portion of the water that passes through the growth medium and to channel the water to the roof drain system. The drainage layer can consist of a layer of aggregate or a manufactured mat or board that provides an open free-draining area. Many manufactured products include “egg carton” shaped depressions that retain a portion of the water for eventual evapotranspiration. Some studies have shown that aggregate drainage layers may provide the better flow control.

For extensive single-course vegetated roofs larger than 1,000 square feet, hydraulic calculations should be submitted showing that the transmissivity and permeability of the media are sufficient to convey the 25-year recurrence interval peak flow.

For aggregate drainage layers, the drainage media should meet the following requirements:

- Minimum total pore volume of 25 percent by volume (per American Society for Testing and Materials [ASTM] E2399)
- Minimum saturated hydraulic conductivity of 0.3 centimeters per second, cm/s (per ASTM E2396-05)
- Maximum total organic matter of 1 percent by mass (per loss on ignition testing).

For optimal flow control, an aggregate drainage layer with a saturated hydraulic conductivity of less than 3.2 cm/s is recommended.

Separation Fabric

A nonwoven geotextile must be installed between the growth medium (soil) and the drainage layer to prevent fine soil and substrate components from being washed out of the growth medium into the drainage layer (note that this does not apply to single-course extensive vegetated roofs). The fabric must be pervious to allow water to percolate into the drainage layer. If a manufactured drainage layer is used, the separation fabric is typically included.

The separation fabric shall be installed between the growth medium and the drainage layer and between the growth medium and all surrounding areas, roof edges, penetrations, and structures. The fabric also shall have average opening size sufficient to retain media.

Growth Medium (Soil)

Vegetated roofs use a light-weight growth medium with adequate fertility and drainage capacity to support plants and allow infiltration and storage of water. Growth medium composition (fines content and water holding capacity) is key to flow control performance.

The growth medium typically has a high ratio of mineral to organic material content and can be a mixture of various components including gravel, sand, compost, soil, or light weight aggregate material. Because of their excessive weight, particularly when wet, native soils are not acceptable substrates for vegetated roofs.

The growth medium must be a minimum of 4 inches deep, and should have the following characteristics:

- Minimum total pore volume should be 45 percent by volume for multi-course systems and 30 percent by volume for single-course systems (per ASTM E2399)
- Water capacity should 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) should be between 0.01 and 0.85 cm/s for single-course systems and 0.002 and 0.02 cm/s for multi-course systems (per ASTM E2396-05)
- Minimum air content at maximum water capacity should be 5 percent by volume (per ASTM E2396-05), or 10 percent by volume (per FLL method)
- Maximum total maximum organic matter should be 4 percent by mass for single-course systems, 6 percent by mass for extensive (shallow) multi-course systems, and 8 percent by mass for intensive (deep) multi-course systems (per loss on ignition testing).

Growth medium depth and characteristics must support growth for selected plant species.

Vegetated roofs must not be subject to any use that will significantly compact the growth medium. Unless designed for foot traffic, vegetated roof areas that are accessible to the public shall be protected (e.g., signs, railing, and fencing).

Mulch, mat, or other measures to control erosion of growth media shall be maintained until 90 percent vegetation coverage is achieved.

Vegetation

Vegetation used on extensive vegetated roofs should be drought tolerant, self-sustaining, low maintenance, and perennial or self-sowing. Appropriate plants should also be able to withstand heat, cold, periodic inundation and high winds. Vegetation with these attributes typically includes succulents, grasses, herbs, and wildflowers that are adapted to harsh conditions.

Plants can be installed as vegetation mats, individual plugs, cuttings, or spread as seeds.

- *Vegetation mats* – vegetation mats are sod-like, pre-germinated mats that achieve immediate full plant coverage. They provide immediate erosion control, do not need mulch, provide the most rapid establishment for sedums, and minimize weed intrusion. They also need minimal maintenance during the establishment period and little ongoing watering and weeding.

- *Plugs or potted plants* – plugs or potted plants may provide more design flexibility than mats. However, they take longer to achieve full coverage, are more prone to erosion, need more watering during establishment, require mulching, and require more weeding. Birds sometimes pull out plugs, in which case netting may be needed until they are fully rooted.

- *Cuttings* – while cuttings may be used, they become established more slowly than mats and plugs and have a higher mortality rate.

- *Seeds* – seeds can be either hand broadcast or applied by hydroseeding. Seed plantings require more weeding, erosion control, and watering than mats and plugs.

In the long term, the generation of warm and cold air currents resulting from heating and air-conditioning vents on the rooftop can cause frost and drought damage to plants. Exhaust gases such as sulfur dioxide or grease from chimneys and exhausts can result in direct damage to vegetation, depending on the species. Therefore, areas that are affected by warm air, variable air currents, and exhaust gasses need to be checked carefully to determine whether they are suitable areas for planting and to identify the type of vegetation that is best suited to the particular conditions. In addition, vegetation must be suitable for harsh (e.g., hot, cold, wet and windy) rooftop conditions.

An additional consideration is the effect of providing a vegetated roof habitat. Habitat may be enhanced by using diverse planting and including some larger plants. Some projects sites may not want to encourage wildlife (e.g., birds near air fields).

Plant spacing and plant size shall be designed by a certified landscape architect. Turf grasses are not recommended for vegetated roof application because of the dangers of longer grasses growth dying, drying out, and becoming a fire danger. Plants must not require fertilizer, pesticides, or herbicides after 2-year establishment period. Plans should specify that vegetation coverage of selected plants shall achieve 90 percent coverage within 2 years or additional plantings shall be provided until this coverage requirement is met.

Irrigation Plan

Provisions must be made for supplemental irrigation during the first two dry seasons after installation to improve plant survival. Subsurface irrigation methods are preferred. If surface irrigation is the only method available, drip irrigation should be used to deliver water to the base of the plant. At a minimum, a water tap should be available on the roof for manual watering.

A permanent irrigation system using potable water may be used, but an alternative means of irrigation, such as air conditioning condensate or another readily available non-potable source should be considered to maximize efficient use of resources. Any non-potable sources must be analyzed to ensure that they do not contain chemicals that might harm or kill the vegetation. Any permanent irrigation system that relies on potable water should be designed to apply no more than 0.2 inches of water every 14 days from June through September, after the 2-year establishment period. It is recommended that permanent irrigation systems have automatic controls, including a rain shutoff sensor.

Sufficient irrigation shall be provided to achieve and maintain 90 percent plant coverage after 2 years following installation.

Drain System

Vegetated roof drainage facilities must be capable of collecting subsurface and surface drainage and conveying it safely to an approved discharge point. To facilitate subsurface drainage, interceptor drains are often installed at a 15 to 25 foot spacing to prevent excessive moisture build up in the media and convey water to the roof drain.

The roof outlets at vegetated roof sites must be protected from the invasion of plant growth and the entry of loose gravel, and they must be constructed and located so that they are permanently accessible.

- Overflow grates tied into the roof downspouts shall be provided set at the height of the soil.

3.18.3 Maintenance Criteria

Vegetated roofs are designed to need very little maintenance and as stated before if designed correctly should have a longer lifespan than traditional roofs because of the protective nature of the soil structure. Inspections still should be performed regularly to identify any leakage of the membrane system or blockages of the overflow system. See Volume I, Appendix I-B for detailed information on maintenance requirements.

Chapter 4 - Supplemental Information

4.1 Hydrologic Analysis

Hydrologic modeling for LID site designs must conform to all applicable minimum requirements outlined in Volume I, and in particular Minimum Requirement #4: Preservation of Natural Drainage System and Outfalls, Minimum Requirement #5: Onsite Stormwater Management, and Minimum Requirement #7: Flow Control (including the applicable predeveloped land-cover assumptions used in hydrologic modeling).

Modeling requirements for individual LID BMPs are included under the description of each BMP in Chapter 3, where applicable.

The field of low impact development is rapidly evolving, and Pierce County may choose to accept or adopt revised LID modeling and hydrologic analysis methods as they are refined and as approved by Ecology, after the publication date of this volume.

4.2 Management, Maintenance, Education, and Enforcement

In order to assure that the LID techniques that have been employed in the project continue to function over time, long-term management and maintenance strategies need to be addressed. The goal is to ensure successful management and maintenance of the vegetation retention areas, open space tracts, and BMPs through proper transition to subsequent owners and/or organizations that have long-term responsibility and vested interest. In addition to the O&M requirements for individual BMPs required under Volume I, Minimum Requirement #10, and outlined in Appendix I-B; the following apply specifically to comprehensive LID site developments.

4.2.1 Dedicated Tracts and Conservation Easements

- Any vegetation retention, open space areas, bioretention areas, bioswales, or any other feature utilized for stormwater purposes shall be adequately protected through the application of dedicated tracts and, where applicable, conservation easements, so that these elements will remain in such capacity in perpetuity.

- Large open space areas adjacent to riparian areas, wetlands, or critical fish and wildlife habitat areas may be transferred to local land trusts for long-term management and stewardship or managed by homeowners/building associations with specific maintenance covenants.

- Onsite stormwater controls such as bioretention areas or bioswales shall be managed by the homeowners/building association with specific maintenance covenants (see also Minimum Requirement #10 in Volume I; Volume I, Section 3.3.4; and Volume I, Appendix I-B).

- Stewardship and management plans that address long-term protection and maintenance shall be developed for these sites and submitted to the county for approval.

4.2.2 Homeowners/Building Covenants

Homeowners/building covenants shall be required for all projects utilizing a comprehensive LID design approach to ensure that the stormwater management applications continue to function as designed. This may also apply to the use of individual LID BMPs that are not necessarily part of a comprehensive LID design approach. The covenants shall specifically address and/or append the requirements and responsibilities for long-term management and maintenance of any bioretention areas, natural resource protection areas, open space tracts, tree and other vegetation retention areas, or other BMPs.

4.2.3 Management Plans and Maintenance Agreements

Management plans and maintenance agreements for vegetation retention areas, open space tracts, and BMPs shall be in conformance with the requirements set forth in the Vegetation Retention section (Section 2.3.1), Volume I of this manual, Title 17A PCC – Site Development and Stormwater Management, Title 18E PCC – Critical Areas, and Title 18H PCC – Forest Practices and Tree Conservation.

Prior to approval of any building or site development permit for a project utilizing the comprehensive LID site design approach, a memorandum of agreement (MOA) that describes the LID project, together with the development's site plan, shall be recorded with the Pierce County Auditors office. The MOA shall be on a form provided by the Pierce County Planning and Land Services (PALS) and shall contain a brief description of the development; LID strategies utilized, and shall be signed by the property owner. Note: an MOA may also be required for individual LID BMPs designed in accordance with Chapter 3 but not part of a comprehensive LID site design approach. For individual BMPs, the need for an MOA will be determined by the county on a case-by-case basis.

The development's site plan shall reflect the approved LID project and shall contain a signature block for the Planning Director or designee. At a minimum, the following shall be specifically addressed:

- Identification of all stormwater management facilities such as but not limited to bioretention areas, bioswales, open space areas, detention or retention ponds, rain gardens, water reuse systems, etc.

- Soil and erosion control management practices.

- Pest and disease management practices.

- Pruning requirements.

- Irrigation requirements.

- Fertilization requirements.

- Fire fuel management practices.

- BMP inspection (monitoring) and maintenance needed to assure continued performance of the intended function. Refer to Volume I, Appendix I-B for minimum guidelines on LID BMP maintenance techniques.

- The department may require that the site plan indicate water quality and quantity sampling locations to be used for monitoring on the site. Any required sampling stations shall be located upstream and downstream of the project site discharge point.

- The department shall require the installation of fencing and signage around natural resource protection areas (see Figure 2-8).

4.2.4 Education

Homeowner education measures describing the functions of conservation areas and LID BMPs must be implemented during sale of the home sites, homes, and periodically during ownership. Brochures or homeowner guides shall provide:

- An overview describing the function and need for natural resource protection, vegetation retention areas, and LID BMPs

- A description of the tree/plant species located within the vegetation retention areas and guidelines for protection of the vegetation

- Operation and maintenance requirements

- Contacts for questions on maintenance needs and enforcement.

4.2.5 Enforcement

Enforcement of this volume shall be in conformance with provisions established in Title 17A PCC – Site Development and Stormwater Management.