ORDINANCE NO. 012-08

AN ORDINANCE OF THE CITY OF PORT ORCHARD, WASHINGTON
AMENDING THE CITY OF PORT ORCHARD’S STORMWATER DESIGN
MANUAL BY INCORPORATING LOW IMPACT DEVELOPMENT
GUIDELINES AND PRACTICES

WHEREAS, on December 19, 2007, the City Council adopted Ordinance No. 046-07 which established Port Orchard Municipal Code Title 16 “Land Use Regulatory Code;” and

WHEREAS, Land Use Regulatory Code Chapter 16.80 provides for voluntary compliance with the Planned Low Impact Development (PLID) – Alternative Development Regulations set forth therein; and

WHEREAS, Land Use Regulatory Code Chapter 16.80 contemplates that at some future date, the City will adopt comprehensive low impact development standards for residential and commercial design and construction; and

WHEREAS, pending the future adoption of such standards, City staff has proposed that the Port Orchard Stormwater Design Manual be amended to incorporate certain low impact development guidelines and practices to provide guidance to those property owners and developers that wish to voluntarily comply with the requirements of Chapter 16.80; now, therefore,

THE CITY COUNCIL OF THE CITY OF PORT ORCHARD, WASHINGTON, DO ORDAIN AS FOLLOWS:

SECTION 1. The City of Port Orchard Stormwater Design Manual is hereby amended by adding a new Appendix 5A relating to Low Impact Development Guidelines to read as follows:

Appendix 5A: Low Impact Development Guidelines

Low Impact Development Guidelines

These guidelines outline methods to reduce the amount of stormwater runoff generated on developed sites. Throughout this Appendix 5A, unless otherwise specified, all references to this Manual shall mean the City of Port Orchard Stormwater Design Manual. The following references may also be of assistance in designing low impact development sites. In cases where these references differ with this Manual, this Manual will prevail.


5A.1 Site Design
Designers are referred to the Low Impact Development Technical Guidance Manual for Puget Sound for detailed guidance on how to plan a low impact development project.

5A.2 Reduced Impervious Surface

5A.2.1 Permeable Pavement

A. The initial 5,000 square feet for each project of permeable pavement shall not be considered impervious when determining whether or not a project meets the definition of a major development. All permeable pavement and shall be modeled as a dirt road or parking lot per table 5-2 for sizing of water quality and quality facilities if:

1. The paving system does not have an under drain system connected to a conveyance system
2. The site has a recorded covenant requirement paving systems maintenance per section 5A.2.1.E.
3. The permeable pavement does not receive stormwater runoff from a separate area larger than 10% of the permeable pavement area.
4. The permeable pavement product has an installed infiltration rate of at least 10 inches per hour.

B. Permeable pavement may not be used in areas with heavy pollutant loading or high chemical spill risk such as but not limited to gas stations, heavy industrial areas, auto body/repair shops, auto wash areas, commercial truck parking areas, areas with heavy industrial activity (as defined by USEPA regulations), or areas with high pesticide use.
C. Permeable pavement overlying an underground infiltration system shall be modeled as an impervious surface draining to an infiltration system designed per section 5.3.5 of this Manual. This system does not require a separate water quality device.

D. Permeable pavement post construction infiltration testing:
   1. Bucket Test – Surfaces can be tested by simply throwing a 5-gallon bucket of water on the surface. If the water puddles, remains on the surface greater than 2 minutes, or runs off the surface, 6-inch ring testing is required prior to accepting the construction.
   2. A 6-inch ring infiltration test: Seal a 6-inch ring to the base of the road surface. Wet the surface continuously for 10 minutes. The surface must infiltrate at least 10 inches per hour to be considered permeable. (See the Stormwater Management Manual for Western Washington, Volume III, Appendix III C or Appendix 8A of this Manual).
   3. Surfaces shall be tested at least once per 10,000 sq. ft. Clogged surfaces (infiltration rate less than 10 inches per hour) totaling greater than 10% of the total surface area shall be removed/replaced and retested.

E. Permeable Pavement Post Construction Maintenance Requirements
   1. Surfaces shall be swept with a high-efficiency or vacuum sweeper at least once per year. The optimum time is in the autumn after leaf fall.
   2. Porous asphalt and concrete shall be cleaned with a high-pressure hose following one of the annual sweepings at least once every other year.
   3. A Bucket Test, and if necessary 6-inch ring infiltration test, shall be performed after the first year of use and each 5 years thereafter. Surfaces shall be tested at least once per 10,000 sq. ft. If this test indicates the infiltration test is less than 10 inches per hour then the sweeping frequency shall be increased to semi-annually and the high pressure washing annually. (See the Stormwater Management Manual for Western Washington, Volume III, Appendix III C or Appendix 8A of this Manual for more details on the 6-inch ring test).
   4. Owner/Operator must keep at least 5 years of written documentation of all cleaning and infiltration tests and make them available to City inspectors upon request.

5A.3 Dispersion

5A.3.1 Full Dispersion:

Impervious surfaces dispersed over native vegetation per section 5.A.2 of this Manual shall be considered mitigated and require no further water quantity controls.
5A.3.2 Partial Dispersion:

A. Impervious surfaces dispersed as sheet flow over a flow length of at least 50 ft. of native vegetation or lawn/landscaped areas shall be considered partially dispersed.

B. Lawn or landscaped areas shall meet the soil amendment requirements of this Manual.

C. Partially dispersed impervious surfaces shall meet all design criteria per section 5.A.2. of this Manual except the minimum flow length shall be 50ft.

D. Partially dispersed impervious surfaces shall be considered impervious when determining whether or not a project meets the definition of a major development.

E. Partially dispersed impervious surfaces shall be modeled as open space in good conditions per table 5-2 “Modified Curve Numbers” of this Manual.

5A.3.3 Vegetated Roofs:

A. Design details for vegetated roofs can be found in section 6.4 of the Low Impact Development Technical Guidance Manual for Puget Sound.

B. Vegetated portions of roofs shall be modeled using the Curve Numbers from table 5-2 of this Manual as:
   1. Open Space Good Condition on till (C soil) for the areas with 3-8 inches of growing media.
   2. Meadow or Pasture on till (C soil) for areas with greater than 8 inches of growing media.

5A.4 Minimum Excavation Foundations:

See section 7.6 of the Low Impact Development Technical Guidance Manual for Puget Sound for modeling credits given for this technology.

5A.5 Bioretention Facilities

A. Bioretention facilities shall be designed as either filtration systems or retention systems.

   1. Facilities designed as retention systems do not require pretreatment per section 5.3.5 of this Manual.
   2. For facilities that receive runoff from less than or equal to 5000 sq. ft. of impervious surface subject to vehicular traffic, there shall be 1 ft. of clearance from the bottom of the facility to the seasonal high water table.
3. For facilities that receive runoff from greater than 5000 sq. ft. of impervious surface subject to vehicular traffic, there shall be 3 ft. of clearance from the bottom of facility to the seasonal high water table.

4. Facilities designed only as filtration systems (water quality devices) shall have an under drain system to ensure that the Stormwater is filtrated through the media prior to discharge.

5. Maximum ponding for bioretention systems shall be 12 inches. However, a maximum ponding depth of 6-8 inches is preferred.

6. Maximum draw down time shall be 24 hours. Draw down volume includes the engineered soil and gravel void spaces within the facility.

7. Filtration systems shall be modeled as having a flow rate equivalent to a filtration rate of 1 inch per hour (no safety factor applied to the 1 inch/hr).

8. Retention systems shall be modeled per section 5.3.5 of this Manual using the native soil infiltration rates. Soil void space shall be assumed to be 40%. Only void space below any under drains may be used for storage calculations.

9. Facilities will have an overflow system that connects the facility to either a designated dispersion area or downstream conveyance system.

10. Facilities receiving runoff from up to 5000 sq. ft. of impervious area shall have a minimum engineered soil depth of 18 inches for systems and an optional mulch layer of 2-3 inches. Facilities receiving runoff from greater than 5000 sq. ft. of impervious surface shall have a minimum engineering soil depth of 24 inches and a mulch layer of 2-3 inches.

11. Figures 5-31a, b, c show possible bioretention facility configurations. Designers may find other configurations in the references listed at the beginning of this Appendix.

12. Engineering soils shall be compacted.

B. the engineered soil component shall meet one of the following soil specifications:

1. **On-Site Soil Mix**
   a) Reuses native soils;
   b) 65% on-site soil, 35% compost (See 5A.1.0);
   c) Mix shall be free of debris, rocks, garbage and organic material greater than 2 inches in any dimension;
   d) On-site soils shall be loam, sandy loam or loamy sand per figure 5-14. Soils may be amended with sand to meet this specification; and
   e) Mix shall be well blended and covered to prevent wetting and saturation.

2. **Off-Site Soil Mix**
   a) Uses imported soils;
   b) 65 to 70% gravelly sand per ASTM D 422;
<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>% Passing</th>
</tr>
</thead>
<tbody>
<tr>
<td>US No 4</td>
<td>100</td>
</tr>
<tr>
<td>US No 6</td>
<td>88-100</td>
</tr>
<tr>
<td>US No 8</td>
<td>79-97</td>
</tr>
<tr>
<td>US No 50</td>
<td>11-35</td>
</tr>
<tr>
<td>US No 200</td>
<td>5-15</td>
</tr>
</tbody>
</table>

c) 30 to 35% compost (See 5A.1.0);
d) Clay content shall be less than 5%;
e) Mix shall be free of debris, rocks, garbage and organic material greater than 2" in any dimension;
f) Mix shall be well blended and covered to prevent wetting and saturation; and
g) This blend is available commercially as “Vegetable Garden Mix” by Cedar Grove Composting.

C. Maintenance: Facilities shall be maintained per Appendix 8A of this Manual.
Figure 5.31b Typical Bioretention Facility

Source: Wisconsin Department of Natural Resources
Figure 5-31c Typical Bioretention Facility

Source: Low Impact Development Technical Guidance Manual for Puget Sound

**SECTION 2.** The City of Port Orchard Stormwater Design Manual is hereby amended by adding a new Appendix 8A to read as follows:

**Appendix 8A**

6-inch ring infiltration test

**Equipment:**

1. An open-ended cylinder of approximately 6-inch diameter, ≥12 inches in length
2. Bucket or other device to contain 2.5 to 5 gallons of water
3. Plumbers putty or other temporary waterproof sealant
4. Stop watch or other time keeping device accurate to a second
5. Infiltration test data sheet (page 8A-11)

**Procedure:**

1. Measure cylinder interior diameter in inches and note on test data sheet
2. Seal one end of the cylinder interior and exterior to the test surface.
3. Place a mark on the interior of the cylinder approximately 6 inches from the bottom.
4. Wet the test surface inside the cylinder continuously for 10 minutes.
5. Allow water to completely infiltrate.
6. Measure a known quantity of water between 1 and 5 gallons.
7. Start stop watch
8. Pour measured water into cylinder as needed until all the water has infiltrated. Do not fill the cylinder above the 6-inch mark.
9. Record time required to infiltrate measured water.
10. Determine infiltration rate
Appendix 8A

6-inch ring infiltration test

Equipment:

1. An open-ended cylinder of approximately 6-inch diameter, more than or equal to 12 inches in length.
2. Bucket or other device to contain 2.5 to 5 gallons of water.
3. Plumbers putty or other temporary waterproof sealant.
4. Stop watch or other time keeping device accurate to a second.
5. Infiltration rate data sheet (page 8A-11).

Procedures:

1. Measure cylinder interior in inches and note on rate data sheet.
2. Seal one end of the cylinder interior and exterior to the test surface.
3. Place a mark on the interior of the cylinder approximately 6 inches from the bottom.
4. Wet the test surface inside the cylinder continuously for 10 minutes.
5. Allow water to completely infiltrate.
6. Measure a known quantity of water between 1 and 5 gallons.
7. Start stop watch.
8. Pour measured water into cylinder as needed until all the water has infiltrated. Do not fill the cylinder above 6-inch mark.
9. Record time required to infiltrate measured water.
10. Determine infiltration rate.
Appendix 8A

Infiltration Rate Data Sheet

Date: ___________________________ Operator: ___________________________

Test Site: __________________________

Quantity of Water Infiltrated: _______ Gallons (W in equations below)

Time to Infiltrate Water: ___________ Seconds (T in equations below)

Cylinder Interior Diameter: ___________ Inches (D in equations below)

Determine Test Surface Area as follows: (A in equations below)

\[ A = \left(\frac{D}{2}\right)^2 \times \pi / 144 \]


(If interior diameter is 6 inches, \( A \approx 0.2 \text{ ft}^2 \))

Determine Infiltration rate as follows: Inches per hour

Divide W by 7.48 \[ \frac{W}{7.48} \]

Divide resultant number by T \[ \frac{W}{7.48} / [T] \]

Divide resultant number by A \[ \frac{W}{7.48} / [T] / [A] \]

Multiply resultant number by 3600 \[ \frac{W}{7.48} / [T] / [A] \times 3600 \]

Multiply resultant number by 12 \[ \frac{W}{7.48} / [T] / [A] \times 3600 \times 12 \]

(If 2.5 gallons infiltrates in a 6 inch cylinder in 600 seconds, rate \( \approx 120 \) inches per hour)

SECTION 3. This ordinance shall be in full force and effect five (5) days after posting and publication as required by law. A summary of this Ordinance may be published in lieu of the entire ordinance, as authorized by State Law.
PASSED by the City Council of the City of Port Orchard, APPROVED by the Mayor and attested by the Clerk in authentication of such passage this 25th day of March 2008.

Lary Coppola, Mayor

ATTEST:

Michelle Merlino, City Clerk

APPROVED AS TO FORM:

City Attorney

Sponsored by:

Robert Putaansuu, Councilman
Table 5-2 MODIFIED CURVE NUMBERS

Runoff curve numbers for selected agricultural, suburban, and urban land use for Type 1A rainfall distribution, 24-hour storm duration. (Published by SCS in 1982)

<table>
<thead>
<tr>
<th>LAND USE DESCRIPTION</th>
<th>CURVE NUMBERS BY HYDROLOGIC SOIL GROUP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
</tr>
<tr>
<td>Cultivated land¹: Winter condition</td>
<td>86</td>
</tr>
<tr>
<td>Mountain open areas: Low growing brush &amp; grassland</td>
<td>74</td>
</tr>
<tr>
<td>Meadow or pasture:</td>
<td>65</td>
</tr>
<tr>
<td>Wood or forest land:</td>
<td></td>
</tr>
<tr>
<td>Undisturbed</td>
<td>42</td>
</tr>
<tr>
<td>Established second growth ⁴</td>
<td>48</td>
</tr>
<tr>
<td>Young second growth or brush</td>
<td>55</td>
</tr>
<tr>
<td>Orchard:</td>
<td></td>
</tr>
<tr>
<td>With cover crop</td>
<td>81</td>
</tr>
<tr>
<td>Open spaces, lawns, parks, golf courses, cemeteries, landscaping</td>
<td></td>
</tr>
<tr>
<td>Good condition: Grass cover on &gt;= 75% of area</td>
<td>68</td>
</tr>
<tr>
<td>Fair condition: Grass cover on 50-75% of area</td>
<td>77</td>
</tr>
<tr>
<td>Gravel roads &amp; parking lots:</td>
<td></td>
</tr>
<tr>
<td>Dirt roads &amp; parking lots:</td>
<td>76</td>
</tr>
<tr>
<td>Impervious surfaces, pavement, roofs, etc.</td>
<td></td>
</tr>
<tr>
<td>Open water bodies: Lakes, wetlands, ponds, etc.</td>
<td>98</td>
</tr>
<tr>
<td>Single family residential ²:</td>
<td></td>
</tr>
<tr>
<td>Dwelling unit/gross acre % Impervious ³</td>
<td></td>
</tr>
<tr>
<td>1.0 DU/GA</td>
<td>15</td>
</tr>
<tr>
<td>1.5 DU/GA</td>
<td>20</td>
</tr>
<tr>
<td>2.0 DU/GA</td>
<td>25</td>
</tr>
<tr>
<td>2.5 DU/GA</td>
<td>30</td>
</tr>
<tr>
<td>3.0 DU/GA</td>
<td>34</td>
</tr>
<tr>
<td>3.5 DU/GA</td>
<td>38</td>
</tr>
<tr>
<td>4.0 DU/GA</td>
<td>42</td>
</tr>
<tr>
<td>4.5 DU/GA</td>
<td>46</td>
</tr>
<tr>
<td>5.0 DU/GA</td>
<td>48</td>
</tr>
<tr>
<td>5.5 DU/GA</td>
<td>50</td>
</tr>
<tr>
<td>6.0 DU/GA</td>
<td>52</td>
</tr>
<tr>
<td>6.5 DU/GA</td>
<td>54</td>
</tr>
<tr>
<td>7.0 DU/GA</td>
<td>56</td>
</tr>
<tr>
<td>PUDs, condos, apartments, Commercial businesses &amp; Industrial areas</td>
<td>% impervious</td>
</tr>
</tbody>
</table>

¹ For a more detailed description of agricultural land use curve numbers, refer to National Engineering Handbook, Sec. 4, Hydrology, Chapter 9, August 1972.
² Assumes roof and driveway runoff is directed into street/storm system.
³ The remaining pervious areas (lawn) are considered to be in good condition for these curve numbers.
⁴ Modified by KCPW, 1995.
6. Properly designed weirs, such as rectangular notched weirs, v-notched weirs, or snotro weirs, may be used as flow restrictors located either in catch basin structures, or mounted on a concrete retaining structure in the open. Formulas for sizing rectangular notched weirs and v-notched weirs are as follows:

**RECTANGULAR NOTCHED, SHARP CRESTED WEIR**

\[ Q = C(L - 0.2H)^{3/2} \]

where:
- \( Q \) = Weir discharge, in cubic feet per second
- \( C \) = \( 3.27 + 0.40 \times \frac{H}{P} \), in feet
- \( P \) = Height of weir bottom above downstream water surface in feet
- \( H \) = Height from weir bottom to crest, in feet
- \( L \) = Length of weir, in feet

*For weirs notched out of circular risers, Length is the portion of the riser circumference, not to exceed 50% of the circumference.

**V-NOTCH, SHARP CRESTED WEIR**

\[ Q = C_d(\tan \theta/2)H^{3/2} \]

where:
- \( Q \) = Weir discharge, in cubic feet per second
- \( C_d \) = Contraction coefficient, in feet
- \( \theta \) = Internal angle of notch, in degrees
- \( H \) = Height from weir bottom to crest, in feet

- \( C_d \) values may be taken from the following chart:

7. The control structure shall be designed to pass the 100-year, 24-hour duration storm event as overflow without causing flooding of the contributing drainage area and without allowing runoff to discharge through the emergency overflow spillway.

5.3.5 RETENTION FACILITIES

Underground infiltration trench systems are highly susceptible to failure by the reduction in infiltration capacity caused by the plugging of the infiltration surface with sediment and/or oily substances, as well as plugging resulting from improper construction practices. Ordinary maintenance usually cannot restore the infiltration function, and when failure occurs the entire system usually requires replacement. Because of the risk involved, these systems shall remain private and it will be the responsibility of the property owner to provide maintenance and to bear the cost of repair or replacement of the system. Infiltration trenches...
will not be allowed for use in residential developments unless a deviation from this requirement is granted by the Director.

Infiltration ponds are allowed for use in all types of developments. The basic requirements for infiltration ponds are the same as for detention ponds, with other specific criteria noted below.

In general, the setback, overflow and safety requirements for detention facilities also apply to infiltration ponds and trenches.

SOILS IDENTIFICATION AND DETERMINATION OF INFILTRATION RATE

Projects considered for on-site stormwater retention systems are required to provide soil classification information verifying the infiltration capability of site soils. A Soils Report is required for the location of each infiltration system proposed. The report shall include a Particle-Size Analysis performed by ASTM Test Method D-422-63. One sample for every 5,000-sf of infiltrating surface area is required to be obtained from the location of the proposed system, at a point 36-inches below the infiltration surface. Test results, including certification of the sample location and the depth to seasonal high groundwater table, shall bear the seal of a licensed professional engineer who has recognized expertise in the classification and mechanics of soils. The analysis will be used as the basis for determining the USDA Textural Classification.

The soil infiltration rate used for final design shall conform to Table 5-4 utilizing a factor of safety of 2.0.

Soils with an infiltration rate of less than 0.5-inches per hour are generally considered unsuitable for streambank erosion control. Infiltration systems shall not utilize fill material, nor be placed over fill soils.
DESIGN CRITERIA FOR INFILTRATION TRENCHES AND PONDS

The following design criteria apply specifically to ponds and trenches designed to infiltrate all or a portion of runoff (retention):

1. All ponds and trenches utilizing infiltration shall be designed using an appropriate storage routing method.

2. Facilities utilizing infiltration shall have bottoms a minimum of 18-inches above seasonal high ground water.

3. All retention facilities shall be a minimum of 200-feet from any slope steeper than 30%. This distance may be reduced based on a geotechnical engineering report.

4. All stormwater, prior to discharge to a facility designed to utilize infiltration, shall pass through a designed biofiltration swale system and through a presettling basin. In addition, all stormwater from paved areas subject to motor vehicle traffic shall flow through a spill-containment type oil/water separator.

5. For runoff quantity control facilities utilizing infiltration, those facilities shall be designed for a 100-year, 7-day storm event and also for a 100-year, 24-hour storm event, and shall have a maximum draw down time of 48-hours.

6. Until all project improvements which produce surface runoff are completed and all exposed ground surfaces are stabilized by revegetation or landscaping, facilities utilizing infiltration may not be operated, and no surface runoff may be permitted to enter the system.

7. The soil infiltration rate used for the design of infiltration systems shall be based on a textural analysis, according to Table 5-4. A safety factor of 2 shall be applied to the infiltration rate.
Table 5-4 SOIL INFILTRATION RATES BASED ON TEXTURAL ANALYSIS

<table>
<thead>
<tr>
<th>SOIL TEXTURE CLASS</th>
<th>INFILTRAION RATE (MIN/IN)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Gravel, coarse sand</td>
<td>1</td>
</tr>
<tr>
<td>2. Sand</td>
<td>5</td>
</tr>
<tr>
<td>3. Loamy sand</td>
<td>15</td>
</tr>
<tr>
<td>4. Sandy loam</td>
<td>30</td>
</tr>
<tr>
<td>5. Loam</td>
<td>Unsuitable</td>
</tr>
</tbody>
</table>

RETENTION PONDS

1. Infiltration ponds can be open or be lined with a 6 to 12-inch layer of filter material such as coarse sand or a suitable filter fabric to help prevent the buildup of impervious deposits on the soil surface. The filter layer can be replaced or cleaned when/if it becomes clogged.

2. Establishing a healthy stand of vegetation on the pond side slopes and floor is recommended. This vegetation will not only prevent erosion and sloughing, but will also provide a natural means of maintaining relatively high infiltration rates. Erosion protection of inflow points to the basin shall also be provided. Removal of accumulated sediment is a problem only at the basin floor. Little maintenance is normally required to maintain the infiltration capacity of side slope areas.

INFILTRATION TRENCHES

1. Trenches shall be designed to utilize infiltration through the bottom only, without taking into account sidewall infiltration. Storage volume shall be based on a maximum 30% void ratio for drainrock.

2. There is no minimum spacing between trench centerlines and no maximum trench width. However, flow distribution lines shall be installed at a spacing of 10-feet or less between pipes.

3. A Type 2 catch basin with sump (see Figure 5-23) shall be located on the upstream end of the trench, which provides a minimum of 36-inches of depth below the invert of the outlet pipe. A FROP-T device shall be provided on the outlet to the trench as shown on the detail. Additional Type 2 catch basins shall be placed along the trench to provide cleanout access such that all portions of the trench are within 150 feet of a catch basin.

4. An observation well (see Figure 5-24) shall be installed adjacent to the infiltration trench and within 25-feet of the facility for the purpose of monitoring ground water conditions.
The observation well should consist of perforated PVC pipe, 6-inches in diameter, backfilled with the same clean gravel material used in the infiltration trench. It should be located in the center of the structure and be constructed flush with the ground elevation of the trench. The top of the well should be capped to discourage vandalism and tampering.

5. The aggregate material for the infiltration trench shall consist of a washed aggregate free of fines with a maximum diameter of 1-1/2-inches and a minimum diameter of 3/4-inches.

6. A geotextile material shall be placed over the top of the trench to prevent backfill material from contaminating the washed rock.

5.3.6 INDIVIDUAL DOWNSPOUT INFILTRATION SYSTEMS

Individual downspout infiltration systems are trench infiltration systems designed to receive only stormwater from roof downspout drains. They shall be designed so as not to receive surface water from paved areas. Also, a single individual downspout infiltration system can only serve a maximum of 5,000 square feet of roof area.

The following standardized design criteria is intended to guide the homeowner in providing an acceptable design for an individual downspout infiltration system. Deviation in design or construction from the standardized design criteria detailed below may require design by a qualified engineer. This will be left to the discretion of the Director.
A study in Connecticut compared driveways constructed from conventional asphalt and permeable pavers (UNI group Eco-Stone) for runoff depth (precipitation measured on-site), infiltration rates, and pollutant concentrations. The Eco-Stone driveways were two years old. During 2002 and 2003, mean weekly runoff depth recorded for asphalt was 1.8 mm compared to 0.5 mm for the pavers. Table 6.3.1 summarizes pollutant concentrations from the study (Clausen and Gilbert, 2003).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Asphalt (mg/L)</th>
<th>Paver (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TSS</td>
<td>47.8</td>
<td>15.8</td>
</tr>
<tr>
<td>NO₃-N</td>
<td>0.6</td>
<td>0.2</td>
</tr>
<tr>
<td>NH₄-N</td>
<td>0.18</td>
<td>0.05</td>
</tr>
<tr>
<td>TP</td>
<td>0.244</td>
<td>0.162</td>
</tr>
<tr>
<td>Cu</td>
<td>18</td>
<td>6</td>
</tr>
<tr>
<td>Pb</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>Zn</td>
<td>87</td>
<td>25</td>
</tr>
</tbody>
</table>

(Adapted from Clausen and Gilbert, 2003)

In the Puget Sound region, a six-year permeable parking lot demonstration project conducted by the University of Washington found toxic concentrations of copper and zinc in 97 percent of the surface runoff samples from an asphalt control parking stall. In contrast, copper and zinc in 31 of 36 samples from the permeable parking stall—that produced primarily subsurface flow—fell below toxic levels and a majority of samples fell below detectable levels. Motor oil was detected in 89 percent of the samples from the surface flow off the asphalt stall. No motor oil was detected in any samples that infiltrated through the permeable paving sections. (Brattebo and Booth, 2003).

### 6.4 Vegetated Roofs

Vegetated roofs (also known as green roofs and eco-roofs) fall into two categories: intensive and extensive. Intensive roofs are designed with a relatively deep soil profile (6 inches and deeper) and are often planted with ground covers, shrubs, and trees. Intensive green roofs may be accessible to the public for walking or serve as a major landscaping element of the urban setting. Extensive vegetated roofs are designed with shallow, light-weight soil profiles (1 to 5 inches) and ground cover plants adapted to the harsh conditions of the roof top environment. This discussion focuses on the extensive design.

Extensive green roofs offer a number of benefits in the urban landscape including: increased energy efficiency, improved air quality, reduced temperatures in urban areas, noise reduction, improved aesthetics, extended life of the roof, and central to this discussion, improved stormwater management (Grant, Engleback and Nicholson, 2003).

Companies specializing in vegetated roof installations emerged in Germany and Switzerland in the late 1950s, and by the 1970s extensive green roof applications were common in those countries. In 2003, 13.5 million square meters of green roofs were installed in Germany (Grant et al., 2003; Peck, Callaghan, Kuhn and Bass, 1999; and Peck, Kuhn and Arch, n.d.). While roof gardens are not as prevalent in the U.S., designers in North America are discovering the value of the technology and green
roofs are becoming more common with installations on large buildings and individual residences in Portland, Philadelphia, Chicago, Seattle, and other cities.

6.4.1 Applications

Initial vegetated roof installations in the 1970s were prone to leaking. New technologies and installation techniques have improved and essentially eliminated past problems. Green roofs can be installed on almost any building with slopes up to 40 degrees and are effective strategies for managing stormwater in highly urbanized settings where rooftops comprise a large percentage of the total impervious surface (Scholtz-Barth, 2001).

6.4.2 Design

Native soils are heavy and would exert unnecessarily heavy loads for an extensive green roof installation, particularly when wet. Extensive roofs utilize light-weight soil mixes to reduce loads. Installations often range from 1 to 6 inches in depth and research from Germany indicates that, in general, a 3-inch soil depth offers the best environmental and aesthetic benefit to cost ratio (Miller, 2002).

While roof gardens can be installed on slopes up to 40 degrees, slopes between 5 and 20 degrees (1:12 and 5:12) are most suitable, and can provide natural drainage by gravity (depending on design, sloped roofs may also require a drainage layer). Flat roofs require a drainage layer to move water away from the root zone and the waterproof membrane. Roofs with slopes greater than 20 degrees require a lath grid to hold the soil substrate and drainage aggregate in place (Scholtz-Barth, 2001).

Vegetated roofs are comprised of four basic components: waterproofing membrane, drainage layer, growth medium, and vegetation. (See Figure 6.4.2 for a typical cross-section of a green roof.)

Waterproof membranes are made from PVC, Hypolan, rubber (EPDM) or polyolfinns. Sixty to 80-mil reinforced PVC with heat sealed seams provides a highly durable and waterproof membrane. EPDM seams must be glued and may be more susceptible to leakage. Thermoplastic polyolfinns are currently not well tested in the U.S., and U.S. manufacturers use bromides in the manufacturing process as a fire
retardant which may interfere with long-term performance. Asphalt-based roofing material should be covered with high-density polyethylene membrane to prevent roots and other organisms from utilizing the organic asphalt as an energy source (Scholtz-Barth, 2001). Some membranes are not compatible with asphalt-based or other roofing materials. Follow manufacturer’s recommendations for material compatibility.

The **drain layer** consists of either aggregate and/or a manufactured material that provides channels designed to transmit water at a specific rate. This layer can include a separation fabric, which with the drainage layer, reduces moisture contact with the waterproof membrane and provides additional protection from root penetration (Peck et al., n.d.).

The **light-weight growth medium** is designed to support plants and infiltrate and store water at a specific rate. The growth medium typically has a high mineral to organic material content and can be a mixture of various components including: gravel, sand, crushed brick, pumice, perlite, encapsulated Styrofoam, compost, and soil (Peck et al., n.d.). Saturated loads of 15 to 50 pounds/square foot are typical for extensive roofs with 1- to 5-inch soil depths (Scholtz-Barth, 2001). Currently, vegetated roofs weighing 15 pounds/square foot (comparable to typical gravel ballast roofs) have been installed and are functioning in the U.S. At 15 to 50 pounds, many roofs can be retrofitted with no or minimal reinforcement. Separating the growth medium from the building perimeter and roof penetrations with a non-combustible material (e.g., gravel) can provide increased protection against spread of fire, easier access to flashing and membrane connections, and additional protection from root penetration (Peck et al., n.d.).

**Vegetation** is typically succulents, grass, herbs, and/or wildflowers adapted to harsh conditions (minimal soils, seasonal drought, high winds, and strong sun exposure—i.e., alpine conditions) prevalent on rooftops. Plants should be adapted or native to the installation area. Some examples of species include: sempervivum, sedum, creeping thyme, alium, phloxes, and anntenaria. (Scholtz-Barth, 2001). Plants can be installed as vegetated mats, individual plugs, spread as cuttings, or by seeding. Vegetated mats and plugs provide the most rapid establishment for sedums. Cuttings spread over the substrate are slower to establish and will likely have a high mortality rate; however, this is a good method for increasing plant coverage on a roof that is in the process of establishing a plant community (Scholtz-Barth, 2001). During the plant establishment period soil erosion can be reduced by using a biodegradable mesh blanket.

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**A bonus for eco-roofs**

The city of Portland encourages the application of eco-roofs in the central city to reduce stormwater runoff. Buildings using eco-roofs can earn bonus floor area (exceeding maximum floor area ratios) depending on the extent of coverage. For example, if the total area of the eco-roof is at least 60 percent of the building’s footprint, each square foot of eco-roof earns three square feet of additional floor area.

**Flow modeling guidance**

See Chapter 7 for flow modeling guidelines for vegetated roofs when using WWHM.
For a sample vegetated roof specification, see Appendix 9.

### 6.4.3 Maintenance

Proper maintenance and operation are essential to ensure that designed performance and benefits continue over the full life cycle of the installation. Each roof garden installation will have specific design, operation, and maintenance guidelines provided by the manufacturer and installer. The following guidelines provide a general set of standards for prolonged roof garden performance. Note that some maintenance recommendations are different for extensive versus intensive roof gardens. The procedures outlined below are focused on extensive roof systems and different procedures for intensive roof recommendations are noted.

**Schedule**

- All facility components, including structural components, waterproofing, drainage layers, soil substrate, vegetation, and drains should be inspected for proper operation throughout the life of the roof garden.
- The property owner should provide the maintenance and operation plan, and inspection schedule.
- All elements should be inspected twice annually for extensive installations and four times annually for intensive installations.
- The facility owner should keep a maintenance log recording inspection dates, observations, and activities.
- Inspections should be scheduled to coincide with maintenance operations and with important horticultural cycles (e.g., prior to major weed varieties dispersing seeds).
Structural and drainage components

- Structural and drainage components should be maintained according to manufacturer’s requirements and accepted engineering practices.
- Drain inlets should provide unrestricted stormwater flow from the drainage layer to the roof drain system unless the assembly is specifically designed to impound water as part of an irrigation or stormwater management program:
  - Clear the inlet pipe of soil substrate, vegetation or other debris that may obstruct free drainage of the pipe. Sources of sediment or debris should be identified and corrected.
  - Inspect drain pipe inlet for cracks, settling and proper alignment, and correct and re-compact soils or fill material surrounding pipe if necessary.
- If part of the roof design, inspect fire ventilation points for proper operation.

Vegetation Management

- The vegetation management program should establish and maintain a minimum of 90 percent plant coverage on the soil substrate.
- During regularly scheduled inspections and maintenance, bare areas should be filled in with manufacturer recommended plant species to maintain the required plant coverage.
- Normally, dead plant material will be recycled on the roof; however specific plants or aesthetic considerations may warrant removing and replacing dead material (see manufacturer’s recommendations).
- Invasive or nuisance plants should be removed regularly and not allowed to accumulate and exclude planted species. At a minimum, schedule weeding with inspections to coincide with important horticultural cycles (e.g., prior to major weed varieties dispersing seeds).
- Weeding should be done manually and without herbicide applications.
- Extensive roof gardens should be designed to not require fertilization after plant establishment. If fertilization is necessary during plant establishment or for plant health and survivability after establishment, use an encapsulated, slow release fertilizer (excessive fertilization can contribute to increased nutrient loads in the stormwater system and receiving waters).
- Intensive green roofs installations require fertilization. Follow manufacturer and installer recommendations.
- Avoid application of mulch on extensive roof gardens. Mulch should be used only in unusual situations and according to the roof garden provider guidelines. In conventional landscaping mulch enhances moisture retention; however, moisture control on a vegetated roof should be through proper soil/growth media design. Mulch will also increase establishment of weeds.

Irrigation

- Surface irrigation systems on extensive roof gardens can promote weed establishment and root development near the drier surface layer of the soil substrate, and increase plant dependence on irrigation. Accordingly, subsurface irrigation methods are preferred. If surface irrigation is the only method available, use drip irrigation to deliver water to the base of the plant.
- Extensive roof gardens should be watered only when absolutely necessary for plant survival. When watering is necessary (i.e., during early plant
establishment and drought periods), saturate to the base of the soil substrate (typically 30 to 50 gallons per 100 square feet) and allow the soil to dry completely.

**Operation and Maintenance Agreements**
- Written guidance and/or training for operating and maintaining roof gardens should be provided along with the operation and maintenance agreement to all property owners and tenants.

**Contaminants**
- Measures should be taken to prevent the possible release of pollutants to the roof garden from mechanical systems or maintenance activities on mechanical systems.
- Any cause of pollutant release should be corrected as soon as identified and the pollutant removed.

**Insects**
- Roof garden design should provide drainage rates that do not allow pooling of water for periods that promote insect larvae development. If standing water is present for extended periods, correct drainage problem.
- Chemical sprays should not be used.

**Access and Safety**
- Egress and ingress routes should be clear of obstructions and maintained to design standards.

(City of Portland, 2002 and personal communication, Charlie Miller, February 2004)

### 6.4.4 Cost
Costs for vegetated roofs can vary significantly due to several factors including size of installation, complexity of system, growth media depth, and engineering requirements. Costs for new construction including structural support range from $10 to $15 per square foot. Retrofit costs range from $15 to $25 per square foot (Portland Bureau of Environmental Services, 2002). While initial installation costs are higher than for conventional roof systems, they are competitive on a full life cycle basis. Vegetated roofs increase the energy efficiency of a building and significantly reduce associated cooling and heating costs. European evidence indicates that a correctly installed green roof can last twice as long as a conventional roof, thereby deferring maintenance and replacement costs (Peck et al., n.d.). The above costs do not include savings on conventional stormwater management infrastructure as a result of reduced flows from a green roof or reduced stormwater utility fees.

### 6.4.5 Performance
Vegetated roof designs require careful attention to the interaction between the different components of the system. **Saturated hydraulic conductivity**, porosity and moisture retention of the growth media, and **transmissivity** of the drainage layer strongly influence hydrologic performance and reliability of the design (Miller and Pyke, 1999).

Research in Europe, in climates similar to the northeastern U.S., has consistently indicated that roof gardens can reduce up to 50 percent of the annual rooftop
European research, in climates similar to the northeastern U.S., has consistently indicated that roof gardens can reduce up to 50 percent of the annual rooftop stormwater runoff (Miller and Pyke, 1999). During a 9-month pilot test in eastern Pennsylvania, 14 and 28 square foot trays with test vegetated roof sections received a total of 44 inches of precipitation and generated 15.5 inches of runoff (runoff was negligible for storm events producing less than 0.6 inches of rainfall). The pilot section was 2.74 inches thick, including the drainage layer (USEPA, 2000b).

In Portland Oregon, a 4- to 4.5-inch eco-roof retained 69 percent of the total rainfall during a 15-month monitoring period. In the first January-to-March period (2002), rainfall retention was 20 percent and during the January-to-March (2003) period retention increased to 59 percent. The most important factors likely influencing the different retention rates are vegetation and substrate maturity, and rainfall distribution. The 2002 period was a more even rainfall distribution and the 2003 period more varied with longer dry periods between storms (Hutchison, Abrams, Retzlaff and Liptan, 2003). This supports observations by other researchers that vegetated roofs are likely more effective for controlling brief (including relatively intense) events compared to long-duration storms (Miller, 2002).

![Figure 6.4.3 Precipitation and percent stormwater retained on a 4- to 4.5-inch eco-roof, Portland, OR. Graphic from Hutchison et al., 2003](image)

### Hamilton West Ecoroof Stormwater Retention by Month

- **Monthly Rainfall (in.)**
- **Monthly % Stormwater Retention**

<table>
<thead>
<tr>
<th>Month</th>
<th>Rainfall (in.)</th>
<th>% Retention</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan '02</td>
<td>0.25</td>
<td>0%</td>
</tr>
<tr>
<td>Feb '02</td>
<td>0.5</td>
<td>0%</td>
</tr>
<tr>
<td>Mar '02</td>
<td>0.75</td>
<td>0%</td>
</tr>
<tr>
<td>Apr '02</td>
<td>1.25</td>
<td>0%</td>
</tr>
<tr>
<td>May '02</td>
<td>2.0</td>
<td>0%</td>
</tr>
<tr>
<td>Jun '02</td>
<td>3.0</td>
<td>0%</td>
</tr>
<tr>
<td>Jul '02</td>
<td>4.0</td>
<td>0%</td>
</tr>
<tr>
<td>Aug '02</td>
<td>5.5</td>
<td>0%</td>
</tr>
<tr>
<td>Sep '02</td>
<td>6.75</td>
<td>0%</td>
</tr>
<tr>
<td>Oct '02</td>
<td>5.0</td>
<td>0%</td>
</tr>
<tr>
<td>Nov '02</td>
<td>3.5</td>
<td>0%</td>
</tr>
<tr>
<td>Dec '02</td>
<td>2.0</td>
<td>0%</td>
</tr>
<tr>
<td>Jan '03</td>
<td>1.25</td>
<td>0%</td>
</tr>
<tr>
<td>Feb '03</td>
<td>0.75</td>
<td>0%</td>
</tr>
<tr>
<td>Mar '03</td>
<td>0.5</td>
<td>0%</td>
</tr>
<tr>
<td>Apr '03</td>
<td>0.25</td>
<td>0%</td>
</tr>
</tbody>
</table>

* Rainfall data missing from November 27 - 30, 2002
** Rainfall data missing from December 15 - 16, 2002
*** Included up to April 14, 2003

### 6.5 Minimal Excavation Foundation Systems

Excavation and movement of heavy equipment during construction compacts and degrades the infiltration and storage capacity of soils. Minimal excavation foundation systems limit soil disturbance and allow storm flows to more closely approximate natural shallow subsurface flow paths. When properly dispersed into the soils adjacent to and in some cases under the foundation, roof runoff that would otherwise be directed to bioretention areas or other LID facilities can be significantly reduced.

Minimal excavation foundation systems can take many forms, but in essence are a combination of driven piles and a connection component at, or above, grade. The piles allow the foundation system to reach or engage deep load-bearing soils without having to dig out and disrupt upper soil layers, which infiltrate, store and filter stormwater flows. These piles are a more "surgical" approach to earth engineering, and may be vertical, screw-augured or angled pairs that can be made of corrosion protected steel, wood or concrete. The connection component handles
Appendix III-C

The Washington State Department of Ecology (Ecology) encourages the use of the Western Washington Hydrology Model (WWHM) and other approved runoff models (currently approved alternative models are the King County Runoff Time Series and MGS Flood) for estimating surface runoff and sizing stormwater control and treatment facilities. This guidance suggests how to represent various LID techniques within those models so that their benefit in reducing surface runoff can be estimated. The lower runoff estimates should translate into smaller stormwater treatment and flow control facilities. In certain cases, use of various techniques can result in the elimination of those facilities.

The flow control credits presented in this chapter were developed by an LID credit committee comprised of stormwater managers from various local jurisdictions, WSDOT, WSU and Ecology.

This section identifies seven categories of LID techniques. For each category, the guidance lists basic design criteria that Ecology considers necessary in order to justify use of the suggested runoff “credit” or “runoff model representation.” More detailed design guidance is available in the Low Impact Development Technical Guidance Manual for Puget Sound (LID Manual), published by the Puget Sound Action Team and the Washington State University Cooperative Extension.

As Puget Sound gains more experience with and knowledge of LID techniques, the design criteria will evolve. Also, our ability to model their performance will change as our modeling techniques improve. Therefore, we anticipate this guidance will be updated periodically to reflect the new knowledge and modeling approaches. Meanwhile, we encourage all to use the guidance, and to give us feedback on its usefulness and accuracy. Comments can be sent to Ed O’Brien of the Washington State Department of Ecology at eobr461@ecy.wa.gov.

Note that the terminology for grass has changed in the WWHM. The term grass has been replaced with landscaped area.
7.1 Permeable Pavements

7.1.1 Credits

7.1.1.1 Porous Asphalt or Concrete

Description of Public Road or Public Parking lot

1. Base material laid above surrounding grade:
   a) Without underlying perforated drain pipes to collect stormwater

   b) With underlying perforated drain pipes for stormwater collection:
      
      at or below bottom of base layer
      elevated within the base course

2. Base material laid partially or completely below surrounding grade:
   a) Without underlying perforated drain pipes

   b) With underlying perforated drain pipes:
      at or below bottom of base layer
      elevated within the base course

   Model Surface as

   Grass over underlying soil type (till or outwash)

   Impervious surface

   Impervious surface

   Option 1: Grass over underlying soil type

   Option 2: Impervious surface routed to an infiltration basin¹

   Impervious surface

   Model as impervious surface routed to an infiltration basin¹

¹ See section 7.8 for detailed instructions concerning how to represent the base material below grade as an infiltration basin in the Western Washington Hydrology Model.

² If the perforated pipes function is to distribute runoff directly below the wearing surface, and the pipes are above the surrounding grade, follow the directions for 2a above.
Description of Private Facilities (driveways, parking lots, walks, patios)

1. Base material below grade without perforated drain pipes
   50% grass on underlying underlying soil; 50% impervious

2. Base material below grade with underlying perforated drain pipes
   Impervious surface

7.1.1.2 Grid/lattice systems (non-concrete) and Paving Blocks

Description of Public Road or Public Parking lot

Model Surface as

1. Base material laid above surrounding grade

a) Without underlying perforated drain pipes
   Grid/lattice systems: grass on underlying soil (till or outwash).

   Paving Blocks: 50% grass on underlying soil; 50% impervious.

b) With underlying perforated drain pipes
   Impervious surface

2. Base material laid partially or completely below surrounding grade

a) Without underlying perforated drain pipes

   Option 1:
   Grid/lattice as grass on underlying soil.
   Paving blocks as 50% grass; 50% impervious.

   Option 2:
   Impervious surface routed to an infiltration basin.¹

b) With underlying perforated drain pipes

   at or below bottom of base layer
   Elevated within the base course²

   Impervious surface

   Model as impervious surface routed to an infiltration basin.¹
Description of Private Facilities (driveways, parking lots, walks, patios)

Base material laid partially or completely below surrounding grade

a) Without underlying perforated drain pipes 0% grass; 50% impervious
b) With underlying drain pipes Impervious surface

7.1.2 Design Criteria for Permeable Pavements

Subgrade

- Compact the subgrade to the minimum necessary for structural stability. Use static dual wheel small mechanical rollers or plate vibration machines for compaction. Do not allow heavy compaction due to heavy equipment operation. The subgrade should not be subject to truck traffic.
- Use on soil types A through C.

Geotextile

- Use geotextile between the subgrade and base material/separation layer to keep soil out of base materials.
- The geotextile should pass water at a greater rate than the subgrade soils.

Separation or Bottom Filter Layer (recommended but optional)

- A layer of sand or crushed stone (0.5 inch or smaller) graded flat is recommended to promote infiltration across the surface, stabilize the base layer, protect underlying soil from compaction, and serve as a transition between the base course and the underlying geotextile material.

Base material

- Many design combinations are possible. The material must be free draining. For more detailed specifications for different types of permeable pavement, see section 6.2: Permeable Paving.
  - Driveways (recommendation):
    ✓ > 4” layer of free-draining crushed rock, screened gravel, or washed sand.
    ✓ < 5% fines (material passing thru #200 sieve) based on fraction passing #4 sieve.
  - Roads & Parking lots: The standard materials and quantities used for asphalt roads should be followed. For example:
    ✓ Pierce Co. cites larger rock on bottom, smaller on top (e.g., 2” down to 5/8”); compacted; minimal fines; 8 inches total of asphal tic concrete and base material.
    ✓ WSDOT lists coarse crushed stone aggregate (AASHTO Grading No. 57: 1.5 inch and lower); stabilized or unstabilized with modest compaction; meets fracture requirements.
    ✓ FHWA suggests three layers between the porous pavement and geotextile. Typical layers would be:
Filter course: 13 mm diameter gravel, 25 to 50 mm thick.
Stone reservoir: 40-75 mm diameter stone.
Filter course: 13 mm diameter gravel, 50 mm thick.

Wearing layer

- For all surface types, a minimum initial infiltration rate of 10 inches per hour is necessary. To improve the probability of long-term performance, significantly higher infiltration rates are desirable.
- *Porous Asphalt*: Products must have adequate void spaces through which water can infiltrate. A void space within the range of 12 – 20% is common.
- *Porous Concrete*: Products must have adequate void spaces through which water can infiltrate. A void space within the range of 15 – 21% is common.
- *Grid/lattice systems filled with gravel, sand, or a soil of finer particles with or without grass*: The fill material must be at least a minimum of 2 inches of sand, gravel, or soil. It should be underlain with 6 inches or more of sand or gravel to provide an adequate base. The fill material should be at or slightly below the top elevation of the grid/lattice structure. Modular-grid openings must be at least 40% of the total surface area of the modular grid pavement. Provisions for removal of oil and grease contaminated soils should be included in the maintenance plan.
- *Paving blocks*: 6 inches of sand or aggregate materials should fill spaces between blocks and must be free draining. Do not use sand for the leveling layer or filling spaces with EcoStone.
- The block system should provide a minimum of 12% free draining surface area (area between the blocks).
- Provisions for removal of oil and grease contaminated soils should be included in the maintenance plan.

Drainage conveyance

Roads should still be designed with adequate drainage conveyance facilities as if the road surface was impermeable. Roads with base courses that extend below the surrounding grade should have a designed drainage flow path to safely move water away from the road prism and into the roadside drainage facilities. Use of perforated storm drains to collect and transport infiltrated water from under the road surface will result in less effective designs and less flow reduction credit.

Acceptance test

- Driveways can be tested by simply throwing a bucket of water on the surface. If anything other than a scant amount puddles or runs off the surface, additional testing is necessary prior to accepting the construction.
- Roads may be initially tested with the bucket test. In addition, test the initial infiltration with a 6-inch ring, sealed at the base to the road surface, or with a sprinkler infiltrometer. Wet the road surface continuously for 10 minutes. Begin test to determine compliance with 10 inches per hour minimum rate.
Limitations

- No run-on from pervious surfaces is preferred. If runoff comes from minor or incidental pervious areas, those areas must be fully stabilized.
- Slope impervious runoff away from the permeable pavement to the maximum extent practicable. Sheet flow from up-gradient impervious areas is not recommended, but permissible if porous surface flow path ≥ impervious surface flow path. (Note: Impermeable surface that drains to a permeable pavement can also be modeled as noted above as long as the flow path restriction is met.
- Do not use at “high-use” sites, auto commercial services (gas stations, mini-marts, commercial fueling stations, auto body and auto repair shops, auto wash), commercial truck parking areas, areas with heavy industrial activity (as defined by USEPA regulations), or areas with high pesticide use.
- Soils must not be tracked onto the wear layer or the base course during construction.
- Slopes:
  - Asphalt: Works best on level slopes and up to 2%. Do not use on slopes ≥ 5%.
  - Concrete: Maximum recommended slope of 6%.
  - Interlocking pavers: Maximum recommended slope of 10%.
  - Grid/lattice systems: Maximum generally in 5-6% range.
- Do not use in areas subject to heavy, routine sanding for traction during snow and ice accumulation.
- Comply with local building codes for separation distances from buildings and wells. Inquire with the local jurisdiction concerning applicable setbacks.

Maintenance

- Inspect project upon completion to correct accumulation of fine material. Conduct periodic visual inspections to determine if surfaces are clogged with vegetation or fine soils. Clogged surfaces should be corrected immediately.
- Surfaces should be swept with a high-efficiency or vacuum sweeper twice per year; preferably, once in the autumn after leaf fall, and again in early spring. As long as annual infiltration rate testing demonstrates that a rate of 10 inches per hour or greater is being maintained, the sweeping frequency can be reduced to once per year. For porous asphalt and concrete surfaces, high pressure hosing should follow sweeping once per year.

7.2 Dispersion

7.2.1 Full Dispersion for the Entire Development Site (fulfills treatment and flow control requirements)

Developments that preserve 65% of a site (or a threshold discharge area of a site) in a forested or native condition, can disperse runoff from the developed portion of the site into the native vegetation area as long as the developed areas draining to the native vegetation do not have impervious areas that exceed 10% of the entire site. Runoff must be dispersed into the native area in accordance with the BMPs cited in BMP T5.30 of Volume V - Chapter 5. Additional impervious areas are allowed, but should not drain to the native vegetation area and are subject to the thresholds, treatment and flow control requirements of this stormwater manual.
7.2.2 Full Dispersion for All or Part of the Development Site

Developments that maintain ratios of:

\[ \geq \ 65\% \text{ forested or native condition; and} \]

\[ \leq \ 10\% \text{ effective impervious surface of the area draining into the native vegetation area may} \]

\[ \text{disperse runoff into the native area in accordance with the BMPs cited in BMP T5.30 of Volume} \]

\[ \text{V - Chapter 5. Examples of such ratios are:} \]

<table>
<thead>
<tr>
<th>% Native Vegetation Preserved (min. allowed)</th>
<th>% Effective Impervious (max. allowed)</th>
<th>% Lawn/Landscape (max. allowed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>65</td>
<td>10</td>
<td>35</td>
</tr>
<tr>
<td>60</td>
<td>9</td>
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<td>40</td>
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<td>60*</td>
</tr>
<tr>
<td>35</td>
<td>5.5</td>
<td>65*</td>
</tr>
</tbody>
</table>

* Where these lawn/landscape areas are established on till soils, and exceed 50% of the total site, they should be developed using guidelines in BMP T5.13 of Volume V – Chapter 5, or a locally approved alternative soil quality and depth specification.

Within the context of this dispersion option, the only impervious surfaces that are ineffective are those that are routed into an appropriately sized dry well or into an infiltration basin that meets the flow control standard and does not overflow into the forested or native vegetation area.

**Note:** For options in 7.2.1 and 7.2.2, native vegetation areas must be protected from future development. Protection must be provided through legal documents on record with the local government. Examples of adequate documentation include: a conservation easement, conservation parcel, deed restriction.

7.2.3 Partial Dispersion on residential lots and commercial buildings

If roof runoff is dispersed on single-family lots or commercial lots greater than 22,000 square feet, according to the design criteria and guidelines in BMP T5.10 of Volume V - Chapter 5, and the vegetative flow path is 50 feet or larger through undisturbed native landscape or lawn/landscape area that meets the guidelines in BMP T5.13, the roof area may be modeled as landscaped area. This is done by clicking on the "Credits" button in the WWHM and entering the percent of roof area that is being dispersed.
The vegetated flow path is measured from the downspout or dispersion system discharge point to the downstream property line, stream, wetland, or other impervious surface.

Where BMP T5.11 (concentrated flow dispersion) or BMP T5.12 (sheet flow dispersion) of Volume V – Chapter 5 is used to disperse runoff into a native vegetation area or an area that meets the guidelines in BMP T5.13 of Volume V – Chapter 5, the impervious area may be modeled as landscaped area. This can be done by entering the impervious area as landscaped area rather than entering it as impervious area.

7.2.4 Road Projects

1) Uncollected or natural dispersion into adjacent vegetated areas (i.e., sheet flow into the dispersion area).

Full dispersion credit (i.e. no other treatment or flow control required) for sites that meet the following criteria:

a) Outwash soils (Type A – sands and sandy gravels, possibly some Type B – loamy sands) that have an initial saturated infiltration rate of 4 inches per hour or greater. The infiltration rate must be based on one of the following: (1) A D_{10} size (10% passing the size listed) greater than 0.06 mm (based on the estimated infiltration rate indicated by the upper-bound line in Figure 3.28 of Volume III – Chapter 3 for the finest soil within a three foot depth; (2) field results using procedures (Pilot Infiltration Test) identified in Appendix V-B of Volume V.

- 20 feet of impervious flow path needs 10 feet of dispersion area width.
- Each additional foot of impervious flow path needs 0.25 feet of dispersion area width.

b) Other soils: (Types C and D and some Type B not meeting the criterion in 1a above)

- Dispersion area must have 6.5 feet of width for every 1 foot width of impervious area draining to it. A minimum distance of 100 feet is necessary.

c) Criteria applicable to all soil types:

- Depth to the average annual maximum groundwater elevation should be at least 3 feet.
- Impervious surface flow path must be ≤ 75 ft. Pervious flow path must be ≤ 150 ft. Pervious flow paths are up-gradient road side slopes that run onto the road and down-gradient road side slopes that precede the dispersion area.
- Lateral slope of impervious drainage area should be ≤ 8%. Road side slopes must be ≤ 25%. Road side slopes do not count as part of the dispersion area unless native vegetation is re-established and slopes are less than 15%. Road shoulders that are paved or graveled to withstand occasional vehicle loading count as impervious surface.
- Longitudinal slope of road should be ≤ 5%.
- Length of dispersion area should be equivalent to length of road.
- Average longitudinal (parallel to road) slope of dispersion area should be ≤ 15%.
- Average lateral slope of dispersion area should be ≤ 15%.
2) Channelized (collected and re-dispersed) stormwater into areas with (a) native vegetation or
(b) cleared land in areas outside of Urban Growth Areas that do not have a natural or man-made
drainage system.

Full dispersion credit (i.e., no other treatment or flow control required) is given to projects that
meet the following criteria:

a) *Outwash soils* (Type A – sands and sandy gravels, possibly some Type B – loamy sands) that
have an initial saturated infiltration rate of 4 inches per hour or greater. The infiltration rate must
be based on one of the following: (1) A D_{10} size (10% passing the size listed) greater than 0.06
mm (based on the estimated infiltration rate indicated by the upper-bound line in Figure 3.28 of
Volume III – Chapter 3 for the finest soil within a three foot depth; 2 field results using
procedures (Pilot Infiltration Test) identified in Appendix V-B of Volume V.

- Dispersion area should be at least ½ of the impervious drainage area.

b) *Other soils*: (Types C and D and some Type B not meeting the criterion in 2a above)

- Dispersion area must have 6.5 feet of width for every 1 foot width of impervious area
draining to it. A minimum distance of 100 feet is necessary.

c) *Other criteria applicable to all soil types:*

- Depth to the average annual maximum groundwater elevation should be at least three feet.
- Channelized flow must be redispersed to produce longest possible flow path.
- Flows must be evenly dispersed across the dispersion area.
- Flows must be dispersed using rock pads and dispersion techniques as specified in BMP
  T5.30, of Volume V – Chapter 5.
- Approved energy dissipation techniques may be used.
- Limited to onsite (associated with the road) flows.
- Length of dispersion area should be equivalent to length of the road.
- Average longitudinal and lateral slopes of the dispersion area should be ≤ 8%.

3) Engineered dispersion of stormwater runoff into an area with engineered soils

Full dispersion credit (i.e., no other treatment or flow control required) is given to projects that
meet the following criteria:

- Stormwater can be dispersed via sheet flow or via collection and re-dispersion in accordance
  with the techniques specified in BMP T5.30 in Volume V – Chapter 5.
- Depth to the average annual maximum groundwater elevation should be at least three feet.
- Type C and D soils must be compost-amended following guidelines in BMP T5.13 of
  Volume V – Chapter 5. The guidance document *Guidelines and Resources for Implementing
  Soil Quality and Depth BMP T5.13 in WDOE Stormwater Management Manual for Western
  Washington* can be used, or an approved equivalent soil quality and depth specification
  approved by the Department of Ecology. The guidance document is available at
  - Dispersion area must meet the 6.5 to 1 ratio for full dispersion credit.
• Type A and B soils that meet the 4 inches per hour initial saturated infiltration rate minimum (See Section 7.2.4.2.a above) must be compost amended in accordance with guidelines in BMP T5.13 of Volume V – Chapter 5. Compost may be incorporated into the soil in accordance with the guidance document cited above, or can be placed on top the native soil.
  * 20 feet of impervious flow path needs 10 feet of dispersion area width.
  * Each additional foot of impervious flow path needs 0.25 feet of dispersion area width.
• Average longitudinal (parallel to road) slope of dispersion area should be ≤ 15%.
• Average lateral slope of dispersion area should be ≤ 15%.
• The dispersion area should be planted with native trees and shrubs.

4) Other Characteristics for Dispersal areas

• Dispersal areas must be outside of the urban growth area; or if inside the urban growth area, in legally protected areas (easements, conservation tracts, public parks).
• If outside urban growth areas, legal agreements should be reached with property owners of dispersal areas subject to stormwater that has been collected and is being re-dispersed.
• An agreement with the property owner is advised for uncollected, natural dispersion via sheet flow that represents a continuation of past practice. If not a continuation of past practice, an agreement should be reached with the property owner.

7.3 Vegetated Roofs

7.3.1 Option 1 Design Criteria

• 3 inches to 8 inches of soil/growing media

Runoff Model Representation

• 50% till landscaped area; 50% impervious area

7.3.2 Option 2 Design Criteria

• ≥ 8 inches of soil/media

Runoff Model Representation

• 50% till pasture; 50% impervious area

Note: These modeling recommendations differ from those in the LID Manual.

7.3.3 Other Necessary Design Criteria

• Soil or growth media that has a high field capacity, and a saturated hydraulic conductivity that is ≥ 1 inch/hour (i.e., equivalent to a sandy loam or soil with a higher hydraulic conductivity).
• Drainage layer that allows free drainage under the soil/media.
• Vegetative cover that is both drought and wet tolerant.
• Waterproof membrane between the drain layer and the structural roof support.
• Maximum slope of 20%.
7.4 Rainwater Harvesting

7.4.1 Design Criteria

- 100% reuse of the annual average runoff volume (use continuous runoff model to get annual average for drainage area).
- System designs involving interior uses must have a monthly water balance that demonstrates adequate capacity for each month and reuse of all stored water annually.

Runoff Model Representation:
- Do not enter drainage area into the runoff model.

7.4.2 Other Criteria

- Restrict use to 4 homes/acre housing and lower densities when the captured water is solely for outdoor use.

7.5 Reverse Slope Sidewalks

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

7.5.1 Design Criteria:

- ≥ 10 feet of vegetated surface downslope that is not directly connected into the storm drainage system.
- Vegetated area receiving flow from sidewalk must be native soil or meet guidelines in BMP T5.13 of Volume V – Chapter 5.

7.5.2 Runoff Model Representation:

- Enter sidewalk area as landscaped area over the underlying soil type.
7.6 Minimal Excavation Foundations

Low impact foundations are defined as those techniques that do not disturb, or minimally disturb 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.

7.6.1 Runoff Model Representation

- Where residential roof runoff is dispersed on the up gradient side of a structure in accordance with the design criteria and guidelines in BMP T5.10 of Volume V – Chapter 5, the tributary roof area may be modeled as pasture on the native soil.
- Where “step forming” is used on a slope, the square footage of roof that can be modeled as pasture must be reduced to account for lost soils. In “step forming,” the building area is terraced in cuts of limited depth. This results in a series of level plateaus on which to erect the form boards. The following equation (suggested by Rick Gagliano of Pin Foundations, Inc.) can be used to reduce the roof area that can be modeled as pasture.

\[ A_1 - \frac{dC(5)}{dP} \times A_1 = A_2 \]

- Where “step forming” is used on a slope, the square footage of roof that can be modeled as pasture must be reduced to account for lost soils. In “step forming,” the building area is terraced in cuts of limited depth. This results in a series of level plateaus on which to erect the form boards. The following equation (suggested by Rick Gagliano of Pin Foundations, Inc.) can be used to reduce the roof area that can be modeled as pasture.

\[ A_1 - \frac{dC(5)}{dP} \times A_1 = A_2 \]

- If roof runoff is dispersed down gradient of the structure in accordance with the design criteria and guidelines in BMP T5.10 of Volume V – Chapter 5, AND there is at least 50 feet of vegetated flow path through native material or lawn/landscape area that meets the guidelines in BMP T5.13 of Volume V – Chapter 5, the tributary roof areas may be modeled as landscaped area.

7.6.2 Limitations

- To minimize soil compaction, heavy equipment cannot be used within or immediately surrounding the building. Terracing of the foundation area may be accomplished by tracked, blading equipment not exceeding 650 psf.
7.7 Bioretention areas (rain gardens)

The design criteria provided below outlines basic guidance on bioretention design specifications, procedures for determining infiltration rates, and flow control guidance. For details on design specifications see section 6.1: Bioretention Areas of the Low Impact Development Technical Guidance Manual for Puget Sound (LID Manual).

7.7.1 Design Criteria

Soils
- The soils surrounding bioretention facilities are a principle design element for determining infiltration capacity, sizing and rain garden type. The planting soil mix placed in the cell or swale is a highly permeable soil mixed thoroughly with compost amendment, and a surface mulch layer.
- Soil depth should be a minimum of 18 inches to provide acceptable minimum pollutant attenuation and good growing conditions for selected plants.
- The texture for the soil component of the bioretention soil mix should be a loamy sand (USDA Soil Textural Classification). Clay content for the final soil mix should be less than 5 percent. The final soil mix (including compost and soil) should have a minimum short-term hydraulic conductivity of 1.0 inches/hour per ASTM Designation D 2434 (Standard Test Method for Permeability of Granular Soils) at 80 percent compaction per ASTM Designation D 1557.
- The final soil mixture should have a minimum organic content of approximately 10 percent by dry weight.
- The pH for the soil mix should be between 5.5 and 7.0.

Mulch layer
- Bioretention areas can be designed with or without a mulch layer.

Compost
- Material must be in compliance with WAC chapter 173-350-220. This code is available online at http://www.ecy.wa.gov/programs/swfa/facilities/350.html.
- pH between 5.5 and 7.0.
- Carbon nitrogen ratio between 20:1 and 35:1 (35:1 CN ratio recommended for native plants)
- Organic matter content should be between 35% and 65%.

Installation
- Minimize compaction of the base and sidewalls of the bioretention area. Excavation should not be allowed during wet or saturated conditions. Excavation should be performed by machinery operating adjacent to the bioretention facility and no heavy equipment with narrow tracks, narrow tires or large lugged, high pressure tires should be allowed on the bottom of the bioretention facility.
• On-site soil mixing or placement should not be performed if soil is saturated. The bioretention soil mixture should be placed and graded by excavators and/or backhoes operating adjacent to the bioretention facility.

Plant materials
• Plants should be tolerant of ponding fluctuations and saturated soil conditions for the length of time anticipated by the facility design, and drought during the summer months.
• In general, the predominant plant material utilized in bioretention areas are facultative species adapted to stresses associated with wet and dry conditions.

Maximum ponding depth
• A maximum ponding depth of 12 inches is recommended.
• A maximum surface pool drawdown time of 24 hours is recommended.
• Ponding depth and system drawdown should be specified so that soils dry out periodically in order to:
  o Restore hydraulic capacity to receive flows from subsequent storms.
  o Maintain infiltration rates.
  o Maintain adequate soil oxygen levels for healthy soil biota and vegetation.
  o Provide proper soil conditions for biodegradation and retention of pollutants.

7.7.2 Limitations
• 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 rain garden meets or exceeds any of the following limitations:
  o 5,000 square feet of pollution-generating impervious surface; or
  o 10,000 square feet of impervious area; or
  o ¼ acres of lawn and landscape.
• If the tributary area to an individual rain garden does not exceed the areal limitations above, a minimum of 1 foot of clearance is adequate between the lowest elevation of the bioretention soil (or any underlying gravel layer) and the seasonal high groundwater elevation or other impermeable layer.

7.7.3 Runoff Model Representation

Pothole design (bioretention cells)

The rain garden is represented as a pond with a steady-state infiltration rate. Proper infiltration rate selection is described below. The pond volume is a combination of the above ground volume available for water storage and the volume available for storage within the imported soil. The above ground volume is the size of the “pothole” that accommodates standing water. A minimum ponding depth of 6-inches is recommended. The soil storage volume is determined by multiplying the volume occupied by the imported soil by the soil’s percent porosity. Use 40
percent porosity for bioretention planting mix soils recommended in section 6.1.2.3: Bioretention components of the LID Manual. That volume is presumed to be added directly below the surface soil profile of the rain garden. The theoretical pond dimensions are represented in the Pond Information/Design screen. The Effective Depth is the distance from the bottom of the theoretical pond to the height of the overflow. This depth is less than the actual depth because of the volume occupied by the soil. Approximate side slopes can be individually entered. On the Pond Information/Design screen, there is a button, which asks, “Use Wetted Surface Area?” Pushing that button is an affirmative response. Do not push the button if the rain garden has sidewalls steeper than 2 horizontal to 1 vertical.

Rain gardens with underlying perforated drain pipes that discharge to the surface can also be modeled as ponds with steady-state infiltration rates. However, the only volume available for storage (and modeled as storage as explained herein) is the void space within the imported material (usually sand or gravel) below the invert of the drain pipe.

Linear Design: (bioretention swale or slopes)

Swales

Where a swale design has a roadside slope and a back slope between which water can pond due to an elevated, and an overflow/drainage pipe at the lower end of the swale, the swale may be modeled as a pond with a steady state infiltration rate. This method does not apply to swales that are underlain by a drainage pipe.

If the long-term infiltration rate through the imported bioretention soil is lower than the infiltration rate of the underlying soil, the surface dimensions and slopes of the swale should be entered into the WWHM as the pond dimensions and slopes. The effective depth is the distance from the soil surface at the bottom of the swale to the invert of the overflow/drainage pipe. If the infiltration rate through the underlying soil is lower than the estimated long-term infiltration rate through the imported bioretention soil, the pond dimensions entered into the WWHM should be adjusted to account for the storage volume in the void space of the bioretention soil. Use 40 percent porosity for bioretention planting mix soils recommended in section 6.1.2.3: Bioretention components of the LID Manual. For instance, if the soil is 40% voids, and the depth of the imported soils is 2 feet throughout the swale, the depth of the pond is increased by 0.8 feet. If the depth of imported soils varies within the side slopes of the swale, the theoretical side slopes of the pond can be adjusted.

This procedure to estimate storage space should only be used on bioretention swales with a 1% slope or less. Swales with higher slopes should more accurately compute the storage volume in the swale below the drainage pipe invert.

Slopes

Where a bioretention design involves only a sloped surface such as the slope below the shoulder of an elevated road, the design can also be modeled as a pond with a steady state infiltration rate. This procedure only applies in instances where the infiltration rate through the underlying soil is less than the estimated long-term infiltration rate of the bioretention imported soil. In this case, the length of the bioretention slope should correspond to the maximum wetted cross-sectional
area of the theoretical pond. The effective depth of the theoretical pond is the void depth of the bioretention soil as estimated by multiplying the measured porosity times the depth of the bioretention soils. Use 40 percent porosity for bioretention planting mix soils recommended in section 6.1.2.3: Bioretention components of the LID Manual.

7.7.4 Infiltration Rate Determinations

The assumed infiltration rate for the pond must be the lower of the estimated long-term rate of the imported soil or the initial (a.k.a. short-term or measured) infiltration rate of the underlying soil profile. Using one of the procedures explained below, the initial infiltration rates of the two soils must be determined. Then after applying an appropriate correction factor to the imported soil of the rain garden, the designer can compare and determine the lower of the long-term infiltration rate of the imported soil, and the initial infiltration rate of the underlying native soil. The underlying native soil does not need a correction factor because the overlying imported soil protects it. Below are explanations for how to determine infiltration rates for the imported and underlying soils, and how to use them with the WWHM.

7.7.4.1 Imported Soil for the rain garden

1. Method for imported soil in a rain garden with a tributary area of or exceeding any of the following limitations: 5,000 square feet of pollution-generating impervious surface; or 10,000 square feet of impervious surface; or ¼ acres of lawn and landscape:
   - Use 4 as the infiltration reduction correction factor.
   - Compare this rate to the infiltration rate of the underlying soil (as determined using one of the methods below). If the long-term infiltration rate of the imported soil is lower, enter that infiltration rate and the correction factor into the corresponding boxes on the pond information/design screen of the WWHM.

2. Method for imported soil in a rain garden with a tributary area less than 5,000 square feet of pollution-generating impervious surface; and less than 10,000 square feet of impervious surface; and less than ¼ acres of lawn and landscape:
   - Use 2 as the infiltration reduction correction factor.
   - Compare this rate to the infiltration rate of the underlying soil (as determined using one of the methods below). If the long-term infiltration rate of the imported soil is lower, enter that infiltration rate and the correction factor into the corresponding boxes on the pond information/design screen of the WWHM.

7.7.4.2 Underlying Soil:

- Method 1: Use Table 3.7 of the 2004 SMMWW to determine the short-term infiltration rate of the underlying soil. Soils not listed in the table cannot use this approach. Compare this short-term rate to the long-term rate determined above for the bioretention imported soil. If
the short-term rate for the underlying soil is lower, enter it into the measured infiltration rate box on the pond information/design screen in the WWHM. Enter 1 as the infiltration reduction factor.

- Method 2: Determine the D₁₀ size of the underlying soil. Use the “upperbound line” in Figure 3-26a of Volume III – Chapter 3 to determine the corresponding infiltration rate. If this infiltration rate is lower than the long-term infiltration rate determined for the imported bioretention soil, enter the rate for the underlying soil into the measured infiltration rate box on the pond/information design screen. Enter 1 as the infiltration reduction factor.

- Method 3: Measure the in situ infiltration rate of the underlying soil using procedures (Pilot Infiltration Test) identified in Appendix V-B of Volume V. If this rate is lower than the long-term infiltration rate determined for the imported bioretention soil, enter the underlying soil infiltration rate into the corresponding box on the pond information/design screen of the WWHM. Enter 1 as the infiltration reduction factor.

7.7.5 WWHM Routing and Runoff File Evaluation

In WWHM2, all infiltrating facilities must have an overflow riser to model overflows that occur should the available storage be exceeded. So in the Riser/Weir screen, for the Riser head enter a value slightly smaller than the effective depth of the pond (say 0.1 ft below the Effective Depth), and for the Riser diameter enter a large number (say 10,000 inches) to ensure that there is ample capacity for overflows.

Within the model, route the runoff into the pond by grabbing the pond icon and placing it below the tributary “basin” area. Be sure to include the surface area of the bioretention area in the tributary “basin” area. Run the model to produce the effluent runoff file from the theoretical pond. For projects subject to the flow control standard, compare the flow duration graph of that runoff file to the target pre-developed runoff file for compliance with the flow duration standard. If the standard is not achieved a downstream retention or detention facility must be sized (using the WWHM standard procedures) and located in the field. A conveyance system should be designed to route all overflows from the bioretention areas to centralized treatment facilities, and to flow control facilities if flow control applies to the project.

7.7.6 Modeling of Multiple Rain Gardens

Where multiple rain gardens are scattered throughout a development, it may be possible to represent those as one rain garden (a “pond” in the WWHM) serving the cumulative area tributary to those rain gardens. For this to be a reasonable representation, the design of each rain garden should be similar (e.g., same depth of soil, same depth of surface ponded water, roughly the same ratio of impervious area to rain garden volume).

7.7.7 Other Rain Garden Designs

Guidance for modeling other bioretention designs is not yet available. Where compost-amended soils are used along roadsides, Section 7.2: Dispersion, can be applied.
7.8 WWHM Instructions for Estimating Runoff Losses in Road Base Material Volumes that are Below Surrounding Grade

Introduction

This section applies to roads or parking lots that have been constructed with a permeable pavement and whose underlying base materials extend below the surrounding grade of land. The over-excavated volume can temporarily store water before it infiltrates or overflows to the surrounding ground surface. This section describes design criteria and modeling approaches for such designs.

Pre-requisite

Before using this guidance to estimate infiltration losses, the designer should have sufficient information to know whether adequate depth to a seasonal high groundwater table, or other infiltration barrier (such as bedrock) is available. The minimum depth necessary is 3 feet as measured from the bottom of the base materials.

7.8.1 Instructions for Roads on Zero to 2% Grade

For road projects whose base materials extend below the surrounding grade, a portion of the below grade volume of base materials may be modeled in the WWHM as a pond with a set infiltration rate.

First, place a “basin” icon in the “Schematic” grid on the left side of the “Scenario Editor” screen. Left clicking on the basin icon will create a “basin information” screen on the right in which you enter the appropriate pre-developed and post-developed descriptions of your project site (or threshold discharge area of the project site). By placing a pond icon below the basin icon in the Schematic grid, we are routing the runoff from the road and any other tributary area into the below grade volume that is represented by the pond.

The dimensions of the infiltration basin/pond to be entered in the Pond Information/Design screen are: the length of the base materials that are below grade (parallel to the road); the width of the below grade material volume; and the Effective Depth. Note that the storage/void volume of the below grade base has to be estimated to account for the percent porosity of the gravel. This can be done by multiplying the below grade depth of base materials by the fractional porosity (e.g., a project with a gravel base of 32% porosity would multiply the below grade base material depth by 0.32). This is the Effective Depth. If the below grade base course has perforated drainage pipes elevated above the bottom of the base course, but below the elevation of the surrounding ground surface, the Effective Depth is the distance from the invert of the lowest pipe to the bottom of the base course multiplied by the fractional porosity.

Also in WWHM2, all infiltrating facilities must have an overflow riser to model overflows that occur should the available storage get exceeded. So in the Riser/Weir screen, for the Riser head enter a value slightly smaller than the effective depth of the base materials (say 0.1 ft below the Effective Depth); and for the Riser diameter enter a large value (say 10,000 inches) to ensure that there is ample capacity should overflows from the trench occur.
On the Pond Information/Design screen, there is a button that asks, “Use Wetted Surface Area?” Pushing that button is an affirmative response. Do not push the button.

Using the procedures explained in Volume III - Chapter 3 and Appendix V-B of the 2004 SMMWW, estimate the long-term infiltration rate of the native soils beneath the base materials. If using Method 1 from Chapter 3 of Volume III, enter the appropriate “short-term infiltration rate” from Table 3.7 into the “measured infiltration rate” box on the “Pond Information Design” screen of WWHM. Enter the correction factor from that table as the “Infiltration Reduction Factor.” If using Method 2, enter the appropriate long-term infiltration rate from Table 3.8 into the “measured infiltration rate” box. Enter “1” as the correction factor. Note that Table 3.8 is restricted to the soil types in the table. For soils with a D10 size smaller than .05 mm, use the “lowerbound” values from Figure 3-26a in Volume III – Chapter 3. If using Method 3, enter the measured in-situ infiltration rate as the “Measured Infiltration Rate” in the Pond Information/Design Screen. Also enter the appropriate cumulative correction factor determined from Table 3.9 as the “Infiltration Reduction Factor.” Wherever practicable, Ecology recommends using Method 3, in-situ infiltration measurements (Pilot Infiltration Test) in accordance with Appendix V-B of Volume V – Chapter 5.

Run the model to produce the overflow runoff file from the base materials infiltration basin. Compare the flow duration graph of that runoff file to the target pre-developed runoff file for compliance with the flow duration standard. If the standard is not achieved a downstream retention or detention facility must be sized (using the WWHM standard procedures) and located in the field. The road base materials should be designed to direct any water that does not infiltrate into a conveyance system that leads to the retention or detention facility.

7.8.2 Instructions for Roads on Grades above 2%

Road base material volumes that are below the surrounding grade and that are on a slope can be modeled as a pond with an infiltration rate and a nominal depth. Represent the below grade volume as a pond. Grab the pond icon and place it below the “basin” icon so that the computer model routes all of the runoff into the infiltration basin/pond.

The dimensions of the infiltration basin/pond to be entered in the Pond Information/Design screen are: the length (parallel to and beneath the road) of the base materials that are below grade; the width of the below grade base materials; and an Effective Depth of 1 inch. In WWHM2, all infiltrating facilities must have an overflow riser to model overflows that occur should the available storage get exceeded. So in the Riser/Weir screen, enter 0.04 ft (½ inch) for the Riser head and a large Riser diameter (say 1000 inches) to ensure that there is no head build up.

Note: If a drainage pipe is embedded and elevated in the below grade base materials, the pipe should only have perforations on the lower half (below the spring line) or near the invert. Pipe volume and trench volume above the pipe invert cannot be assumed as available storage space.

Estimate the infiltration rate of the native soils beneath the base materials. See the previous section (Instructions for Roads on Zero to 2% Grade) for estimating options and for how to enter
infiltration rates and infiltration reduction factors into the “Pond Information/ Design” Screen of WWHM. Enter the appropriate information for the theoretical pond of 1/2-inch maximum depth.

On the Pond Information/Design screen, there is a button that asks, “Use Wetted Surface Area?” Pushing that button is an affirmative response. Do not push the button.

Run the model to produce the effluent runoff file from the base materials. Compare the flow duration graph of that runoff file to the target pre-developed runoff file for compliance with the flow duration standard. If the standard is not achieved a downstream retention or detention facility must be sized (using the WWHM standard procedures) and located in the field. The road base materials should be designed to direct any water that does not infiltrate into a conveyance system that leads to the retention or detention facility.

7.8.3 Instructions for Roads on a Slope with Internal Dams within the Base Materials that are Below Grade

In this option, a series of infiltration basins is created by placing relatively impermeable barriers across the below grade base materials at intervals. The barriers inhibit the free flow of water down the grade of the base materials. The barriers must not extend to the elevation of the surrounding ground. Provide a space sufficient to pass water from upgradient to lower gradient basins without causing flows to surface out the sides of the base materials that are above grade.

Each stretch of trench (cell) that is separated by barriers can be modeled as an infiltration basin. This is done by placing pond icons in series in the WWHM. For each cell, determine the average depth of water within the cell (Average Cell Depth) at which the barrier at the lower end will be overtopped.

Specify the dimensions of each cell of the below-grade base materials in WWHM on the screen, which asks for pond dimensions. The dimensions of the infiltration cell to be entered in the Pond Information/Design screen are: the length of the cell (parallel to the road); the width; and the Effective Depth (In this case, it is OK to use the total depth of the base materials that are below grade).

Also in WWHM2, all infiltrating facilities must have an overflow riser to model overflows that occur should the available storage get exceeded. For each trench cell, the available storage is the void space within the Average Cell Depth. So, the storage/void volume of the trench cell has to be estimated to account for the percent porosity of the base materials. For instance, if the base materials have a porosity of 32%, the void volume can be represented by reducing the Average Cell Depth by 68% (1-32%). This depth is entered in the Riser/Weir screen as the Riser head. The gross adjustment works because WWHM2 (as March 2004) does not adjust infiltration rate as a function of water head. If the model is amended such that the infiltration rate becomes a function of water head, this gross adjustment will introduce error and therefore other adjustments should be made.) For the *Riser diameter* in the Riser/Weir screen, enter a large number (say 10,000 inches) to ensure that there is ample capacity should overflows from the below-grade trench occur.
Each cell should have its own tributary drainage area that includes the road above it, any project site pervious areas whose runoff drains onto and through the road, and any offsite areas. Each drainage area is represented with a "basin" icon.

Up to four pond icons can be placed in a series to represent the below grade trench of base materials. The computer graphic representation of this appears as follows:

![Diagram of Western Washington Hydrology Model for Thurston County](image)

It is possible to represent a series of cells as one infiltration basin (using a single pond icon) if the cells all have similar length and width dimensions, slope, and Average Cell Depth. A single "basin" icon is also used to represent all of the drainage area into the series of cells.
On the Pond Information/Design screen (see screen below), there is a button, which asks, “Use Wetted Surface Area?” Pushing that button is an affirmative response. Do not push the button if the below-grade base material trench has sidewalls steeper than 2 horizontal to 1 vertical.

![Pond Information/Design Screen]

Using the procedures explained above for roads on zero grade, estimate the infiltration rate of the native soils beneath the trench. Also as explained above, enter the appropriate values into the “Measured Infiltration Rate” and “Infiltration Reduction Factor” boxes of the “Pond Information/Design” screen.

Run the model to produce the effluent runoff file from the below grade trench of base materials. Compare the flow duration graph of that runoff file to the target pre-developed runoff file for compliance with the flow duration standard. If the standard is not achieved a downstream retention or detention facility must be sized (using the WWHM standard procedures) and located in the field. The road base materials should be designed to direct any water that does not infiltrate into a conveyance system that leads to the retention or detention facility.
7.6 Minimal Excavation Foundations

Low impact foundations are defined as those techniques that do not disturb, or minimally disturb, 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.
APPENDIX 8A

PORT ORCHARD MAINTENANCE GUIDELINES
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<td>General</td>
<td>Trash &amp; debris cleared from site.</td>
<td>Twice per year.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Poisonous vegetation</td>
<td>Any poisonous vegetation which may constitute a hazard to County personnel or the public. Examples of poisonous vegetation include: tansy ragwort, poison oak, stinging nettles, devils club.</td>
<td>No danger of poisonous vegetation where County personnel or the public might normally be. (Coordination with Bremerton Kitsap County Health District.)</td>
<td>Twice per year.</td>
</tr>
<tr>
<td></td>
<td>Pollution</td>
<td>Oil, gasoline, or other contaminants that could: 1) cause damage to plant, animal, or marine life; 2) constitute a fire hazard; or 3) be flushed downstream during rainstorms.</td>
<td>No contaminants present other than a surface film. (Coordination with Kitsap Water Quality Manager.)</td>
<td>Twice per year.</td>
</tr>
<tr>
<td></td>
<td>Unmowed grass/ground cover</td>
<td>If facility is located in private residential area, mowing is needed when grass exceeds 18&quot; in height. In other areas, the general policy is to make the pond site match adjacent ground cover and terrain as long as there is no interference with the function of the facility.</td>
<td>When mowing is needed, grass/ground cover should be mowed to 4&quot; in height.</td>
<td>Twice per year.</td>
</tr>
<tr>
<td></td>
<td>Rodent holes</td>
<td>Any evidence of rodent holes, if facility is acting as a dam or berm, or any evidence of water piping through dam or berm via rodent holes.</td>
<td>Rodents destroyed and dam or berm repaired. (Coordination with Bremerton Kitsap County Health District.)</td>
<td>Twice per year.</td>
</tr>
<tr>
<td></td>
<td>Insects</td>
<td>When insects such as wasps and hornets interfere with maintenance activities.</td>
<td>Insects destroyed or removed from site.</td>
<td>Twice per year.</td>
</tr>
<tr>
<td></td>
<td>Tree growth</td>
<td>Tree growth does not allow maintenance access or interferes with maintenance activity (i.e. slope mowing, silt removal, vactoring or equipment movement). If trees are not interfering with access, leave trees.</td>
<td>Trees do not hinder maintenance activities. Selectively cultivate trees such as alders for firewood.</td>
<td>Twice per year.</td>
</tr>
<tr>
<td></td>
<td>Side slopes of pond Erosion</td>
<td>Eroded damage where cause of damage is still present or where there is potential for continued erosion.</td>
<td>Slopes should be stabilized by using appropriate erosion control measure(s); e.g. rock reinforcement, planting of grass, compaction, etc.</td>
<td>Twice per year.</td>
</tr>
<tr>
<td>MAINTENANCE COMPONENT</td>
<td>DEFECT</td>
<td>CONDITIONS WHEN MAINTENANCE IS NEEDED</td>
<td>RESULTS EXPECTED WHEN MAINTENANCE IS PERFORMED</td>
<td>SCHEDULED FREQUENCY OF MAINTENANCE/INSPECTION</td>
</tr>
<tr>
<td>-----------------------</td>
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<td>----------------------------------------------</td>
</tr>
<tr>
<td>Storage volume</td>
<td>Sediment</td>
<td>Accumulated sediment that exceeds 10% of the design storm depth.</td>
<td>Sediment cleaned out to designed pond shape and depth; pond re-seeded if necessary to control erosion.</td>
<td>Twice per year.</td>
</tr>
<tr>
<td>Pond dikes</td>
<td>Settlements</td>
<td>Any part of dike which has settled 4&quot; lower than the design elevation.</td>
<td>Dike should be built back to the design elevation.</td>
<td>Twice per year.</td>
</tr>
<tr>
<td>Emergency overflow/ spillway</td>
<td>Rock missing</td>
<td>Only one layer of rock exists above native soil in area five sq. ft. or larger, or any exposure of native soils.</td>
<td>Replace rocks to design standards.</td>
<td>Twice per year.</td>
</tr>
<tr>
<td></td>
<td>Does not control storm flow</td>
<td>Emergency overflow or spillway is not large enough to handle heavy rainstorms.</td>
<td>Increase capacity of overflow so that there is no danger of flood damage to downstream property. Reevaluate design and enlarge storage, adjust control structure, etc.</td>
<td>Twice per year.</td>
</tr>
<tr>
<td>Debris barrier-general</td>
<td>Trash &amp; debris</td>
<td>Trash or debris that is plugging more than 20% of the openings in the barrier.</td>
<td>Barrier clear to receive capacity flow.</td>
<td>Twice per year (typ)</td>
</tr>
<tr>
<td>Debris barrier-metal</td>
<td>Damaged/missing bars</td>
<td>Bars are bent out of shape more than 3&quot;.</td>
<td>Bars in place with no bends more than 3/4&quot;.</td>
<td>Twice per year</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bars are missing or entire barrier is missing.</td>
<td>Bars in place according to design.</td>
<td>Twice per year</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bars are loose and rust is causing 50% deterioration to any part of barrier.</td>
<td>Repair or replace barrier to design standard.</td>
<td>Twice per year</td>
</tr>
</tbody>
</table>

B. CLOSED DETENTION SYSTEMS (TANKS/VAULTS)

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>Plugged air vents</td>
<td>½ of the end area of a vent is blocked at any point with debris and sediment.</td>
<td>Vents free of debris and sediment.</td>
<td>Twice per year.</td>
</tr>
<tr>
<td>Debris &amp; sediment</td>
<td>Accumulated sediment depth exceeds 10% of the storage depth or ½ length of storage vault or any point depth exceeds 15% of storage depth.</td>
<td>Sediment cleaned out.</td>
<td>Twice per year.</td>
</tr>
<tr>
<td>Gaps between tank/pipe sections</td>
<td>Any crack allowing material to be transported into facility.</td>
<td>All gaps between tank/pipe sections are sealed.</td>
<td>Twice per year</td>
</tr>
<tr>
<td>Manhole</td>
<td>Cover not in place</td>
<td>Cover is missing or only partially in place. Any open manhole requires a cover.</td>
<td>Manhole is closed.</td>
</tr>
<tr>
<td>MAINTENANCE COMPONENT</td>
<td>DEFECT</td>
<td>CONDITIONS WHEN MAINTENANCE IS NEEDED</td>
<td>RESULTS EXPECTED WHEN MAINTENANCE IS PERFORMED</td>
</tr>
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</tr>
<tr>
<td>C. CONTROL STRUCTURES</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control structure or manhole</td>
<td>Ladder rungs unsafe</td>
<td>Ladder is unsafe due to missing rungs, misalignment, rust or cracks.</td>
<td>Ladder meets with design standards and allows maintenance persons safe access.</td>
</tr>
<tr>
<td></td>
<td>Trash &amp; debris (includes sediment)</td>
<td>Distance between debris build-up and bottom of orifice plate is less than 1 1/2 feet.</td>
<td>All trash &amp; debris removed.</td>
</tr>
<tr>
<td>Damage to outlet structure</td>
<td>Structure is not securely attached to manhole wall and outlet pipe.</td>
<td>Structure is securely attached to wall and outlet pipe.</td>
<td>Structure is plumb.</td>
</tr>
<tr>
<td></td>
<td>Structure is out of plumb more than 6&quot;.</td>
<td>Connections to outlet pipe are not watertight and show signs of rust.</td>
<td>Connections to outlet pipe are watertight; structure repaired or replaced and works as designed.</td>
</tr>
<tr>
<td>Cleanout gate damaged/missing</td>
<td>Cleanout gate is not watertight or is missing.</td>
<td></td>
<td>Gate is watertight and works as designed.</td>
</tr>
<tr>
<td>Orifice plate damaged/missing</td>
<td>Control device is not working, out of place, or bent orifice plate.</td>
<td>Control device is in place and orifice plate works as designed.</td>
<td></td>
</tr>
<tr>
<td>D. FENCING</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>General</td>
<td>Missing or broken parts</td>
<td>Any defect in the fence that permits easy entry to a facility.</td>
<td>Parts in place to provide adequate security.</td>
</tr>
<tr>
<td></td>
<td>Parts broken or missing that can be seen by the public that are below the appearance standards of the neighborhood.</td>
<td>Broken or missing parts replaced to conform to the standards of the neighborhood.</td>
<td></td>
</tr>
<tr>
<td>Erosion</td>
<td>Erosion more than 4&quot; high and 12-18&quot; wide permitting an opening under a fence.</td>
<td>No opening under the fence that exceeds 4&quot; in height.</td>
<td></td>
</tr>
<tr>
<td>Damaged or missing parts</td>
<td>Any part of fence (including posts, top rails, and fabric) more than 1 ft out of design alignment.</td>
<td>Fence is aligned and meets design standards.</td>
<td></td>
</tr>
<tr>
<td>MAINTENANCE COMPONENT</td>
<td>DEFECT</td>
<td>CONDITIONS WHEN MAINTENANCE IS NEEDED</td>
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<tr>
<td></td>
<td></td>
<td>Missing or loose tension wire.</td>
<td>Tension wire in place and holding fabric.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Extension arm missing, broken, or bent out of shape more than 1 1/4&quot;.</td>
<td>Extension arm in place with no bends larger than 3/4&quot;.</td>
</tr>
<tr>
<td>Deteriorated paint or protective coating</td>
<td>Part or parts that have a rusting or scaling condition that has affected structural adequacy.</td>
<td>Structurally adequate posts or parts with a uniform protective coating.</td>
<td>Quarterly</td>
</tr>
<tr>
<td>Openings/holes</td>
<td></td>
<td>Openings in fabric are such that an 8&quot; diameter ball could fit through (intent is to prevent small children from entering).</td>
<td>No openings in fence.</td>
</tr>
<tr>
<td>Warning signs</td>
<td></td>
<td>Missing, loose or vandalized warning signs.</td>
<td>Signs in place and readable.</td>
</tr>
<tr>
<td>Gates</td>
<td>Damaged or missing parts</td>
<td>Missing gate or locking device.</td>
<td>Gates and locking devices in place.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Broken or missing hinges such that gate cannot be easily opened and closed.</td>
<td>Hinges intact and lubed. Gate is working freely.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Gate is out of plumb more than 6&quot; and more than 1 ft. out of design alignment.</td>
<td>Gate is aligned and plumb.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Missing stretcher bar, stretcher bands, and ties.</td>
<td>Stretcher bar, bands, and ties in place.</td>
</tr>
</tbody>
</table>

**E. ACCESS ROADS/EASEMENTS**

<table>
<thead>
<tr>
<th>General</th>
<th>Trash &amp; debris</th>
<th>Trash &amp; debris exceeds 1 c.f. per 1,000 sq. ft., i.e. trash and debris would fill up one standard size office garbage can.</th>
<th>Trash &amp; debris cleared from site.</th>
<th>Twice per year</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Blocked roadway</td>
<td>Any obstructions restricting the access to a road surface to less than 15 ft.</td>
<td>Obstruction removed to allow at least 15 ft. access.</td>
<td>Twice per year</td>
</tr>
<tr>
<td>Road Surface</td>
<td>Settlement, potholes, mush spots, ruts.</td>
<td>When any surface defect exceeds 6&quot; in depth and 6 sq. ft in area. In general, any surface defect which hinders or prevents maintenance access.</td>
<td>Road surface uniformly smooth with no evidence of settlement, potholes, mush spots, or ruts.</td>
<td>Twice per year</td>
</tr>
<tr>
<td>MAINTENANCE COMPONENT</td>
<td>DEFECT</td>
<td>CONDITIONS WHEN MAINTENANCE IS NEEDED</td>
<td>RESULTS EXPECTED WHEN MAINTENANCE IS PERFORMED</td>
<td>SCHEDULED FREQUENCY OF MAINTENANCE/INSPECTION</td>
</tr>
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</tr>
<tr>
<td>Vegetation in road right-of-way</td>
<td>Weeds growing in the road surface that are more than 6&quot; tall and less than 6&quot; apart within a 400 sq. ft. area.</td>
<td>Road surface free of weeds taller than 2&quot;.</td>
<td>Twice per year</td>
<td></td>
</tr>
<tr>
<td>Shoulders &amp; ditches</td>
<td>Erosion damage</td>
<td>Erosion within 1 ft. of the roadway more than 8&quot; wide and 6&quot; deep.</td>
<td>Shoulder free of erosion and matching the surrounding road.</td>
<td>Twice per year</td>
</tr>
<tr>
<td><strong>F. BIOFILTRATION SWALES</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>General</td>
<td>Trash &amp; debris</td>
<td>See that trash &amp; debris is removed in order to keep biofilters attractive in appearance and to prevent loss of vegetation.</td>
<td>Trash &amp; debris cleared from swale.</td>
<td>Inspect bio-filters periodically, especially after periods of heavy runoff. Remove sediments, fertilize, and reseed as necessary. Be careful to avoid introducing fertilizers to receiving waters or ground water.</td>
</tr>
<tr>
<td></td>
<td>Unmowed grass</td>
<td>Groomed biofilters must be mowed regularly during the summer months to promote growth and pollutant uptake. Be sure not to cut below the design flow. Remove cuttings promptly, and dispose in a way so that no pollutants can enter receiving waters.</td>
<td>Grass is mowed thereby allowing it to function within its intended capacity as a pollutant remover.</td>
<td>Periodically</td>
</tr>
<tr>
<td></td>
<td>Grass/vegetation growth</td>
<td>If the objective is prevention of nutrient transport, mow grasses or cut emergent wetland-type plants to a low height at the end of the growing season. For other pollution control objectives, let the plants stand at a height exceeding the design water depth by at least 2&quot; at the end of the growing season. Vegetation should at no time exceed 8&quot; in order to avoid plugging inlets.</td>
<td>Grasses and emergent wetland vegetation are maintained to allow them to function in their intended roles.</td>
<td>Periodically</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Clean curb cuts when soil and vegetation buildup interferes with flow introduction.</td>
<td>All vegetation is removed allowing water to flow through the swale unimpeded.</td>
<td>Periodically</td>
</tr>
<tr>
<td>MAINTENANCE COMPONENT</td>
<td>DEFECT</td>
<td>CONDITIONS WHEN MAINTENANCE IS NEEDED</td>
<td>RESULTS EXPECTED WHEN MAINTENANCE IS PERFORMED</td>
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<td>-----------------------------------------------</td>
</tr>
<tr>
<td>Sediment accumulation</td>
<td>Remove sediments during summer months when they build up to 3-4&quot; at any spot, cover biofilter vegetation, or otherwise interfere with biofilter operation. Use of equipment like a Ditch Master is strongly recommended over a backhoe or dragline. If the equipment leaves bare spots, reseed immediately.</td>
<td>All sediment is removed and swale is restored to its design depth.</td>
<td>Periodically</td>
<td></td>
</tr>
<tr>
<td>Roadside ditch cleaning</td>
<td>Base roadside ditch cleaning on an analysis of hydraulic necessity. Use a technique such as the Ditch Master to remove only the amount of sediment necessary to restore needed hydraulic capacity leaving vegetative plant parts in place to the maximum extent possible.</td>
<td>Sediment is removed from roadside ditch allowing it to convey its design hydraulic capacity.</td>
<td>Periodically</td>
<td></td>
</tr>
</tbody>
</table>

**G. OIL/WATER SEPARATORS**

<p>| Spill control o/w separators | Structure is not containing oil spills and is ejecting resident oil back into stormwater system. | After each spill event. | O/W separator is retaining small oil spills and is not ejecting oil into the stormwater system. | Quarterly and after each spill event. |
| API o/w separators | Structure is not separating oil and is ejecting resident oil back into stormwater system. | When oil accumulation exceeds ½&quot; in the first chamber or any visible oil in the second or third chamber. When the sediment level reaches 6&quot; it should be removed. | The structure is separating and retaining oil found in the stormwater system. | Quarterly and after each spill event. |</p>
<table>
<thead>
<tr>
<th>MAINTENANCE COMPONENT</th>
<th>DEFECT</th>
<th>CONDITIONS WHEN MAINTENANCE IS NEEDED</th>
<th>RESULTS EXPECTED WHEN MAINTENANCE IS PERFORMED</th>
<th>SCHEDULED FREQUENCY OF MAINTENANCE/INSPECTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coalescing plate separators</td>
<td>Structure is not separating oil and is ejecting resident oil back into stormwater system.</td>
<td>When oil accumulation exceeds ½&quot; in the first chamber or any visible oil in the second or third chamber. When the sediment level reaches 6&quot; it should be removed.</td>
<td>The structure is separating and retaining oil found in the stormwater system.</td>
<td>Quarterly and after each spill event.</td>
</tr>
</tbody>
</table>