

# BMP T5.15: Permeable Pavements

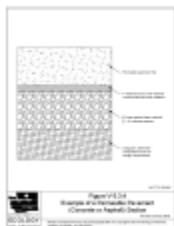
## *Purpose and Definition*

Pavement for vehicular and pedestrian travel occupies roughly twice the space of buildings. Stormwater from vehicular pavement can contain significant levels of solids, heavy metals, and hydrocarbon pollutants. Both pedestrian and vehicular pavements also contribute to increased peak flow durations and associated physical habitat degradation of streams and wetlands. Optimum management of stormwater quality and quantity from paved surfaces is, therefore, critical for improving fresh and marine water conditions in Puget Sound.

The general categories of permeable paving systems include:

- ***Porous hot or warm-mix asphalt pavement*** (see [Figure V-5.3.4 Example of a Permeable Pavement \(Concrete or Asphalt\) Section](#)) is a flexible pavement similar to standard asphalt that uses a bituminous binder to adhere aggregate together. However, the fine material (sand and finer) is reduced or eliminated and, as a result, voids form between the aggregate in the pavement surface and allow water to infiltrate.
- ***Pervious Portland cement concrete*** (see [Figure V-5.3.4 Example of a Permeable Pavement \(Concrete or Asphalt\) Section](#)) is a rigid pavement similar to conventional concrete that uses a cementitious material to bind aggregate together. However, the fine aggregate (sand) component is reduced or eliminated in the gradation and, as a result, voids form between the aggregate in the pavement surface and allow water to infiltrate.

### **Figure V-5.3.4 Example of a Permeable Pavement (Concrete or Asphalt) Section**

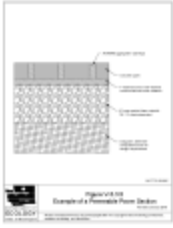


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- ***Permeable interlocking concrete pavements (PICP) and aggregate pavers.*** (see [Figure V-5.3.5 Example of a Permeable Paver Section](#)) PICPs are solid, precast, manufactured modular units. The solid pavers are (impervious) high-strength Portland cement concrete manufactured with specialized production equipment. Pavements constructed with these units create joints that are filled with permeable aggregates and installed on an open-graded aggregate bedding course. Aggregate pavers (sometimes called pervious pavers) are a different class of pavers from PICP. These include modular precast paving units made with similar sized aggregates bound together with Portland cement concrete with high-strength epoxy or other adhesives. Like PICP, the joints or

openings in the units are filled with open-graded aggregate and placed on an open-graded aggregate bedding course. Aggregate pavers are intended for pedestrian use only.

### **Figure V-5.3.5 Example of a Permeable Paver Section**



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- **Grid systems** include those made of concrete or plastic. Concrete units are precast in a manufacturing facility, packaged and shipped to the site for installation. Plastic grids typically are delivered to the site in rolls or sections. The openings in both grid types are filled with topsoil and grass or permeable aggregate. Plastic grid sections connect together and are pinned into a dense-graded base, or are eventually held in place by the grass root structure. Both systems can be installed on an open-graded aggregate base as well as a dense-graded aggregate base.

### **Applications and Limitations**

Permeable paving surfaces are an important integrated management practice within the LID approach and can be designed to accommodate pedestrian, bicycle and auto traffic while allowing infiltration, treatment and storage of stormwater.

Permeable pavements are appropriate in many applications where traditionally impermeable pavements have been used. Typical applications for permeable paving include parking lots, sidewalks, pedestrian and bike trails, driveways, residential access roads, and emergency and facility maintenance roads.

#### Limitations:

- No run-on from pervious surfaces is preferred. If runoff comes from minor or incidental pervious areas, those areas must be fully stabilized.
- Unless the pavement, base course, and subgrade have been designed to accept runoff from adjacent impervious surfaces, 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 the permeable pavement area is > the impervious pavement area.
- Soils must not be tracked onto the wear layer or the base course during construction.

#### **Infeasibility Criteria:**

These are conditions that make permeable pavement not required. If a project proponent wishes to use permeable pavement - though not required to because of these feasibility criteria - they may propose a functional design to the local government.

These criteria also apply to impervious pavements that would employ stormwater collection from the surface of impervious pavement with redistribution below the pavement.

Citation of any of the following infeasibility criteria must be based on an evaluation of site-specific conditions and a written recommendation from an appropriate licensed professional (e.g, engineer, geologist, hydrogeologist)

- Where professional geotechnical evaluation recommends infiltration not be used due to reasonable concerns about erosion, slope failure, or down gradient flooding.
- Within an area whose ground water drains into an erosion hazard, or landslide hazard area.
- Where infiltrating and ponded water below new permeable pavement area would compromise adjacent impervious pavements.
- Where infiltrating water below a new permeable pavement area would threaten existing below grade basements.
- Where infiltrating water would threaten shoreline structures such as bulkheads.
- Down slope of steep, erosion prone areas that are likely to deliver sediment.
- Where fill soils are used that can become unstable when saturated.
- Excessively steep slopes where water within the aggregate base layer or at the sub-grade surface cannot be controlled by detention structures and may cause erosion and structural failure, or where surface runoff velocities may preclude adequate infiltration at the pavement surface.
- Where permeable pavements can not provide sufficient strength to support heavy loads at industrial facilities such as ports.
- Where installation of permeable pavement would threaten the safety or reliability of pre-existing underground utilities, pre-existing underground storage tanks, or pre-existing road sub-grades.

The following criteria can be cited as reasons for a finding of infeasibility without further justification (though some require professional services to make the observation):

- Within an area designated as an erosion hazard, or landslide hazard.

- Within 50 feet from the top of slopes that are greater than 20%.
- For properties with known soil or ground water contamination (typically federal Superfund sites or state cleanup sites under the Model Toxics Control Act (MTCA)):
  - Within 100 feet of an area known to have deep soil contamination;
  - Where ground water modeling indicates infiltration will likely increase or change the direction of the migration of pollutants in the ground water;
  - Wherever surface soils have been found to be contaminated unless those soils are removed within 10 horizontal feet from the infiltration area;
  - Any area where these facilities are prohibited by an approved cleanup plan under the state Model Toxics Control Act or Federal Superfund Law, or an environmental covenant under [Chapter 64.70 RCW](#).
- Within 100 feet of a closed or active landfill.
- Within 100 feet of a drinking water well, or a spring used for drinking water supply, if the pavement is a pollution-generating surface.
- Within 10 feet of a small on-site sewage disposal drainfield, including reserve areas, and grey water reuse systems. For setbacks from a “large on-site sewage disposal system”, see [Chapter 246-272B WAC](#).
- Within 10 feet of any underground storage tank and connecting underground pipes, regardless of tank size. As used in these criteria, an underground storage tank means any tank used to store petroleum products, chemicals, or liquid hazardous wastes of which 10% or more of the storage volume (including volume in the connecting piping system) is beneath the ground surface.
- At multi-level parking garages, and over culverts and bridges.
- Where the site design cannot avoid putting pavement in areas likely to have long-term excessive sediment deposition after construction (e.g., construction and landscaping material yards).
- Where the site cannot reasonably be designed to have a porous asphalt surface at less than 5 percent slope, or a pervious concrete surface at less than 10 percent slope, or a permeable interlocking concrete pavement surface (where appropriate) at less than 12 percent slope. Grid systems upper slope limit can range from 6 to 12 percent; check with manufacturer and local supplier.

- Where the native soils below a pollution-generating permeable pavement (e.g., road or parking lot) do not meet the soil suitability criteria for providing treatment. See SSC-6 in [III-3.3.7 Site Suitability Criteria \(SSC\)](#). Note: In these instances, the local government has the option of requiring a six-inch layer of media meeting the soil suitability criteria or the sand filter specification as a condition of construction.
- Where seasonal high ground water or an underlying impermeable/low permeable layer would create saturated conditions within one foot of the bottom of the lowest gravel base course.
- Where underlying soils are unsuitable for supporting traffic loads when saturated. Soils meeting a California Bearing Ratio of 5% are considered suitable for residential access roads.
- Where appropriate field testing indicates soils have a measured (a.k.a., initial) native soil saturated hydraulic conductivity less than 0.3 inches per hour. (Note: In these instances, unless other infeasibility restrictions apply, roads and parking lots may be built with an underdrain, preferably elevated within the base course, if flow control benefits are desired.)
- Roads that receive more than very low traffic volumes, and areas having more than very low truck traffic. Roads with a projected average daily traffic volume of 400 vehicles or less are very low volume roads (AASHTO, 2001)(U.S. Dept. of Transportation, 2013). Areas with very low truck traffic volumes are roads and other areas not subject to through truck traffic but may receive up to weekly use by utility trucks (e.g., garbage, recycling), daily school bus use, and multiple daily use by pick-up trucks, mail/parcel delivery trucks, and maintenance vehicles. Note: This infeasibility criterion does not extend to sidewalks and other non-traffic bearing surfaces.
- Where replacing existing impervious surfaces unless the existing surface is a non-pollution generating surface over an outwash soil with a saturated hydraulic conductivity of four inches per hour or greater.
- At sites defined as “high use sites” in Volume I of this manual.
- In areas with “industrial activity” as identified in 40 CFR 122.26(b)(14).
- Where the risk of concentrated pollutant spills is more likely such as gas stations, truck stops, and industrial chemical storage sites.
- Where routine, heavy applications of sand occur in frequent snow zones to maintain traction during weeks of snow and ice accumulation.

A local government may designate geographic areas within which permeable pavement, or certain types of permeable pavement, may be designated as infeasible due to year-round, seasonal or periodic high groundwater conditions, or due to inadequate infiltration rates. Designations must be based upon a

preponderance of field data, collected within the area of concern, that indicate a high likelihood of failure to achieve the minimum groundwater clearance or infiltration rates identified in the above infeasibility criteria. The local government must develop a technical report, and make it available upon request by the Dept. of Ecology. The technical report must be authored by (a) professional(s) with appropriate expertise (e.g., registered engineer, geologist, hydrogeologist, or certified soil scientist), and document the location and pertinent values/observations of data that were used to recommend the designation and boundaries for the geographic area. The types of pertinent data include, but are not limited to:

- Standing water heights or evidence of recent saturated conditions in observation wells, test pits, test holes, and well logs.
- Observations of areal extent and time of surface ponding, including local government or professional observations of high water tables, frequent or long durations of standing water, springs, wetlands, and/or frequent flooding.
- Results of infiltration tests

In addition, a local government can map areas that meet a specific infeasibility criterion listed above provided they have an adequate data basis. Criteria that are most amenable to mapping are:

- Where land for bioretention is within an area designated by the local government as an erosion hazard, or landslide hazard
- Within 50 feet from the top of slopes that are greater than 20% and over 10 feet vertical relief
- Within 100 feet of a closed or active landfill

## ***Design Guidelines***

Ecology has listed below the critical design criteria you must consider when designing permeable pavement. Local governments can adopt alternative design criteria, as long as it does not conflict with the criteria listed below. For modeling guidance of permeable pavements, refer to [Appendix III-C: Washington State Department of Ecology Low Impact Development Flow Modeling Guidance](#), and the 2012 WWHM User Manual.

You can find additional guidance for permeable pavement design in the *LID Technical Guidance Manual for Puget Sound (2012)*.

Note that the *LID Technical Guidance Manual for Puget Sound (2012)* is for additional informational purposes only. You must follow the guidance within this manual if there are any discrepancies between this manual and the *LID Technical Guidance Manual for Puget Sound (2012)*.



## Subgrade

- Compact the subgrade to the minimum necessary for structural stability. Two guidelines currently used to specify subgrade compaction are “firm and unyielding” (qualitative), and 90- 92% Standard Proctor (quantitative). Do not allow heavy compaction due to heavy equipment operation. The subgrade should not be subject to truck traffic.
- To prevent compaction when installing the aggregate base, the following steps (back-dumping) should be followed: 1) the aggregate base is dumped onto the subgrade from the edge of the installation and aggregate is then pushed out onto the subgrade; 2) trucks then dump subsequent loads from on top of the aggregate base as the installation progresses.
- Use on soil types A through C.

## 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

- Local governments should adopt their own minimum base material requirements as they see necessary for support of flexible pavements. Many design combinations are possible. The material must be free draining. The municipality should determine and publish estimates of the void space for each standard base material allowed in their jurisdiction.
- To increase infiltration, improve flow attenuation and reduce structural problems associated with subgrade erosion on slopes, impermeable check dams may be placed on the subgrade and below the pavement surface (See [Figure V-5.3.6 Example of a Check Dam Along a Sloped Section of Permeable Pavement](#)). Check dams should have an overflow drain invert placed at the maximum ponding depth. The distance between berms will vary depending on slope, flow control goals and cost.

### **Figure V-5.3.6 Example of a Check Dam Along a Sloped Section of Permeable Pavement**



[2014 Figure V-5.3.6 pdf download](#)

## Wearing layer

- For all surface types, a minimum initial infiltration rate of 20 inches per hour is necessary. To improve the probability of long-term performance, significantly higher initial infiltration rates are desirable.
- **Porous Asphalt:** Products must have adequate void spaces through which water can infiltrate. A void space within the range of 16 – 25% is typical.
- **Pervious Concrete:** Products must have adequate void spaces through which water can infiltrate. A void space within the range of 15 – 35% is typical..
- **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.
- **Permeable Interlocking Concrete Pavement and Aggregate Pavers:** Pavement joints should be filled with No. 8, 89 or 9 stone.

## 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 benefit.

## Underdrains

Note that if an underdrain is placed at or near the bottom of the aggregate base in a permeable pavement design, the permeable pavement is no longer considered an LID BMP and cannot be used to satisfy [I-2.5.5 Minimum Requirement #5: On-site Stormwater Management](#). However, designs utilizing an underdrain that is elevated within the aggregate base course to protect the pavement wearing course from saturation is considered an LID BMP and can be used to satisfy [I-2.5.5 Minimum Requirement #5: On-site Stormwater Management](#). See [Appendix III-C: Washington State Department of Ecology Low Impact Development Flow Modeling Guidance](#) and the WWHM Users Manual for guidance in modeling permeable pavements with underdrains.

## 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 20 inches per hour minimum rate. Use of ASTM C1701 is also recommended.

### ***Stormwater-related Design Procedures***

See [III-3.4 Stormwater-related Site Procedures and Design Guidance for Bioretention and Permeable Pavement](#) for more specific guidance regarding required field testing, assignment of infiltration rate correction factors, project submission requirements, and modeling.

### ***Runoff Model Representation***

See [Appendix III-C: Washington State Department of Ecology Low Impact Development Flow Modeling Guidance](#) for runoff modeling guidance under WWHM3 and under WWHM 2012.

### ***Maintenance***

Please see [Table V-4.5.2\(22\) Maintenance Standards - Permeable Pavement](#).

Maintenance recommendations for all facilities:

- Erosion and introduction of sediment from surrounding land uses should be strictly controlled after construction by amending exposed soil with compost and mulch, planting exposed areas as soon as possible, and armoring outfall areas.
- Surrounding landscaped areas should be inspected regularly and possible sediment sources controlled immediately.
- Installations can be monitored for adequate or designed minimum infiltration rates by observing drainage immediately after heavier rainstorms for standing water or infiltration tests using ASTM C1701.
- Clean permeable pavement surfaces to maintain infiltration capacity at least once or twice annually following recommendations below.
- Utility cuts should be backfilled with the same aggregate base used under the permeable paving to allow continued conveyance of stormwater through the base, and to prevent migration of fines from the standard base aggregate to the more open graded permeable base material (Diniz, 1980).
- Ice build up on permeable pavement is reduced and the surface becomes free and clear more rapidly compared to conventional pavement. For western Washington, deicing and sand application may be reduced or eliminated and the permeable pavement installation should be

assessed during winter months and the winter traction program developed from those observations. Vacuum and sweeping frequency will likely be required more often if sand is applied.

#### Porous asphalt and pervious concrete

- Clean surfaces using suction, sweeping with suction or high-pressure wash and suction (sweeping alone is minimally effective). Hand held pressure washers are effective for cleaning void spaces and appropriate for smaller areas such as sidewalks.
- Small utility cuts can be repaired with conventional asphalt or concrete if small batches of permeable material are not available or are too expensive.

#### Permeable pavers

- ICPI recommends cleaning if the measured infiltration rate falls below 10 in/hr.
- Use sweeping with suction when surface and debris are dry 1-2 times annually (see next bullet for exception). Apply vacuum to a paver test section and adjust settings to remove all visible sediment without excess uptake of aggregate from paver openings or joints. If necessary replace No 8, 89 or 9 stone to specified depth within the paver openings. Washing or power washing should not be used to remove debris and sediment in the openings between the pavers (Smith, 2000).
- For badly clogged installations, wet the surface and vacuumed aggregate to a depth that removes all visible fine sediment and replace with clean aggregate.
- If necessary use No 8, 89 or 9 stone for winter traction rather than sand (sand will accelerate clogging).
- Pavers can be removed individually and replaced when utility work is complete.
- Replace broken pavers as necessary to prevent structural instability in the surface.
- The structure of the top edge of the paver blocks reduces chipping from snowplows. For additional protection, skids on the corner of plow blades are recommended.
- For a model maintenance agreement see “Permeable Interlocking Concrete Pavements” (Smith, 2011).

#### Plastic or Concrete grid systems

- Remove and replace top course aggregate if clogged with sediment or contaminated (vacuum trucks for stormwater collection basins can be used to remove aggregate).

- Remove and replace grid segments where three or more adjacent rings are broken or damaged.
- Replenish aggregate material in grid as needed.
- Snowplows should use skids to elevate blades slightly above the gravel surface to prevent loss of top course aggregate and damage to plastic grid.
- For grass installations, use normal turf maintenance procedures except do not aerate. Use very slow release fertilizers if needed.

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*Washington State Department of Ecology*

[2012 Stormwater Management Manual for Western Washington, as Amended in December 2014 \(The 2014 SWMMWW\)](#)