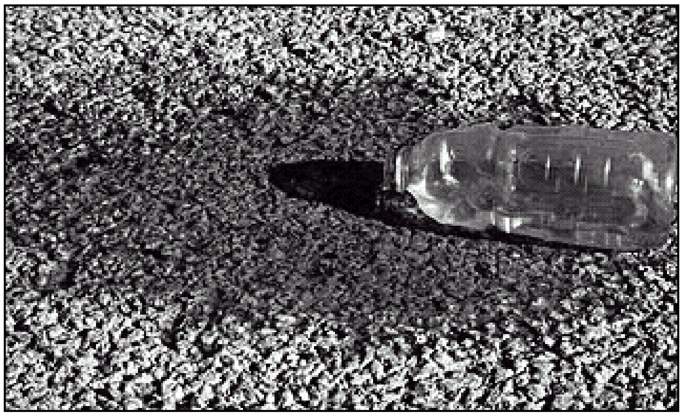
4.3.12 Porous Pavement

General Application Water Quality BMP



Description: Infiltration practices that are alternatives to traditional asphalt and concrete surfaces. Stormwater runoff is infiltrated into the ground through a permeable layer of pavement and is naturally filtered.

KEY CONSIDERATIONS

DESIGN GUIDELINES:

- Design considerations are similar to any paved area (soil properties, load-bearing design, hydrologic design of pavement and subgrade).
- Soil infiltration rate of 0.5 in/hr or greater is required if no underdrain is present.
- Soil groups "D" and "C" typically require and underdrain.
- Not appropriate for heavy or high traffic areas.
- Not appropriate as a water quality treatment BMP for drainage discharged from other areas.

ADVANTAGES / BENEFITS:

- Reduces runoff volume, attenuates peak runoff rate and outflow.
- Can be used as pretreatment for other BMPs for pollutants other than TSS.
- High level of pollutant removal for pollutants other than TSS.

DISADVANTAGES / LIMITATIONS:

- Sediment-laden runoff can clog porous pavement causing failure.
- Subgrade cannot be overly compacted.
- Construction must be sequenced to avoid compaction and clogging of pavement.

MAINTENANCE REQUIREMENTS:

- Vacuum to increase porous pavement life and avoid clogging.
- Ensure that contributing area is clear of debris and areas of erosion.

STORMWATER MANAGEMENT SUITABILITY

Stormwater Quality:	**Yes**
Channel Protection:	**No**
Detention/Retention:	**No**

Accepts hotspot runoff: *Yes, but does not provide stormwater treatment.*

COST CONSIDERATIONS

Land Requirement:	**Low**
Capital Cost:	**Med - High**
Maintenance Burden:	**Med**

LAND USE APPLICABILITY

Residential/Subdivision Use:	**Yes**
High Density/Ultra Urban Use:	✷
Commercial/Industrial Use:	✷

✷ in certain situations

POLLUTANT REMOVAL

Total Suspended Solids:	**0%**

(Porous pavement is not considered a water quality removal BMP, but is used to reduce impervious area and therefore reduces the volume required for treatment.)

4.3.12.1 General Description

Porous pavement is a paved concrete or asphalt driving surface that permits the infiltration of water through the pavement and into the underlying soil. When considering the post-development stormwater runoff from a site, porous pavement is a best management practice (BMP) that allows a developed land surface to "appear" more like undeveloped land – runoff volumes and peak discharges of stormwater runoff from a developed site with porous pavement will be less than on a site without porous pavement. Porous pavement is an excellent application to reduce the effective impervious area on a site, therefore, reducing the design volumes and peak discharges that must be controlled. This will allow a reduction in the cost of other stormwater infrastructure, a fact that may offset the greater placement cost somewhat. Porous pavement can also eliminate problems with standing water, provide for groundwater recharge, control erosion of streambeds and riverbanks, facilitate pollutant removal, reduce thermal pollution of receiving waters, and provide for a more aesthetically pleasing site. **Porous pavement is not a BMP that can be used to remove total suspended solids (TSS).**

There are two types of porous pavement: porous asphalt and pervious concrete. Porous asphalt pavement consists of open-graded coarse aggregate, bonded together by asphalt cement, with sufficient interconnected voids to make it highly permeable to water. Pervious concrete consists of a specially formulated mixture of Portland cement, uniform, open-graded coarse aggregate, and water. Pervious concrete has enough void space to allow rapid percolation of water through the pavement. The void space in pervious concrete is in the 15%-22% range compared to 3%-5% for conventional pavements. The permeable surface is placed over a layer of open-graded gravel and crushed stone. The void spaces in the stone act as a storage reservoir for runoff. Pervious concrete is considered to be more durable than porous asphalt and is thought to have a greater ability than pervious asphalt to maintain its porosity in hot weather.

Porous pavements are best applied in areas that experience low vehicular traffic including parking lots and overflow parking areas; portions of streets such as residential parking lanes; driveways; plazas; and pedestrian or golf cart paths. Porous pavements are not recommended, and will not be approved, for use on driving surfaces that experience high traffic volume, heavy loads, and sediment-laden traffic (e.g., construction areas, dump sites).

A drawback to porous pavement is the cost and complexity of it compared to conventional pavements. Porous pavement requires a very high level of construction workmanship to ensure that it functions as designed. Like any BMP, porous pavement can fail, either for use as a driving/parking surface or an impervious area reduction measure, when improperly designed, constructed, or used. Past failures of porous pavement have been attributed to poor design, inadequate construction techniques, soils with low permeability, heavy vehicular traffic, and poor maintenance (USEPA, 1999). This measure, if used, should be monitored and maintained over the life of the development.

Porous pavement is designed primarily for impervious area reduction and the subsequent reduction in stormwater treatment volumes and peak discharges, particularly for smaller storm events. For some smaller sites, trenches can be designed to capture and infiltrate the water quality volume (WQv), and in some cases, the channel protection volume (CPv). Modifications or additions to the standard design presented in this section have been used to pass flows and volumes in excess of the WQv, or to increase storage capacity or treatment. These include:

- placing a perforated pipe near the top of the crushed stone reservoir to pass excess flows after the reservoir is filled;
- providing surface detention storage in a parking lot, adjacent swale, or detention basin with suitable overflow conveyance;
- connecting the stone reservoir layer to a stone filled trench;
- adding a sand layer and perforated pipe beneath the stone layer for filtration of the water quality volume; or,
- placing an underground detention tank or vault system beneath the layers.

Porous pavement has the positive characteristics of volume reduction due to infiltration, groundwater recharge, and an ability to blend into the normal urban landscape relatively unnoticed.

4.3.12.2 Stormwater Management Suitability

Water Quality (WQv)

Porous pavement is designed solely for impervious area reduction and water quality treatment of pollutants other than TSS. Porous pavements shall not be used for TSS removal. These pavements require some pretreatment BMP such as a filter strip for runoff entering the pavement to prevent clogging from sediment.

4.3.12.3 Pollutant Removal Capabilities

Porous pavement has a high removal of soluble pollutants, where they become trapped, absorbed or broken down in the underlying soil layers. However, due to the potential for clogging, porous pavement surfaces shall **not** be used for the removal of sediment or other particulate pollutants.

4.3.12.4 Application and Feasibility Criteria

Porous pavement is applicable only for use in low-traffic areas that do not encounter heavy loads and/or sediment-laden traffic or runoff, such as:

- parking pads in parking lots;
- overflow parking areas;
- residential driveways;
- residential street parking lanes;
- recreational trails;
- golf cart and pedestrian paths; and,
- emergency vehicle and fire access lanes.

4.3.12.5 Planning and Design Standards

The design standards for porous pavement are presented below. Design specifications developed by a commercial vendor for prefabricated proprietary systems can also be utilized, but must be approved where such specifications differ and/or are less stringent from the standards presented below. The local jurisdiction shall have the authority to require additional design conditions if deemed necessary.

A. CONSTRUCTION SEQUENCING

- Ideally, the construction of the porous pavement should take place after the construction site has been stabilized.
- In the event that the pavement is not constructed after site stabilization, care should be taken during construction to minimize the compaction of the soil in the area of the porous pavement and the deposition of sediments from disturbed, unstabilized areas.
- Diversion berms and erosion prevention and sediment controls shall be maintained around the porous pavement area during all phases of construction. No runoff or sediment shall enter the area prior to completion of construction and the complete stabilization of construction areas.
- Porous pavement shall not be used as a temporary sediment trap for construction activities.
- During and after excavation of the porous pavement area, all excavated materials shall be placed downstream, to prevent redeposition of the material during runoff events.

B. LOCATION AND SITING

- Suitable sites for porous pavement are limited to low traffic volume areas with a minimum soil infiltration rate of 0.5 in/hr without an underdrain system. Ideally, the soil should allow the entire runoff capture volume to be discharged from the porous pavement within 24 to 48 hours.

- Geotechnical testing of the proposed installation site is required to verify an acceptable infiltration rate.
- Porous pavement shall **not** be located:
  - Within four (4) feet above bedrock or the seasonally high water level;
  - Within 100 feet of a well;
  - Within ten (10) feet of a building foundation that is above the proposed porous pavement area or 100 feet from a building foundation that is below the proposed porous pavement location;
  - Within close proximity of sources of contaminants such as gas stations; and,
  - On slopes greater than 5%.
- Ideally, slopes should be flat or nearly flat to facilitate infiltration as opposed to runoff.
- The seasonally high water table or bedrock should be at least two feet below the bottom of the gravel layer if infiltration is to be relied on to remove the stored volume.
- Because porous pavement is not a stormwater control device, the area where the porous pavement is located should not receive stormwater runoff discharges from other areas. However, if that situation cannot be avoided, pretreatment of the discharges must be performed to remove sediment and other solids that can clog the porous pavement. Further, stormwater runoff discharging to the porous pavement area must flow into the area in a manner that will not cause damage to, or undermine, the porous pavement. Low velocity, unchannelized discharges are most favorable.
- Each porous pavement area shall be placed in an easement that is recorded with the deed. The easement shall be defined as the outer edge of the porous pavement.

C. PHYSICAL SPECIFICATIONS / GEOMETRY

Porous asphalt or pervious concrete for the top layer or surface of the porous pavement should be chosen depending on strength required due to traffic loads, infiltration needs, and other site constraints. However, the sub-layers are generally similar, consisting of four to five layers as shown in Figure 4-51. The aggregate reservoir layer can sometimes be avoided or minimized if the subgrade is sandy and if there is adequate time to infiltrate the water quality volume into the sandy soil without bypassing any of the water quality volume. Descriptions of each of the layers is presented below.

- *Porous Pavement Layer* – This layer consists of a porous mixture of concrete or asphalt or a modular pavement grid of plastic, concrete, or brick and an aggregate or a vegetation medium. This layer is usually 2 to 4 inches deep depending on required bearing strength, pavement design requirements, and manufacturer's specifications.
- *Reservoir Layer or Open Graded Base Material* – The reservoir gravel base layer consists of washed, bank-run gravel, 1.5 to 2.5-inches in diameter with a void space of about 40%. The depth of this layer depends on the desired storage volume, which is a function of the soil infiltration rate and void spaces, but typically ranges from two to four feet. The layer must have a minimum depth of nine inches. The layer shall be designed to drain completely in 48 hours. If the porous pavement area is being utilized for stormwater quality treatment (for pollutants other than sediment/TSS), then the area must be designed to store, at a minimum, the WQv. Aggregate contaminated with soil shall not be used for the reservoir layer.
- *Bottom Filter Layer* – In cases where infiltration needs to be increased, a 6-inch layer of sand or a 2-inch thick layer of 0.5-inch crushed stone can be installed. The layer must be completely flat to promote infiltration across the entire surface. This layer serves to stabilize the reservoir layer, to protect the underlying soil from compaction, and act as the interface between the reservoir layer and the filter fabric covering the underlying soil.
- A *Lateral Flow Barrier -* as shown in Figure 4-52 is recommended around the porous pavement area to prevent flow of water downstream and then surfacing at the toe of the porous pavement installation. If the porous pavement area is large enough, it may be divided into cells with cut-off barriers having a maximum distance (L_{max}) between them that shall not exceed:

Equation 4.3.12.1

$$L_{\max} = \frac{D}{1.5S}$$

where: L_{max} = Maximum distance between cut-off membrane normal to the flow (ft)
S = Slope of the reservoir layer (ft/ft)
D = Depth of reservoir layer (ft)

Figure 4-51. Porous Pavement Layers

(Source: Urban Drainage and Flood Control District, 2004)

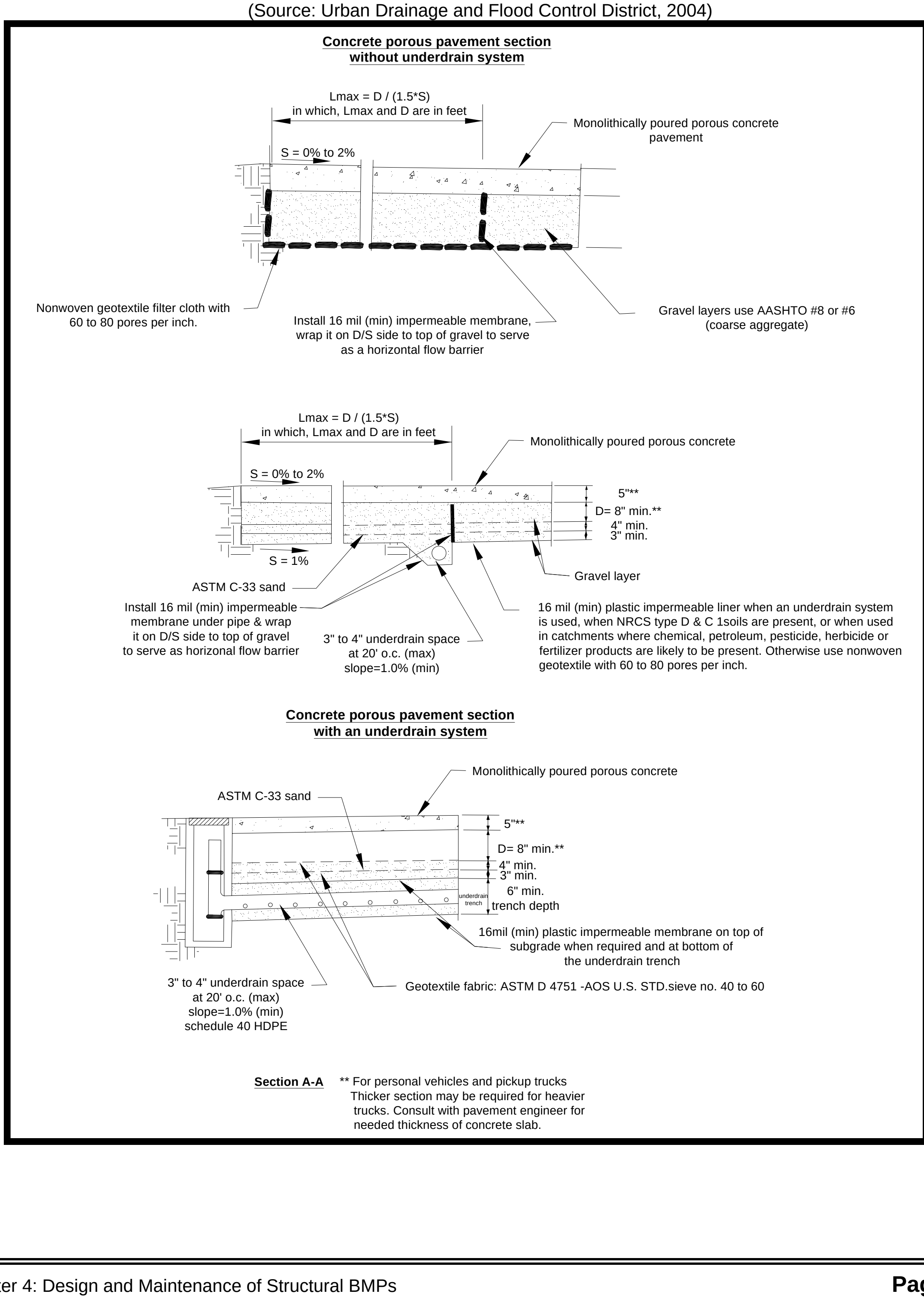
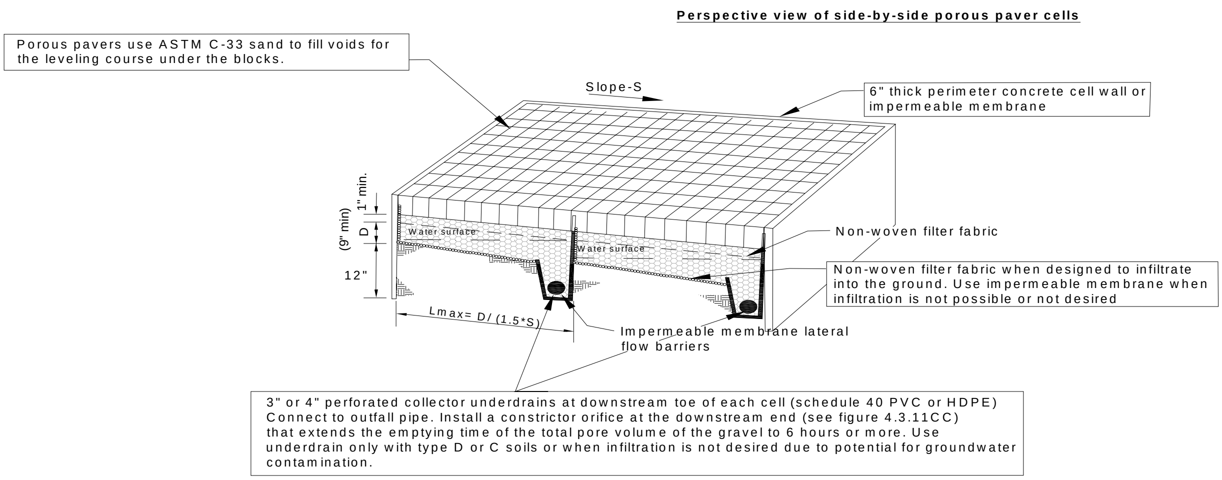


Figure 4-52. Schematic of Lateral Flow Barriers
(Source: Urban Drainage and Flood Control District, 2004)

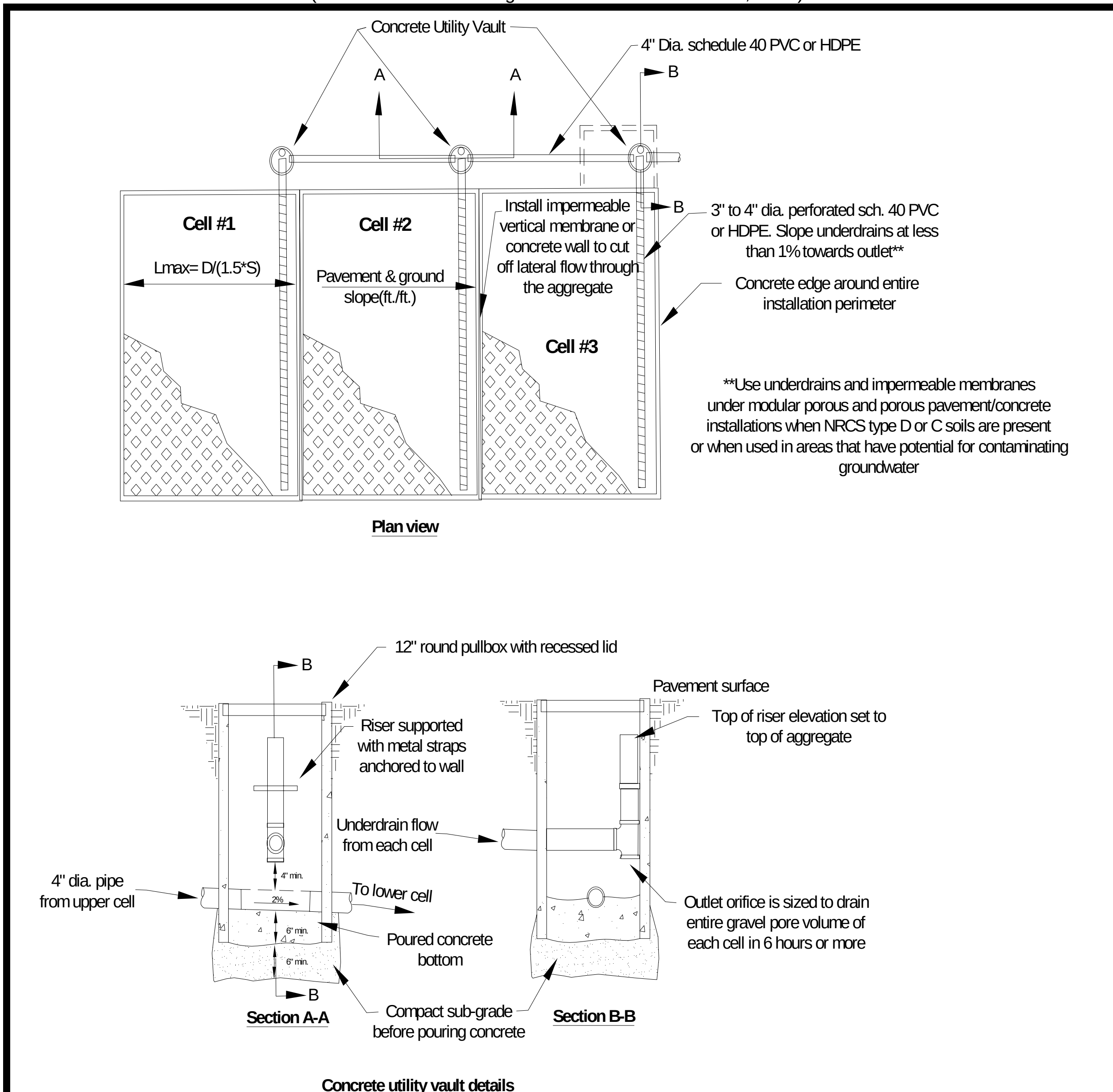


- *Filter Fabric* – It is very important to line the entire trench area, including the sides, with filter fabric prior to placement of the aggregate. The filter fabric serves to inhibit soil from migrating into the reservoir and reducing storage capacity.
- *Underlying Soil* – The underlying soil should have an infiltration capacity of at least 0.5-inches/hour but preferably greater than 0.5-inches/hour. Soils at the lower end of this range may not be suited for a full infiltration system or may require additional infiltration measures such as a perforated pipe or additional sand layer. Test borings are recommended to determine the soil classification, seasonal high ground water table elevation, and impervious substrata, and an initial estimate of permeability.
- The *Underdrain System* (if required) shall be designed per the porous pavement manufacturers' recommendation or through the use of another reference. A typical underdrain schematic is shown in Figure 4-53.

D. PRETREATMENT

- Although it is not recommended that runoff from other areas be discharged to the porous pavement area, stormwater runoff that discharges to the porous pavement system from surrounding areas requires pretreatment to remove sediment and debris. Pretreatment can be provided by a sediment forebay or equivalent upstream pretreatment. A sediment forebay is designed to remove incoming sediment from the stormwater flow prior to run-on to the area covered by porous pavement.
- If a sediment forebay is used, it shall be sized to contain 0.1 inch per impervious acre (363 ft^3) of contributing drainage and shall be no more than 4 to 6 feet deep. The pretreatment storage volume is part of the total WQv design requirement and may be subtracted from the WQv calculated for the site.

Figure 4-53. Schematic of an Underdrain System
(Source: Urban Drainage and Flood Control District, 2004)



E. OUTLET STRUCTURES

- If an underdrain system is incorporated into the design, an outlet pipe shall be provided from the underdrain system to the local stormwater conveyance system. Discharges shall not exit the outlet pipe in an erosive manner. Due to the slow rate of discharge, outlet erosion protection is generally unnecessary for modular porous pavement systems.

F. MAINTENANCE ACCESS

- A minimum 20’ wide maintenance right-of-way or easement shall be provided from a driveway, public or private road. The maintenance access easement shall have a minimum unobstructed drive path width of 12 feet, appropriately stabilized to withstand maintenance equipment and vehicles.

G. LANDSCAPING

- Landscaped areas that may discharge, or are adjacent to, the porous pavement should consist largely of grassy vegetation and have no exposed soil. Mulch, sticks, and leaves are debris that can clog the surface of the porous pavement, reducing its ability to infiltrate stormwater runoff. If such landscaped areas are utilized near the porous pavement, care should be taken to design and maintain the landscaped area in a manner and frequency that prevents such debris from entering the porous pavement, or ensures frequent removal of such debris from the area. For example, maintenance practices should increase during the fall to remove leaves from the porous pavement if deciduous trees are located near the system.

H. SPECIAL CONSIDERATIONS FOR THE AS-BUILT CERTIFICATION AND PLANS/PLATS

- Because the use of porous pavement reduces the WQv for the site and provides for stormwater treatment of some pollutants, the area must be shown on the as-built certification and the final plat specifically as a water quality BMP. The following components must be addressed in the as-built certification and final plat:

  1. The boundaries of the porous pavement area; clearly identified with a note that states “Pervious pavement area. Do not pave with impervious pavement surfaces.”
  2. Clear identification of the type of porous pavement used.
  3. The underdrain design and specification (if an underdrain is utilized).

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4.3.12.6 Maintenance Requirements and Inspection Checklist

Note: Section 4.3.12.6 must be included in the Operations and Maintenance Plan that is recorded with the deed.

Regular inspection and maintenance is critical to the effective use of porous pavement as a stormwater best management practice. It is the responsibility of the property owner to maintain all stormwater facilities in accordance with the minimum design standards and other guidance provided in this manual. The local jurisdiction has the authority to impose additional maintenance requirements where deemed necessary.

This page provides guidance on maintenance activities that are typically required for porous pavement, along with a suggested frequency for each activity. Individual porous pavement applications may have more, or less, frequent maintenance needs, depending upon a variety of factors including traffic loads, the occurrence of large storm events, overly wet or dry (i.e., drought) regional hydrologic conditions, and any changes or redevelopment in the upstream land use. Each property owner shall perform the activities identified below at the frequency needed to maintain porous pavement properly at all times.

Inspection Activities	Suggested Schedule
• Ensure that the porous pavement surface is free of sediment and debris (e.g., mulch, leaves, trash, etc.). • Ensure that the contributing area upstream of the porous pavement surface is free of sediment and debris.	As needed
• Check to make sure that the porous pavement dewaters between storms.	Monthly
• Inspect the surface for structural integrity. Inspect for evidence of deterioration or spalling.	Annually
Maintenance Activities	**Suggested Schedule**
• Ensure that contributing area and porous pavement surface are clear of debris (e.g., mulch, leaves, trash, etc.). • Ensure that the contributing and adjacent area is stabilized and mowed, with clippings removed.	As needed, based on inspection
• Vacuum sweep porous pavement surface to keep free of sediment.	Typically three to four times a year
• Replace the porous pavement, including the top and base course, as needed.	Upon failure

The local jurisdiction encourages the use of the inspection checklist presented below for guidance in the inspection and maintenance of porous pavement. The local jurisdiction can require the use of this checklist or other form(s) of maintenance documentation when and where deemed necessary in order to ensure the long-term proper operation of the unit. Questions regarding inspection and maintenance should be referred to the local jurisdiction.

INSPECTION CHECKLIST – POROUS PAVEMENT

Location: ____ Owner Change since last inspection? Y N
Owner Name, Address, Phone: ____
Date: ___________ Time: ______________ Site conditions:____

Inspection Items	Satisfactory (S) or Unsatisfactory (U)	Comments/Corrective Action
Signs of clogging (e.g., standing water)?		
Debris (mulch, trash) accumulation?		
Sediment accumulation?		
Standing water?		
Erosion from underdrain (if present)?		
Exposed soil in areas discharging or adjacent to the porous pavement area?		
Runoff discharge from pavement area 24 to 48 hours after the end of a storm event?		
Other (describe)?		
Other (describe)?		
Hazards		
Have there been complaints from residents?		
Public hazards noted?		

If any of the above inspection items are **UNSATISFACTORY**, list corrective actions and the corresponding completion dates below:

Corrective Action Needed	Due Date

Inspector Signature:________________________________ Inspector Name (printed)________________________________

4.3.12.7 Example Installations

Figure 4-54. Porous Pavement Installation

Figure 4-55. Typical Porous Pavement Applications
(Photos by Bruce Ferguson, Don Wade)

4.3.12.8 References

Atlanta Regional Council (ARC). *Georgia Stormwater Management Manual Volume 2 Technical Handbook.* 2001.

City of Knoxville. *Knoxville Best Management Practices Manual.* City of Knoxville Stormwater Engineering Division, March 2003.

City of Nashville, Tennessee. *Metropolitan Nashville and Davidson County Stormwater Management Manual, Volume 4 Best Management Practices.* 2006.

Knox County, Tennessee. *Knox County Stormwater Management Manual Volume 2, Technical Guidance*. 2006.

Metropolitan Council. *Minnesota Urban Small Sites BMP Manual.* Metropolitan Council Services, St. Paul Minnesota, 2001.

Urban Drainage and Flood Control District, Denver, Colorado. *Urban Storm Drainage Criteria Manual – Volume 3 – Best Management Practices – Stormwater Quality.* 2004

4.3.12.9 Suggested Reading

California Storm Water Quality Task Force. *California Storm Water Best Management Practice Handbooks.* 1993.

US EPA. *Storm Water Technology Fact Sheet: Modular Treatment Systems.* EPA 832-F-99-044, Office of Water, 1999.